Local Content Requirements and Industrial Development

Economic Analysis and Cost Modeling of the Automotive Supply Chain

by

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Submitted to the Engineering Systems Division
in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Technology, Management and Policy
at the
Massachusetts Institute of Technology

February 2001

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on January 12, 2001 in Partial Fulfillment of the Requirements for the Degree of
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ABSTRACT

This dissertation addresses the issue of performance standards in developing nations, focusing on the role of local content requirements. It proposes a theoretical framework to understand the impact of this policy on the decisions of firms and the welfare of the domestic economy, and offers a methodology to apply the analysis to the context of the automotive supply chain. The central conclusion of the thesis relates to the existence of a gap between private and social opportunity returns and costs, an aspect that has been overlooked by previous literature.

In a developing country, resources employed by foreign investors and their local suppliers often generate spillovers and learning effects that are not accounted for in the valuations of private economic agents. This creates an externality-from-entry, whereby positive economic effects of new domestic suppliers are overlooked in the sourcing decision of the foreign firm. This dissertation proposes a model to illustrate how this gap between social and private valuations justifies the enactment of domestic content requirements, which become welfare enhancing. The analysis also reveals that content requirements are a preferable policy to tariffs and subsidies as a means to increase domestic purchases and discusses the use of subsidies and requirements as incentive mechanisms to align firm decisions with government objectives.

A case study of the automotive industry, where content restriction policies are extremely active, is used to demonstrate the applicability of the model. This entailed the development of a new methodology, called Systems Cost Modeling (SCM), which uses simple metrics and rules to build bottom-up cost structures where estimates for large number of components have to be considered. Detailed empirical data from a particular car is then used to build a sourcing cost structure. These costs are integrated with the domestic content model to show how, for existing market and policy conditions; there can be value to the enactment of modest levels of domestic content requirements in the auto industry. It also explains that the impact of the policy is very sensitive to project characteristics and that this should be factored into national decisions.

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ACKNOWLEDGMENTS

I would like to acknowledge the generous financial support of Praxis XXI and Fundação Calouste Gulbenkian for my MIT studies. I also wish to thank INTELI for travel support.

I would like to thank my advisors for their guidance, support and friendship throughout my tenure at the MIT. Professor Alice Amsden provided the initial stimulation for this thesis and has been since then an inexhaustible source of insightful and provocative thoughts, not only about my work, but also on how to think about industrial development. Professor Richard de Neufville has been a dedicated mentor since my first day here. His advice, encouragement and careful reflections have been instrumental in all the steps of my education and research at MIT. Professor Joel Clark deposited immense confidence in me. Not only he has accepted me in the Materials Systems Laboratory and provided financial and intellectual support, but he has also willingly taken a strong personal and institutional involvement in a set of projects that I suggested. My sincere thank you also goes to the unofficial member of the committee, Dr. Richard Roth. He has been an enthusiastic supporter of my work, providing significant insights to the dissertation, as well as detailed comments on grammar and structure. Through his guidance of the 'Portugal' project, I have learned a great deal a bout manufacturing, and I have come to value his friendship.

I also want to recognize the importance of MSL, where it has been a great pleasure to work. The warm advice of Dr. Frank Field and Dr. Randy Kirchain is invaluable and the interactions with all the other students provide a unique learning and human experience. Thank you Ashish, Alexandra, Bruce, Chris, Erika, Gilles, Luis, Mon, Patrick, and Randy for the wonderful time. Special thank you for my friend Sebastian, which has been my daily companion of long academic discussions, frequent working nights, regular squash and irregular drinking (to be corrected in the future). The same appreciation goes to my friends at TPP and TMP, in particular Enrique, Ian, Jason, Mag and Pato, with whom I have learned to appreciate life at MIT and around Cambridge.

The Portuguese 'connection' has also been an important ingredient during these years. Among many others, my good friends José Rui, Manuel Heitor and Pedro Conceição have been part of my work since well before entering MIT. Their strong encouragement, the intense collaboration and the common goals are a constant source of motivation. I am particularly indebted to José Rui, personally and through the INTELI team. He has always been a major stimulus and a partner in a number of endeavors (I know, more work is waiting for us!). My involvement in PSA and PAPS provided an escape from research and an opportunity to meet extraordinary persons that have been a supply of stimulation and many joyful events. Among many, I thank Pedro Ferreira for being a good friend and a cheerful companion (more cigars to come).

Finally I want to thank my family for their unwavering confidence and warm feelings despite the distance and the absence. Notwithstanding the physical separation, my spirit is particularly close to my mother and my youngest brother. David has shared with me some of the most difficult, as well as the most awesome periods of my existence, and our time together here in Cambridge has made him a true element of my life. Through her immense generosity, her devoted love for the family and an intense strength and will power, my mother has always been a foremost inspiration. This period at MIT was no exception. Thank you both so much. This work is for you. At heart, my thanks go to Inês, for her love, encouragement, patience, and bringing joy to my everyday life.

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Chapter 1. Overview

This thesis addresses the question of performance standards in developing nations. In particular, it aims at providing further understanding of the conditions under which local content requirements (LCR) on foreign investors can have a positive welfare impact on the host economy. Local content requirements is a policy enacted by governments that forces a firm or all the companies in an industry to source a certain share of the inputs used in the manufacturing process from the domestic market. It has been widely used throughout the world, principally in the context of the developing world.

Local content requirements have been extensively discussed in the context of trade, foreign investment and industrial development issues. International organizations, in particular the World Trade Organization (WTO), have strongly attacked these policies, but policy makers in developing countries continue to be firm believers in their potential benefits. In fact, while content requirements may formally disappear at a national level in the future because of WTO regulations on Trade Related Investment Measures, they are likely to continue on an informal basis, at a supra-national basis and explicitly in developing countries, which have been given some latitude in the adoption of these regulations. Meanwhile, multinationals actively pressure against content policies, but have mostly chosen to abide and sometimes surpass these requirements whenever present. This set of inconsistent perspectives and the limited research in the subject generate the opportunity for the dissertation.

Theoretical models and empirical analysis seem to point to the existence of competing views on the potential role of local content requirements. The small amount of empirical research on the issue has documented evidence of both good and bad outcomes of this policy. Analysis shows that the impact of the policy on companies and domestic welfare seems to depend on a number of different aspects ranging from industry conditions to the degree of discretion in the policy or the severity of the requirement. Nevertheless, most economic models proposed so far seem to discourage these types of policies. They explain how, under most circumstances, domestic content requirements increase the cost of intermediate goods and, consequentially, the price of the final good, leading to higher prices and an inevitable reduction of consumer surplus. Although consumer surplus is partially transferred to producers, some deadweight loss that reduces country welfare is also generated. The problem is that most research has focused on rent-shifting effects of these policies and has overlooked the potential role that external and learning effects play in host countries, precisely the issues that have been the core motivation for the enactment of these policies.

One question is why enacting local content requirements and not alternative policies such as tariffs or subsidies to local producers? In fact, it is intuitive to understand that a tariff on imported components will make domestic production of some of these components more attractive. Local firms that could not previously compete on price suddenly become competitive, and therefore it is likely that domestic content increases. This is precisely the initial aspect that the dissertation covers. A simple model is proposed to compare domestic content requirements with potential substitutes, aiming at understanding their merits and demerits.

The core of the dissertation, nevertheless, is a study of the potential role of local content as a mechanism to correct a gap between private and social benefits arising from foreign investment in a host nation. In a developing country, a new large OEM investment in an industry like automotive generates a unique opportunity for a set of local firms to enter into the manufacturing of complex products like automotive components. Because of spillovers or learning effects, this possibility tends to propel the overall capability of the industry to levels that would not be attainable by alternative means. Under some circumstances, these industry external effects are not accounted in the valuations of private economic agents. This gap between private and social valuations generates the opportunity for the enactment of domestic content requirements. The dissertations develops a model to study how this policy can be welfare enhancing in the presence of these extra social benefits.

This study also covers implementation. The question it addresses is how a government can lure an investing OEM into compliance with a particular level of domestic content without creating an obvious price distortion in the final good. This is an important aspect because it has been at the core of the negative evaluation that previous authors have made on the subject. An incentive model is used to assess this problem.

A case study for the automotive industry, where content restriction policies are extremely active, is used to demonstrate the applicability of the theoretical models mentioned in the previous paragraphs. To build the automotive sourcing cost structure required for the analysis, the dissertation proposes a new methodology, called Systems Cost Modeling (SCM), which enables bottom-up estimates of component manufacturing costs. Detailed empirical data from a typical mid size car is then used to evaluate local content requirements according to the aspects outlined above.

This thesis has contributions in three areas. The first one is in the area of industrial development. With the new WTO rules on investment measures, developing nations will be under greater scrutiny from the developed world and international organizations concerning the use of domestic content requirements. This thesis provides a model to assess conditions under which domestic content policy is welfare enhancing for the country, with valuable insights for the nations and international organizations. In addition, it will provide benchmark levels for the case of investments in the auto industry.

The second area is methodological. The proposed analysis merges economic and management analysis with methods and technical solutions used to assess cost in the auto components industry. The combined work enables a fair assessment of the cost structure of the auto components industry. Moreover, it will inform how the reliance on simplified economic analysis may tend to bias conclusions regarding technology cost and firm performance.

The third area is in the characteristics and global sourcing decisions of the auto industry. Since it provides an analysis of a scenario for the auto industry, it provides valuable insights into the purchasing options available to auto sector managers. In particular, it shows when is it worthwhile for managers to engage in constructive engagement in local sourcing decisions in new investments in the auto industry. There will be a number of these situations in the auto industry in the coming years in developing nations and the results presented in the thesis may prove to be valuable.

In addition to this overview, the dissertation includes seven other chapters. Chapter 2 presents the motivation and key issues that are the focus of the thesis, reviews previous literature and presents the central research question and associated hypothesis. Chapter 3 proposes a model to assess the impact of domestic content regulation in a country. Chapter 4 discusses implementation of content requirements through incentive contracts. Chapter 5 puts forward a system cost model framework to estimate cost implications of sourcing decisions. The model is then implemented for the automotive industry case in Chapter 6. Chapter 7 integrates the system cost model of chapters 5 and 6 with the theoretical models of chapters 3 and 4 to perform a full analysis of the domestic content issue in the context of the auto industry. Chapter 8 presents conclusions and future work. A summary of all these chapters is presented below.

Chapter 2: Foreign Investment, Supply Chain Structures and Domestic Content Regulation

Chapter 2 reviews the perspectives of the key agents that participate in the local content policy debate, analyzes the key issues associated with the local content decisions in the developing world and discusses the research question and hypothesis explored in the thesis.

This chapter explains that the crucial issue driving the potential contribution of foreign investment to development is the spillover of knowledge and technology to the local economy. It also details how domestic linkages, in particular to local suppliers, are the critical mechanisms through which these effects materialize in the economy. This situation generates the gap between social and private valuations of resources associated with foreign investment, resulting in sub optimal domestic investment if decisions are left only to the market.

It also reviews the perspective of the government regarding foreign investment. The conclusion is that local governments have been aware of the external effects associated with foreign direct investment (FDI). Their concern with the appropriation of these benefits led to the enactment of performance standards with clear objectives of attracting FDI and assuring that local spillovers and learning were achieved. Domestic content requirements were among the most important measures. The detailed research review on the effects of domestic content regulation on economic welfare presented in the chapter shows that these policies have had mixed results. It also showed that most analyses focused on the rent-shifting effects of these policies and have overlooked the potential role of external and learning effects.

These findings lead to the hypotheses addressed in the thesis: Domestic Content Requirements contribute to the development of the local industry when used together with subsidies to (1) internalize differences between private and social valuations of the resources used in the OEM and its suppliers; (2) create incentive structures that align the objectives of the foreign investor with those of the domestic government.

Chapter 3: A model to evaluate local content decisions

This chapter proposes a model to benchmark the effects of a local content requirement policy on the investment of a particular OEM and the welfare of the economy. Using principles of social cost benefit analysis, impact is measured through welfare generated by the overall project, including any restrictions.

First, competitive decisions are analyzed. This enables an understanding of the underlying decision mechanisms associated with OEM sourcing decisions and a benchmark evaluation of the impact of a content requirement policy on economic agents and welfare. The analysis includes a comparison with alternative policies, in particular tariffs and subsidies. The relevant conclusion is that content requirements are a superior to tariffs and subsidies as a means to increase the share of OEM domestic purchases. By setting a standard and letting the OEM make the decisions on how to comply, the government benefits from the firm's ability to minimize potential negative impacts on its cost and, as a result, on the overall economy.

Second, the model studies how the existence of gaps between the private and social opportunity costs of the resources employed by the OEM and its suppliers effects the impact of LCR on the domestic economy. The analysis shows that local content requirements can improve welfare as long as the opportunity cost gap of the components sourced beyond the OEM market decision is above the cost penalty associated with them. The key idea underlying the model is that a foreign OEM investing in a developing economy generates unaccounted learning and spillovers effects that depend on the breadth of the supplier structure. These effects generate an externality-from-entry associated with domestic suppliers that drives the gap between social and private valuation.

The model also describes an extension related to the potential risk aversion of the OEM. It is shown that a foreign manager may demand a price premium from local suppliers to hedge for the fact that they may have cost overruns, which decreases domestic sourcing. Content requirements can help to avoid the behavior of the manager and improve domestic welfare.

Chapter 4: Performance Standards, Information and Content Decisions

This chapter analyzes the mechanisms that can be used by the government to induce the OEM to choose the level of domestic purchases that yields maximum welfare to the local economy. The argument is that subsidies and requirements coupled through reciprocity principles act as incentive mechanisms that align their decision with the optimum for the economy. When offered the appropriate choices with bundles of content requirements and subsidies, companies will self-select themselves in an optimal way while correcting for the gap between social and private benefits and costs. Nevertheless, the analysis also shows that uncertainty on how the enactment of content requirements affects the cost structures of the firms reduces the ability of the government to enact efficient incentive contracts and to improve domestic welfare.

The incentive model described in this Chapter is an extension of the work presented in Chapter 3 (although stronger regularity conditions are necessary for the formal proofs). In fact, for the case with full information, the conclusions of both models converge, and the incentive contract results provide the necessary justification for the assumption used in Chapter 3 of having the cost penalty of the investing firm paid by the government.

Chapter 5: System Cost Modeling

Understanding the decisions of investing firms and local governments with regard to domestic content requirements depends heavily on the cost structures of the firms and the influence of regional market contexts on cost. In particular, it is important to know how the manufacturing conditions in the developing nation contrast with those found in the world market in order to be able to examine on the trade-offs between local sourcing and importing of components.

To be able to make this assessment, chapter 5 proposes a methodology to evaluate the cost of complex systems with a large number of individual components and subsystems. This methodology, called Systems Cost Modeling (SCM) is based on the Technical Cost Modeling technique that has been widely used to assess manufacturing costs of individual or small groups of components. The SCM approach involves critical simplifications from traditional technical cost modeling techniques through the use of simple metrics and rules that enable it to be used to build bottom-up cost structures from a limited set of inputs for large number of components.

Unlike most existing cost estimation methods that aim at obtaining an accurate evaluation of the manufacturing cost of an individual component level, SCM focuses on providing reliable calculations of the overall system cost and the influence of key parameters (such as volume and factor input costs) on cost behavior. This is precisely the objective associated with the domestic content decision question addressed in this thesis.

Chapter 6: Modeling Costs in the Automotive Components Industry

Since it is important to examine the relevance of the issues identified in the thesis in the context of a particular business and policy environment, a case study of the automotive industry is presented in this chapter. The automotive sector has traditionally been one where performance standards such as domestic content requirements have been present and where they are still very active. It is also an industry where the influx of investment in the coming decade towards the developing world is expected to grow significantly.

This chapter also explores the System Cost Model described in Chapter 5 in the context of the chosen case study. It describes the detailed empirical data from a particular car used to build a sourcing cost structure and how it can be used to investigate the car manufacturing costs in both a developed and developing region and the potential sourcing decisions of the OEM. The calculations presented show that the regional conditions have a significant impact on cost and describe the best solution through mixing component sourcing from developing and developed regions.

Chapter 7: Domestic Content Requirements and the Auto Industry

This Chapter analyzes the specific context of domestic content requirements, integrating the theoretical models presented in chapters 3 and 4 with the system cost model proposed in chapter 5 and the specific context of the auto industry supply chain presented in chapter 6.

The base scenario presented in Chapter 7 excludes external effects associated with the investment or the purchasing practices. The results confirm typical conclusions from previous authors, whereby enacting domestic content requirements has a negative economic welfare effect. Similarly, it also shows that welfare effects from a tariff policy are always substantially inferior to the ones resulting for a content requirement.

In the presence of external effects, the results presented in the chapter confirm the net benefit that results from a forced increase in domestic content beyond the natural level of sourcing. The results for the base case are meaningful, with a potential increase of 20% in annual domestic sales of components and 13% in net external value. The results also show that the optimal level of content requirement and the related market effects depend on a number of variables, in particular the production volume of the vehicle and the opportunity cost of capital. The model is then used to consider explicit learning mechanisms associated with the cumulative output of the industry and the firm. As expected, these effects also justify an increase in the level of domestic content. An important aspect to note is the fact that the optimal level of domestic content is similar whether justified through gaps in the valuations of the critical resources, or by considering an explicit learning dynamics, suggesting the convergence of the two approaches.

The incentive analysis describes how it is possible to find a contract structure for the case studied. In the presence of asymmetric information, the incentive contract involves offering the investing OEM a menu that includes both a level of required domestic content and an associated subsidy targeted to the base cost as well as one aimed towards the high cost scenario. The results confirm the expected contract inefficiency that results from the differences in information between the government and the firms. Nevertheless, large cost gaps between efficient and inefficient plants create a natural separation between potential players that enable the government to offer tailored contracts without the problem of having the low cost firm mimicking the high cost one.

Finally, the analysis associated with risk averse purchasing managers shows how this is a pressing problem, as it may lead to substantial reductions in the level of domestic purchasing, even with only modest levels of uncertainty on domestic component costs.

Chapter 8: Conclusions and Future Research

This chapter discusses overall conclusions of the dissertation, bridges the results to observed policy condition in the developing world and points to research lines through which the analysis of the thesis can be further expanded.

Chapter 2.
Foreign Investment, Supply Chain Structures and Domestic Content Regulation: A Review of the Issues

This chapter has three objectives. The first is to review the perspectives of the key agents that participate in the local content policy debate: investing firms, local firms and the government. The second is to identify and analyze the key issues associated with the local content decisions and regulations in the developing world. The last is to present the perspective that will be explored in the dissertation, that in a developing economy, resources employed by foreign investors and firms selected to be domestic suppliers are associated with spillover effects that make them more valuable than alternative uses in the economy. This generates a gap between social and private valuations that can be corrected through appropriate bundles of subsidies and domestic content requirements.

The chapter has four sections. The first section describes the perspective of the firms in establishing foreign investments. The second section presents an overall perspective of why and how foreign investment is important for domestic economies. The third section explains why the government might want to play a role regarding foreign investment and discusses the perspective of establishing performance standards. Next, the existing analysis on domestic content requirements is debated, both in terms of theoretical models and empirical work, highlighting their insights and limitations. The fifth section explains how some of the unanswered questions can be addressed, outlines the key hypothesis that this dissertation addresses and explains its contribution to the research in the area.

2.1. Foreign Direct Investment and Supply Chain Decisions

As Markusen (1995) writes in a review often quoted in the literature, “if foreign multinationals are exactly like domestic firms, they will not find it profitable to enter the domestic market. After all, there are added costs of doing business in another country”. In this article, the author reviews the evolution of the theories explaining the growing phenomena of having companies from one area investing directly in another region of the globe. The key ideas sustaining this empirical observation are what Dunning (1981) summarized as Ownership, Location and Internalization (OLI) advantages.

First, firms may own a particular product, technology, reputation or secret that gives them a competitive edge over their competitors. This idea of ownership advantage, initially proposed by Hymer (1976) and further developed by Caves (1976; 1996), can be used to offset the disadvantages of doing business in a foreign region. Second, there must be advantages to having operations locally, rather than producing in the home market and exporting the product to the foreign destination. These advantages are often related to logistics costs, tariffs or preferential access to production factors, although other intangible aspects such as proximity to knowledge centers and clients are increasingly playing a role. Finally, the foreign company should have a perceived advantage of keeping the new investment internal to the company rather than licensing its ownership advantage, or finding solutions such as contract manufacturing. According to Rugman (1980; 1986), the preference for an internal investment solution is the result of the inexistence of a market for the ownership advantage, e.g. intangible assets such as reputation can't be contracted on; or the foreign firm may not be able to exclude its licensee from the knowledge it transfers and may well prefer to invest abroad and protect their rights over technology[1].

The OLI framework has been the basis for most of the empirical work in the literature over the last decades. In fact both anecdotal evidence and empirical studies have associated multinational enterprises with industries where intangible firm-specific assets such as R&D and brands are crucial parts of their business (among many others see Buckley and Casson, 1976; Teece, 1986; Blomstrom and Kokko, 1998). Therefore, there has been a rather good historical fit between theory and empirics. Markusen (1995) summarizes four key characteristics of multinationals that

[1] Recent papers have proposed an extension of the theory, suggesting that firms may also decide to invest abroad not to exploit advantages they already possess, but rather to acquire new knowledge or with technology sourcing objectives (Kogut and Chang, 1991; Braunerhjelm and Svensson, 1996; Neven and Siotis, 1996; Fosfuri and Motta,

have been sorted out by a number of studies: high levels of R&D relative to sales; a large share of professional and technical workers in their workforce; products that are new or technically complex; and high levels of product differentiation and advertising.

It is exactly these characteristics of the investing firms that make it attractive to local economies. By investing in a developing nation, the firm will assist the local economy through the provision of new goods, or the supply of products more efficiently, increasing consumer surplus and improving welfare. Nevertheless, firms do not act in isolation. When investing in a new location, they establish a number of links to the local economy. The one obviously required is the inclusion of local labor[2]. But their involvement usually goes far beyond labor. Purchasing of raw materials and components are the two other areas usually associated with investment of a multinational in a particular location, and their involvement could go as far as sourcing capital in local capital markets or working with local units in development activities. Moreover, as described below, these linkages are seen as the key channel through which technology and proprietary knowledge of the firm can trickle down to the host economy.

The decision of firms regarding what to source in the local market is based on market criteria. Whatever is less expensive (quality adjusted) in the host market, will be sourced locally; but what is not found at the right prices will be sourced from the global market. This sometimes means that the local business environment agents are often put aside, due to the inability to produce the goods and services that the multinational requires at the required level of price, quality or service. As a result, investing firms sometime work almost in isolation from the host economy, which limits the benefits it can bring to the host economy and misses most of the opportunity for the generations of spillovers to the overall economy (Brannon, James et al., 1994).

Unlike the issues related to the motivation and characteristics of foreign investment that have attracted a lot of attention from economics researchers, the options and strategies that firms

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1999). This situation is mostly associated to investments in the developed world, therefore beyond the objective of this thesis

[2] In labor intensive processes, access to local cheap labor is sometimes the only reason for the investment

follow concerning their foreign sourcing decisions has been addressed mostly in the management literature, within what has been named global supply chain management (Tayur, Ganeshan et al., 1999 chapter 21) or international operations management (Prasad and Sunil, 2000). The perception is that an effective management of the activities dispersed throughout the global supply chain can result in lower production costs and better service of customer demands. Firms are concerned with articulating comparative advantages of countries, tax and duty structures as well as risks and logistics costs associated with international sourcing, choosing supply chain configurations that maximize profits (Cohen and Mallik, 1997).

In this research work, local conditions are treated as inputs (e.g. wages, transportation costs, taxes) or constraints that the company faces (e.g. local content requirements, mandatory exports) when making decisions. Nevertheless, research work in operations has not considered the interaction of firm decisions with the social impact in host economies and, in particular, it has not addressed how government policy may effect firm decisions at a strategic level. This aspect has been particularly noted in a recent survey of the literature on global operations, which also referred the shortage of analyses focusing on the realities of developing nations (Prasad and Sunil, 2000).

In fact, as detailed below, given the importance of firm decisions to host economies and the widespread presence of local policies conditioning firm manufacturing costs, particularly in the developing world (see below), this seems to be a very important lack in the literature. There is a clear opportunity to bridge research on global supply chain decisions with economic analysis on the implications and drivers of government policies in developing nations. A more sound understanding of this interaction will enable better informed decisions, both form policy makers and managers, that may better solutions for all players involved.

2.2. Development, Foreign Participation and the Role of Linkages

Knowledge accumulation lies at the heart of economic development. Yet, less developed nations lack skills, institutions and organizations that embody most of this knowledge and form the core of modern industrial activities. Therefore, they are very limited in their ability to generate new knowledge capable of pushing the technological frontiers back and thus enabling them to compete with the developed world on equal footing. Rather, they have tried to imitate technology developed in the advanced world, adapting it to local conditions. It does not follow, however, that the effort of technology imitation is a simple and straightforward one. Such an inference would be valid only if technological effort were conceived narrowly, as the employment of resources devoted to that purpose. In fact, absorption of technology is a complex learning process that requires resources (often the kind that are most scarce in a developing economy), involves risk and entails a far from negligible cost (Dahlman and Westphal, 1985; Lall, 1992; Bell, 1993; Hobday, 1995).

Because of its complexity, the successful adoption of technology in a developing nation, measured as the ability of a firm or industrial sector to become internationally competitive, is far from a natural process. Even when firms, regions or nations are given large financial resources and extended periods of time, success is far from being granted. The uneven development path among post-war industrializing nations is probably the best reminder of this fact. Therefore, research on the conditions, strategies and policies that foster technology catch-up in developing nations has long been considered critical to understand industrialization paths (Stewart and James, 1982; Bell, 1993; Lall, 1993; Hikino and Amsden, 1994; Hobday, 1995; Amsden, 2000). While it is known that many factors influence the ability of a nation to learn and accumulate knowledge, the focus here is on three interrelated issues. The first is a well-documented positive association between foreign direct investment and economic growth. The second is the role of imperfect markets and the third is the importance of linkages in fostering economic development.

2.2.1. Foreign Investment, Externalities and the Gap Between Social and Private Returns

Foreign Direct Investment (FDI) has become a core issue in the development policy agenda. During the last decade, FDI to developing nations grew eightfold, reaching US$150 billion in 1998 (World Bank, 1999). Therefore, its potential impact on developing economies is being given and increasing attention. There are several means in which FDI can contribute in developing economies (de Mello Jr., 1997 and Moran, 1998 provide extensive reviews of the relationship between foreign direct investment and development). It may provide a commodity to its nationals that domestic firms cannot provide, or stimulate the domestic economy by creating additional demand for local intermediate and primary inputs in general, and labor in particular. It can also complement domestic savings in contributing to capital accumulation. Nonetheless, it is not so much the quantitative nature of foreign capital that is critical for the promotion of long term economic growth. The important aspect is that FDI can provide a bundle of knowledge and technology transfer that generates external effects leading to greater productivity and increasing returns on domestic production.

One of the mechanisms through which foreign investment contributes to economic growth in developing nations is complementarity to domestic capital. Technologies embodied in foreign capital are usually not only new to the region, but they also contribute to increase the portfolio of intermediate and final goods products, rather than replacing technologies for older ones (de Mello Jr., 1995). This results in external effects that increase the marginal productivity of existing technologies and create additional rents to the regions (Romer, 1986). Complementarity can be important for investments associated with physical capital, as well as for leasing, licensing, management contracts or technology transfer, where no significant physical capital accumulation is at stake (de Mello Jr., 1997).

FDI is also expected to augment the existing stock of knowledge in the recipient economy through labor training and skill acquisition, as well as through the introduction of alternative management and organizational practices (Borensztein, Gregorio et al., 1995)[3]. This is translated in greater labor productivity that naturally results in higher wages paid by foreign firms (Haddad and Harrison, 1993; Aitken, Harrison et al., 1996). Through mobility and interactions in the economy, these workers become important instruments for knowledge diffusion and spillover generation in the local economy.

Most of these arguments have been incorporated in formal models in endogenous growth (Grossman, 1991; de Mello Jr., 1997; Aghion and Howitt, 1998) and there is a wide theoretical acceptance of the positive role that FDI can play as a driver for long term economic growth.

[3] Though a minimum threshold level of human capital has to be achieved before this effect can happen. This is also the reason why authors have used the notion of capital augmentation rather than accumulation to designate these effects

Empirical studies have also demonstrated that the overall result of the participation of multinational companies in industrializing nations is rather encouraging. Both econometric analyses (Haddad and Harrison, 1993; Borensztein, Gregorio et al., 1995; Kokko and Blomstrom, 1995; Aitken, Hanson et al., 1997; de Mello Jr., 1997; Blomstrom and Kokko, 1998; Aitken and Harrison, 1999) and case studies (Lim and Fong, 1991; Helleiner, 1992; Hobday, 1995) have shown that FDI contributes to economic development and reinforces the learning process of industrializing nations. In addition, research has shown that spillovers are a fundamental part of the contribution of FDI to economic growth (Kokko, 1994; Chuang and Lin, 1999; Sjoholm, 1999). The external effect of foreign investment can be extremely high. In Taiwan, a country where FDI has been quite important, Chuang (1999) finds that a one per cent increase in the foreign investment ratio in the industry increases domestic firm productivity from 1.4 percent to 1.88 percent.

The important presence of externalities means that they create benefits in the economy that cannot be captured by private investors that generate the spillovers. This generates a gap between social and private return in the presence of foreign capital. As a result, developing economies are likely to be better off if more investment than the one that would result from market decisions of the firms would take place. In fact, this is often the argument for awarding incentives to private investors. The idea is that an incentive up to the difference between private and social returns might optimize total net benefits to the society (UNCTAD, 1996).

2.2.2. Linkages and Spillovers

Despite the overall positive effects from FDI, empirical studies have also pointed to the fact that there may not always be learning from multinationals, or that learning may be restricted to segments of local firms (Haddad and Harrison, 1993; Aitken, Hanson et al., 1997). These findings raise questions concerning the process through which spillovers to the local economy happen and how can they be improved.

Industry case studies have often indicated out the importance of firmly rooting foreign investment in the local economy, promoting forward and backward linkages to domestic suppliers (Weisskoff and Wolff, 1977; Lall, 1978; Pack and Westphal, 1986; Amsden, 1989; Lim and Fong, 1991; Helleiner, 1992; Wilson, 1992; Lall, 1993; Hobday, 1995; Veloso, Soto et al., 1998). This builds the case for the importance of backward linkages[4]. The importance of linkages for development is definitely not a newfound topic. Hirschman (1958) was probably one of the first economists to highlight their role. Nevertheless, despite the case study results, the body of theory explicitly addressing the significance of linkages in late industrialization is rather limited (see de Mello Jr., 1997)[5].

Using data from Mexico, Blomstrom and Pearsson (1983) and Kokko (1994) show that spillovers are least likely to occur in industries with high concentrations of foreign firms. This is analytically equivalent to saying that dissociation from the local value chain (often called production enclaves) negatively affects the existence of spillovers. The importance of less concentration and more agglomeration to spur spillovers is also confirmed by Braunerhjelm and Svenssson (1996). Gorg and Ruane (2000) looking at Ireland, as well as Mazolla and Bruni (2000)[6] examining Italy, which point specifically to the role of backward linkages in the development and performance of local firms. Authors have documented learning across related facilities, such as in the same industry or segment (Group, 1978; Lieberman, 1984; Argote, Beckman et al., 1990), as well as to those in close proximity to one another (Jarmin, 1994) also for cases where foreign investment was not the relevant issue.

Recently, Rodrik (1996), Rodriguez-Clare (1996) and Markusen & Venables (1999) have proposed the most relevant models that explore how linkages to the intermediate sector can affect the catching up process in developing nations. They suggest that the existence of advanced technology sectors that push the economy to high levels of development depends critically on the existence of linkages to a dense intermediate goods sector[7]. Rodriguez-Clare (1996) explains how

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[4] Linkages are understood as activities that connect a firm to its local environment, in particular purchases of goods and services from intermediate and raw material suppliers – backward linkages – or sales to distribution channels – forward linkages.

[5] An indication of this is the fact that the comprehensive book on development by Ray (1998) only cites Hirschman in its section on linkages; Rodriguez-Clare (1996) also notes the limited work on these issues.

[6] Although these authors do not specifically look at foreign investment, their conclusions are generic for any kind of industrial linkages

[7] The critical assumptions of the models are love for variety in the final goods sector and that increasing the variety of imperfectly traded specialized inputs enhances the overall efficiency of the economy. This is similar to the idea

backward linkages may be the critical difference in terms of spillovers and overall contribution of FDI to industrialization. The author derives a model where he shows that whenever MNCs invest in a new region and backward and forward linkages materialize, the economy ends up with a deep division of labour and high wages. However it can be the case that if these linkages do not materialize, the economy may remain underdeveloped.

His research also shows that there are potential coordination failures, an issue that is explored in more detail by Rodrik (1996). According to Rodrik, the economy would reach a higher level of equilibrium if individual agents would produce the necessary intermediate goods to enable entry into a higher technology sector. The problem is that each of the firms may not face the necessary individual economic incentives to do so. To counter a potential lower equilibrium resulting from this situation, the author suggests that the enactment of coordination policies, namely through subsidies could move the economy to a superior equilibrium.

This perception that different firms in diverse conditions may choose several degrees of backward linkages, thereby affecting their role as development catalysts, is again confirmed in Markusen and Venables (1999). The model they propose illustrates how product market competition generated by multinational entry tends to substitute for domestic firms and reduce domestic welfare; it also shows that if investing firms are able to generate stronger backward linkages than the national firms, they will improve welfare.

These theoretical and empirical results are extremely relevant because they imply that one of the critical mechanisms through which spillovers take place is through domestic linkages. The relevant conclusion is that domestic investment in the network that functions as recipient of FDI spillovers are subject to the same gap between private and social returns as the foreign investor. Without local linkages, the domestic economy is not able to gain as much benefit from FDI. Nevertheless, suppliers and customers of foreign investors are not accounting for these effects, and there will be under investment from the societal point of view. Like before, it becomes of paramount importance for domestic governments to foster these links.

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presented above that new technologies resulting from the foreign investment increase the productivity of domestic technologies

2.2.3. Foreign Investment and Imperfect Markets

Although the majority of the studies support the positive role that FDI can play, this may not always be the case. The potential negative effect of FDI is associated with the fact that most markets where foreign direct investment is taking place are also those with increasing returns to scale and barriers to entry that result in highly concentrated industrial structures (Moran, 1998 p.23). The problem of imperfect competition was first considered at the level of developed nations, where there are national champions in major oligopolistic structures acting in the global market (Brander and Spencer, 1985; Krugman, 1986). Nevertheless, it also became an important issue at the level of developing nations (Rodrik, 1988).

Under strategic trade conditions, entry of foreign firms with market power can displace local firms, or may extract capital that would be applied to more productive uses for the economy. In addition, market power may generate supra-normal rents that are appropriated by the foreign player. These are rent shifting effects that have a welfare reducing result (Levy and Nolan, 1991). Moreover, although relative factor and production costs are still important for the location of imperfect competitor, these firms have some discretion on where to establish their activities (Krugman, 1986; Krugman, 1991). This removes some of the assumptions associated with perfect competition that push nations towards the deterministic path of development.

This opened the opportunity for nations to use trade and investment policies such as taxes, restrictions and subsidies to affect the behaviour of foreign investment. Their objective has been to try to assure that rents are not misappropriated by foreign investors in the country, as well as to attract or breed investments that enable the region to capture a share of the rents and potential externalities associated to the presence of these imperfect competitors. As expected, theory and evidence on the effects of strategic trade theory are mixed, with the conclusion mostly depending on the particular context of the model or the policy context (see the review by Moran, 1998).

2.2.4. Policy Considerations

This review shows that the participation of multinationals is likely to benefit local economies. As explained, FDI can provide a bundle of knowledge and technology transfer that fosters economic growth. Moreover, the fundamental mechanism supporting greater productivity and increasing returns in domestic production are spillovers effects to domestic firms, which can benefit substantially from foreign participation. This important presence of externalities generates a gap between social and private return that is likely to result in less investment stemming from the market decisions of the firms that what it would be desirable to the perspective of the local economy.

The effect of FDI depends on the extent to which the company established relations with local businesses. Deeper forward and backward linkages to the local economy are bound to have stronger effects in terms development. Studies have also demonstrated that the positive impact of foreign investment in host economies may depend on the structure of market. Oligopolistic behavior may shift rents away from the developing nations, or may prevent investment altogether, hurting the welfare of the domestic economy.

The gaps between private and social benefits as well as the potential negative effects and limitations of FDI suggest that governments may play a strategic or coordinating role in directing local and foreign investment. In fact, in most developing economies, governments have traditionally controlled most of the key investment decisions, tailoring them to the developmental objectives, in particular the establishment of links with the local economy. They used a wide assortment of policies including subsidies and import restrictions, among many others. The following sections analyze precisely these policies and instruments, evaluating their objectives, execution and impact. Because of their importance, the focal point will be on backward linkages and the mechanism that governments have used to foster them: the enactment of domestic content requirements.

2.3. Performance Standards as Catalysts of Local Economic Development

In her most recent work, Amsden (2000) explores how, short of original innovations that drove the growth of the developed world, late industrializing nations evolved through adoption of technologies generated in the most advanced regions. She also describes how the governments of these nations used a set of large incentives and strong requirements as performance standards aimed at disciplining and speeding this learning process. These policies were used throughout the economy, but were of particular importance for multinationals entering developing economies. Requirements usually included minimum amounts of domestic factors, or intermediate inputs in production, restrictions on the amount of imports and export requirements equal to a certain minimum proportion of output, among others. Tax breaks and subsidies were among the most popular incentives.

The use of incentives and requirements has been pervasive, both in developing and developed nations. Developed nations such as Canada (autos), Australia (autos and tobacco) and most of Europe (autos, electronics) have made some use of these policies to nurture their local industries (see OECD, 1989, for an assessment of incentives and requirements in the OECD countries). In the developing world, these policies were widespread, cutting across most industrial sectors. Several surveys on the issue confirm this perception.

In 1985, a study commissioned by the World Bank found that half of the 74 projects surveyed were subject to both incentives and requirements (Guisinger and Associates, 1985). A 1987 study of the US Overseas Private Investment Corporation (OPIC) on 50 projects in Asia, the Middle East, Africa and Latin America found a similar share of incidence of these measures. In the large majority of these, investors received favorable treatment in return for compliance with performance standards (Moran and Pearson, 1987). In 1989, as part of the preparation for the Uruguay Round trade negotiations, The United States Trade Representative (USTR) prepared a survey by country of the use of performance standards (see UNCTAD, 1991 p. 23). The study concluded that Local Content Requirements were the most used measure, with 75% of the developing countries adopting it, against 30% of the developed world. This was followed by export performance (50% for developing countries and 10% in the developed ones) and local equity requirements (55% in developing countries and 35% in the developed ones)[8].

[8] These high numbers contrast with the 1977 and 1982 results of the Benchmark Survey of the US affiliates abroad, that report that only 1-6% of the foreign affiliates are subject to each of the performance requirements considered in the survey (although with local content still as the more prevalent restriction), while 7-26% have some type of investment incentives. The reason for this, that will be discussed below, is that a large majority of the requirements are considered redundant. So, when answering to standard questionnaires, companies may not consider them if they do not influence their day to day work. This problem does not occur in the more detailed interview work.

Policies of incentives and requirements seem to be quite general, although some industries seem to be more affected by them than others. For example, in the automotive industry, virtually every developed country has used one or more of these types of measures to promote the development of the local firms (75% of the auto projects surveyed in the World Bank study described above, and 80% of the projects of an International Trade Commission report cited in UNCTAD, 1991)[9]. Similar policies were used in the electronics or chemical sectors (Guisinger and Associates, 1985 chapters 4 and 5). Among the types of measures referenced in these studies, export requirements and local content requirements are the most prevalent. Given the conclusions of the previous section on the importance of exposure to international markets and the establishment of linkages to the local economy, it is not surprising to find these results.

Despite their importance, the economic evaluations of the impacts and success or failure of these policy measures is surprisingly limited. A profusion of work on measures such as quotas and tariffs can be found. Incentives, in particular subsidies, have been also been widely considered and analyzed in the literature (OECD, 1989; UNCTAD, 1996; UNCTAD, 1997; Moran, 1998). On the contrary, the literature includes limited efforts to analyze requirements, in particular at an empirical level. This situation is partially due to the difficulty of conducting proper tests that are able to measure indicators associated with performance standards policies and their impact on key variables. Because these policies are often coupled with tariffs, quotas and other regulations, it becomes difficult to distinguish each individual effect. It is also due to a questionable theoretical framework, which has assured that performance standards in their very nature could lead to no other outcome except distortion. This section tries to explain why have performance standards often been misread and the conditions for an objective analysis of the issue.

On the role of performance standards for foreign investment, Davidson et. al. (1985) write:

> *It is well known that many countries are ambivalent towards foreign direct investment domiciled within their boundaries. They are cognizant of the benefits with foreign capital but they are fearful of its real or imagined cost. That ambivalence is certainly*

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[9] For country case studies see Veloso (1998) for Mexico, Taiwan and Thailand; Shapiro (1993) for Brazil

reflected in the juxtaposition of incentives designed to attract foreign direct investment and a variety of restrictions placed on the activities of foreign firms.

What is claimed is that the use of both subsidies and requirements often may not express ambivalence, but rather clear objectives for the investment project, most of the time derived in conjunction with government and local industry. But this may not always be so. Performance standards may also be a disguise for wasteful protection. In fact, the reason authors have mostly considered them as protective measures is because the difference between protection and performance objectives is subtle, and it has often been easier for researchers to label them as different forms of protection[10]. Nevertheless, the characteristics and goals may be quite different in nature, and understanding them becomes crucial for distinguishing a positive government intervention from a negative one.

The notion of reciprocity is crucial in order to understand performance standards. Developing nations that successfully used performance requirements did not use them in isolation, and they were certainly not a mere protective policy. On the contrary, particular developmental objectives are associated with the enactment of these policies (Amsden, 2000, ch. 7). Faced with the costly and lengthy process of foreign technology adaptation to make local firms competitive, government responded through the enactment of learning oriented subsidies to local firms and spillover focused ones to international firms. Nevertheless, support was allocated according to the principle of reciprocity, whereby assistance was only allocated in exchange for performance requirements. Sometimes these performance requirements took the form of exports---a firm would have to export so much over a certain time period in exchange for, say, tax breaks. Sometimes it took the form of requiring firms to incorporate a certain value of national intermediaries, or to invest a specific amount in worker training or R&D. East Asian economies were particularly keen and savvy in the implementation of performance standards as reciprocals of subsidies and overall support schemes (see for example Guisinger and Associates, 1985; Lim and Fong, 1991; Veloso, Soto et al., 1998; Amsden, 2000).

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[10] There is a body of literature on government failure and rent-seeking activities that provide a clear perspective of why would a government be interested in protection not having in mind the maximization of social welfare (see for example Krueger, 1990)

The logic for performance standards seems straightforward. Governments in industrializing nations were aware that local firms needed to learn how to master the technologies of the developed world to be able to catch up and compete. Nevertheless, as discussed above, market power and coordination problems may result in under-investment by both local firms and foreign investors in the types of skills and technologies that are critical for industrialization. The government response was to step in and intervene, setting targets and defining milestones that could steer the economy in the right direction. Some of their main targets were export promotion and backward linkage formation, exactly those that are recognized as having more importance for development, and also those that are more prone to be subject to increasing returns and externalities that generate under-investment.

To achieve these targets they used both a ‘carrot and a stick’. Incentives were granted to companies that would agree to enter the challenging export markets, or endure learning or teaching tasks that would be more costly, and subject to more external effects[11]. Nevertheless, to prevent firms simply from taking the money and then shirking their responsibilities, performance requirements would be agreed up-front, with severe penalties for non-compliance. Within this logic, the juxtaposition of subsidies and performance requirements is hardly the result of an ambivalent feeling towards multinationals, but rather the result of clear developmental objectives.

2.4. Understanding the Impact of Domestic Content Requirements

2.4.1. Models of Performance Standards with a Focus on Local Content Requirements

Based on the underlying logic described in the previous sections, this section describes and assesses some of previous work that addressed the subject of performance standards, highlighting

[11] For example the cost of training a technical people in an industrializing environment is extremely high because human capital and supporting technical resources are scarce. Moreover, once trained, an individual can easily be lured into another firm with a small wage premium, rendering the investment of the original firm useless. While this is a loss from the point of view of an individual firm, it certainly is not from the social perspective. Therefore, government support for technical training can be easily accepted.

critical insights and major limitations. The focus will be in the analysis on domestic content, with particular attention to its relations with the establishment of backward linkages.

Grossman (1981) developed one of the original formal models exploring the issue of performance requirements. The purpose of his article was to investigate the resource reallocations associated with content protection and content preference schemes. This model embodies the critical intuition that has been used to explore this issue in most of the subsequent literature. It assumes the existence of a domestic consumer goods sector that purchases from an intermediate sector, either nationally or abroad. Nevertheless, because of inferior technological capability, the domestic cost of intermediate goods is greater than the international price. The market equilibrium would be to have local producers of the consumer good sourcing from abroad. Concerned with firm survival and learning in the intermediate sector, the government enacts local content requirements. Protection causes an increase in the output of domestic components sector. Nevertheless, because of the higher prices of local components, the price of the final good will increase and, as a result, the quantity sold will go down. Which effect dominates depends on the sensitivity of the intermediate good production to changes in its output price, and of the final good production to changes in the price of the intermediate. In any case, there is a clear transfer of surplus from consumer to producer, eventually with some dead-weight loss in the process[12].

Following the paper by Grossman, subsequent work has been mostly focused on the issue of market power. The idea has been to explore how performance standards such as domestic content and export requirements fit with the rent-shifting argument proposed by Brander and Spencer in 1985 . Most research has addressed the impact of market power in the final goods market assuming a competitive supply industry, either with a fixed cost for local purchases that is higher than the international one, or with a generic upward sloping supply curve. Hollander (1987) investigates how domestic content requirements imposed on a vertically integrated monopolist affect production and welfare. He shows that a there are potential schemes where a small

[12] Herander and Thomas (1986) build on Grossman and reach a similar conclusion for the joint analysis of domestic content and export requirements.

tightening in local purchasing requirements can increase the range of intermediate goods, as well as the quantity of final goods produced, although welfare effects are ambiguous.

Davidson et al. (1985) analyze the duopoly situation where a local firm in the final goods market competes against a subsidiary of an international firm that is lured into the host country by high tariffs, but is also subject to export and local content requirements. It assumes that unit costs of the intermediate good in the host country are above the international prices. Local content and export requirements reduce the output of the foreign firms, increases the output of local companies, but overall output is reduced. Host country effects are ambiguous because loss in consumer surplus due to reduction in output is coupled with profits shifting to domestic producers. Richardson (1991) obtains similar qualitative results by looking at a duopsony and considering an upward sloping supply curve on the local supply industry. Lahiri and Ono (1998) propose a model with oligopolistic competition between domestic firms and foreigners, but where the number of foreigner investors is endogenously determined and can be influenced by a government taxes and domestic content regulations (that forces firms to buy the more expensive local intermediates). The article focuses on the trade-off between employment and final good price, concluding that local sourcing should be encouraged if FDI has a large efficiency impact, while local sourcing should be discouraged for inefficient investment.

The impact of domestic purchasing requirements on production and welfare has also been considered when there are market distortions in the intermediate goods sector. Vousden (1987) shows how the relative efficiency of local content and tariffs depends on the degree of monopoly power in the upstream industry. Krishna and Itoh (1988) analyze the effects of content protection through a model with perfect competition in the final goods market and duopoly in the intermediate inputs market, with one national and one foreign supplier. They conclude that a physical content protection scheme raises domestic profits if products are substitutes, but lowers them if products are complements.

Recently, these original models were expanded to incorporate multiple firms both in the upstream and downstream sectors. Belderbos and Sleuwaegen (1997) analyze the effect of local content requirements in a setting with monopolistic competition in the upstream and downstream industries. Their model shows how the ability of the upstream firms to charge a mark-up higher than marginal cost and international prices determines the outcomes of the model, again a reinterpretation of the original conclusions of Grossman. Forcing international companies to source part of their inputs locally increases the market power of upstream companies (and therefore their profit), which has a negative effect on the cost (as well as the profit) of the final good producers, which may be more critical in national firms than in foreign firms if the former rely more heavily on local inputs. Consumer surplus is also reduced and, as a result, an overall reduction in national welfare is likely. Lahiri and Ono (1998) explore an oligopolistic model of entry where multiple domestic firms and foreigners compete selling a final good. The number of foreigners is endogenously determined, and the government can influence it through a tax on foreign firms or a domestic content regulation. There are two competing effects of FDI, an employment effect and a price lowering effect. Efficient FDI has mostly a price lowering effect, while inefficient FDI affects mostly employment creation. They show that local content and tax profit can be used to balance the two.

A recent study by Kim (1997) adds a time dimension to the analysis. The study focuses on the long-run macroeconomic effects of content protection policy in a small, open economy within the intertemporal optimizing framework typical of endogenous growth models. He assumes that content requirements force the local producers of the final good to buy domestic intermediate goods, which have a cost always above international prices. His results show that a more restrictive content protection policy leads to a lower level of the capital stock, an improvement in the current account, and a decrease in employment.

The research performed so far on this area has helped to understand resource reallocations associated with performance standards. Forcing domestic sourcing when prices are above international ones is bound to increase overall prices and, if the demand is downward sloping, reduce output of both the final and intermediate goods markets. In terms of welfare implications, local content regulations imply a surplus transfer from consumers to producers, often with some deadweight losses on the process. According to the models described so far, the net result of these transfers tends to be negative. Market power in the upstream industry often aggravates local inefficiencies and contributes to reducing welfare.

The key limitation of existing models is their sole focus on the rent shifting effects that derive from imperfect competition between players in the market. As shown in the previous paragraphs, models have analyzed how welfare is affected by strategic behavior and supra-normal profits in the presence of government restrictions on sales and purchases[13], an important aspect associated with the impact of FDI in the domestic market. Nevertheless, as exposed in section 2.2, the crucial issue driving the potential contribution of foreign investment to development is the dissemination of knowledge and technology to the local economy. Moreover, section 2.3 explained that performance standards enacted by governments in developing nations had clear objectives of attracting FDI and assuring that local spillovers and learning were achieved. Yet, existing models of local content requirements seem to have mostly ignored these issues at the core of these policies. This conclusion becomes even more pertinent once we observe the lack of empirical analysis on the subject.

2.4.2. Empirical Assessment of Local Content Policies and Decisions

The evidence on the impact of performance standards is rather limited. In 1991, the United Nations prepared a review of the meager studies published until then, which will be briefly described here (UNCTAD, 1991). Since then, few new results have been unfolded. I will mostly address the effects of performance standards on the host country[14].

The results of the assessment of the impacts of performance standards on company behavior are particularly relevant, precisely because a substantial share of the companies report that the existence of performance standards has not affected their investment decisions. This conclusion seems to be consistent across the studies mentioned in the previous section, with the conclusion holding for several industries surveyed (World Bank, OPIC, USTR and the ITC, all of them reviewed in UNCTAD 1991). Companies report that performance standards has made them increase the levels of investment in host countries from what they had initially planned, precisely according to the host country objective. The World Bank Study states that in several of the cases subject to performance standards, corporate officials informed that their firms would have

[13] With the exception of Lahiri and Ono (1998) that also consider employment effects

eventually achieved the level of exports or domestic content required by the government on their own. The principal impact of the measures seems to have been the acceleration of the firms' efforts to develop local firms or to enter export markets. In the auto industry, in particular, the same study found that these policies did increase exports and reduce the imports of intermediate products.

When performance standards did matter, they were seen to be discretionary and negotiable (this happened in 58% of the measures in the countries surveyed by USTR). In these circumstances, requirements were bundled with incentive packages to balance the objectives of the government and the multinational until a viable deal would be achieved (see Guisinger and Associates, 1985 for several examples). In fact, competition in incentives between governments seems to be more of a critical issue. Several of the officials interviewed in the World Bank study reported that, at the margin, the host country government could not reduce their incentive packages without losing substantial investment.

The conclusions from these studies seem to be that performance standards do not have a major influence on the behavior of the investing companies. They do not seem to divert much of the investment away from the original intentions of the investors, and when they do change the behavior, it has been seen to be such that it would favor the objectives of the host country when they enact standards by increasing investment, improving backward linkages and enhancing exports. When they become important, they are also usually flexible and framed within a package that includes investments that compensate part of the additional cost or risk to the investors. Moreover, although we can't measure them, they are also likely to have drawn away investments that were too far from the government standards. One could hypothesize that it was part of the objective of the government to 'weed out' investments that would not benefit the development of the local industry. This again brings up the possibility that at incentives and performance requirements can be used as screening mechanisms, something to be explored in the next section. This perspective is corroborated by the conclusion of the UNCTAD (1991) report that fear-of-loss coupled with promise-of-gain can overcome firm rigidities that generate under-investment.

[14] One could also analyze the impact on home countries. Nevertheless, this is not the focus of this research

The analysis of entry and behavior does not answer the question of the impact of these standards on countries' resource allocation and welfare. A small number of industry case studies provide some preliminary assessment, but the evidence is still scarce to make any conclusion. Evidence seems to show that the impact of incentives and performance standard packages seems to cluster at two extremes. Failures are associated with sub-optimal economic size and shelter from competition, with subsidies to make up for permanent high costs. Successes are associated with full utilization of economies of scale and ultimate subjection of the project to competition, with implicit and explicit subsidies aimed at overcoming corporate reluctance to bear transitional and redesign costs and uncertainties (a conclusion shared by the report of UNCTAD 1991).

In a study of the Indian auto industry, Krueger (1975) analyzed the impact of the complex local policy, where local content requirements were part of a detailed production and import licensing scheme. She suggests that the existing policy was more restrictive than an equivalent (effective) flat tariff of 200% and that industry value added could rise by as much as 34% if the existing policy were to be replaced by an uniform protection level of 50%. Given the complexity of the policy, the study does not address the particular impact of any of its components. In a generic cross country analysis, Bale and Walters (1986) report that 16 countries with less 100,000 vehicles output per year, requiring 18% to 100% domestic content were supporting the industry with import tariffs that averaged 100%. They do not provide any detail on the relative effect of any of the two policies.

Takacs (1991; 1994) estimated the static inefficiency of performance requirements in Uruguay and the Philippines, which included an embargo on imports of cars, tariffs on imported parts, local content requirements and export requirements. For the Philippines, she estimates the consumer cost of the protective environment to be 40% of vehicle price. Part of this cost was transferred to the producers, 13% to the assemblers, and 9% to the component manufacturers, with a dead weight loss corresponding to 10% of vehicle sales price. Nevertheless, as the author recognizes in the analysis, most of the negative effect of the policy was due to the tariff, and the result would only change by roughly 10% if the domestic content and export requirements would be removed. Moreover, her calculations for the components sector rely on an upward sloping supply curve (with elasticity equal to one), which is assumed without any supporting data. This is a very fragile assumption for volumes of twenty to thirty thousand components found in the local market because economies of scale are very likely to exist.

Contrasting with the previous cases, authors claim that performance standards played an important role in the development of the Mexican auto industry (Bennet and Sharpe, 1990; Veloso, Soto et al., 1998). These measures seem to have played even a greater role in the development of the Taiwanese and Portuguese auto industries, whose autoparts firms, despite the small size of the local market are leaders in volume of exports in relation to the volume of cars assembled domestically (Veloso, Soto et al., 1998; Veloso, Henry et al., 2000). In a survey of 16 projects in the chemical industry, Gray and Walter (1984) found that performance standards seem to be both the reason for success and failure, depending on the specific conditions of the project. Similar contrasting findings have been reached in studies of the computer industry. Frischtak (1986) estimated that foreign computer producers in Brazil, facing large domestic content regulations and high protection, charged two to three times as much as prices available outside the country, reducing the local use of computers and dragging the pace of technology upgrading. On the contrary, Nunez (1990) credited the 1985 export performance standards policy of Mexico with being partially responsible for the rapid growth of the industry thereafter.

The pattern of studies seems to follow the characteristics of the theoretical models described above. Virtually all the detailed microeconomic studies describe static scenarios of price distortion and transfer of surplus from consumers to producers, eventually with deadweight losses. Nevertheless, none of these seems to incorporate issues related to external effects and spillovers. Longer-term industry assessments, albeit with no quantitative cost-benefit analysis, seem to indicate that the impact can go either way depending on particular conditions of the investment and local market.

The only econometric study on the impact of local content on development seems to be by Beghin and Lovell (1993). These authors evaluate the economic impact of a requirement to include domestically produced leaves in the local tobacco industry, concluding that this policy has not contributed to an increase in the demand of local leaf, and that there has been distortions of local and international prices. Despite these negative conclusions, this paper is hardly adequate to derive conclusions in what concerns local content requirements as a viable industrial development policy. In fact, the production of tobacco leaves in Australia since the sixties would hardly qualify as an industrial intermediate where relevant learning, increasing returns or barriers to entry may lead to under-investment from local firms. The described situation is more likely to belong to the cluster of protectionist policies enacted by governments to artificially sustain an inefficient industry. As a result, the conclusions found by the author are not surprising.

Overall, the small number of studies described above give an ambiguous result of the impact of performance standards, in particular local content requirements Therefore, any overall conclusions can only be made based on perception. For example, Moran (1998) strongly dismisses domestic content as a reasonable policy to promote development, stating that it distorts the incentives of investors in such a way that they end up promoting stasis and inefficiency, rather than accrued development. Nevertheless, he does offer some support for export oriented performance standards. With a contrary opinion to Moran, Amsden (2000) builds a case for performance standards as an important development tool. Based on a series of country case studies, she highlights the particular role they can play if properly mastered and articulated with the right incentive structure.

2.4.3. WTO, TRIMS and he Use of Performance Standards

Performance standards such as domestic content have been the hallmark of industrial policy, particularly in developing nations and intermediate economies. But in the Uruguay Round of trade negotiations, the member states agreed to limit the ability of nations to use this type of policy mechanism. The agreement on Trade Related Investment Measures (TRIMs) of the World Trade Organization prohibits restrictive measures applying to any investment, whether foreign or national, and whether the measures are in the form of mandatory requirements or in the form of conditions to be met to obtain an advantage. This includes a prohibition for WTO members to link subsidies to local content requirements, import restrictions, or export objectives. The apparent inclusiveness of the TRIMs agreement would make it seem that these policies were soon going to be eliminated across the globe. However, recent history since the contract was signed has shown that they are being revived under several forms.

First, developing nations were given up to eight years to implement this agreement (depending on the measure), a period scheduled to end in 2002. Yet, seven nations have already applied for an extension on a number of products and other may follow suit (UNCTAD, 1998). Second, developing nations were given permission to deviate temporarily from TRIMs requirements associated with national favored treatment and quantitative restrictions (including domestic content) in accordance with rules on the protection of infant industries or balance of payments safeguard measures. No limit on the temporary deviation was set (Fukasaku, 2000). Third, performance standards have evolved from a national policy to a regional trade issue. Since its inception the WTO has been notified of roughly 100 regional trade agreements (Amsden, 2000). So, instead of individual country policies, trade blocks are enacting ever-stronger rules for investment and subsidies in the region. In the automotive industry, for example, this trend is quite strong, even in the developed world. Automotive plants in the NAFTA are required to source 62.5% of the components in the region; in the Mercosur and European regions, this value is 60%. Similar levels are expected in the AFTA – ASEAN Free Trade Area under creation. Fourth, these policies are also re-emerging on an informal basis. In a recent investment in Portugal, despite an official EU court decision overthrowing a local content requirement associated with a large investment in the auto sector, the investing firms kept the local content as an explicit objective and an informal commitment with the Government (Veloso, Henry et al., 2000). Brazil hammered out a direct agreement with a number of developed countries where the big manufacturers are based to be able to maintain some degree of protection in the local industry (Amsden, 2000).

Recent events show that performance standards may be part of industrial development policy for a much longer period than had been anticipated in 1994, when the TRIMs agreement was signed. Nevertheless, it is unquestionable that there will be more probing from the WTO upon the enactment of these measures, whether in a regional trade block, or as part of temporary protection measures. Therefore, it is important to have a better understanding of the motivations and contribution that these measures may have for development.

2.5. Research Question, Hypothesis and Methodology

The theoretical models and empirical analysis described above seem to point to the existence of conflicting views on the potential role of performance standards, in particular local content requirements. Empirical results have documented evidence of both very good and very bad outcomes of this policy. Economic models proposed so far seem to discourage these types of policies. They explain how, under most circumstances, there will be a reduction of consumer surplus, which is partially transferred to producers and eventually generates deadweight losses that reduce country welfare. Nevertheless, they have focused on the rent-shifting effects of these policies and have overlooked the potential role that external and learning effects can play in host countries, precisely the issues that have been the core motivation for the enactment of these policies.

A better understanding of these issues is even more pertinent because policy makers in developing nations have been and continue to be firm believers in performance standards, in particular local content requirements. While some of these may formally disappear at a national level in the future because of WTO regulations, they are likely to continue on an informal basis, at a supra-national level and particularly in the developing world, that has been given some latitude in the adoption of the new WTO rules.

Multinational firms have sometimes pressured and eventually campaigned for the removal of performance standards. Nevertheless, interviews with corporate decisions makers of companies subject to performance standards have revealed that they often accept the requirements that are imposed by the governments, incorporating them in the decision making processes (Guisinger and Associates, 1985). Sometimes, these companies even report that the whole bundle of requirements and performance requirements fit well with the overall business environment and they gladly accept compliance (Veloso, Henry et al., 2000, chapter 3). On the contrary, local firms that are potential suppliers to large multinational investors actively endorse policies that require domestic purchasing (Veloso, Soto et al., 1998; Veloso, Henry et al., 2000, chapter 3). They often feel marginalized by large multinationals, even when they are able to comply with price, quality and delivery requirements. They consider that domestic content regulations generate unique opportunities for local firms that would not be possible otherwise.

The question then is whether it is possible to reconcile economic analysis with the perceptions of the policy makers enacting local content policies and firms making decisions. The particular interest is understanding if there are reasonable conditions under which this policy may improve domestic economic conditions.

Therefore, the major research questions that this thesis is addressing are:

> *Does it make economic sense for a host country to enact local content requirements? Who benefits and who loses from this policy? Are there market, technology and policy regimes where content requirements can improve welfare in the economy?*

To try to answer this question and guide the establishment of the working hypothesis, the main results of the literature review of the previous section are used. The crucial issue driving the potential contribution of foreign investment to development is the effect of spillovers of knowledge and technology on the local economy. Moreover, one of the critical mechanisms through which these effects materialize is domestic linkages, in particular to local suppliers. This situation generates a gap between social and private valuations of resources associated with foreign investment and to its links in the economy, which would result in sub-optimal societal investment if decisions were left only to the market.

Section 2.3 showed that local governments have been aware of the external effects associated with FDI. Their concern with the appropriation of these benefits led them to enact performance standards with clear objectives of attracting FDI, assuring that local spillovers and learning were achieved. Domestic content requirements were among the most important measures. Research on the effects reported on section 2.4 show that these policies have had mixed results.

These findings suggest the following hypotheses that will be address in the thesis:

> *Domestic Content Requirements contribute to the development of the local industry when used together with subsidies to (1) internalize differences between private and social valuations of OEM and supplier resources and (2) create incentive structures that align the objectives of the foreign investor and domestic government.*

To test this hypothesis, a firm level model of investment in a local economy will be developed, so that it can capture the decisions of the relevant agents and their impact on the welfare of the local economy. Then, the model will be tested for the context of the automotive sector, an industry where the use of domestic content has been very pervasive and where it is expected to continue to play an important role in the next decade. This testing implies generating a detailed cost analysis of the auto supply industry to construct a set of benchmarks for the industry.

Because of its interdisciplinary nature, this thesis has contributions in three areas. The first one is in the area of industrial development. With the new rules of WTO, the developing nations will be under stricter probing from the developed world and international organizations concerning the use of performance standards like domestic content requirements. This thesis will provide a model to assess conditions under which domestic content policy is welfare enhancing for the country, with valuable insights for the nations and international organizations. In addition, it will provide benchmark levels for the case of investments in the auto industry.

The second area is methodological. The proposed analysis merges economic and management analysis with methods and technical solutions used to assess cost in the auto components industry. The combined work enables a fair assessment of the cost structure of the auto components industry. Moreover, it will inform how the reliance on simplified economic analysis may tend to bias conclusions regarding technology cost and firm performance.

The third area is in the characteristics and global sourcing decisions of the auto industry. Since it provides an analysis of a scenario for the auto industry, it provides valuable insights into the purchasing options available to auto sector managers. In particular, it shows when it is worthwhile for managers to engage in constructive engagement in local sourcing decisions in new investments in the auto industry. There will be a number of these situations in the auto industry in the coming years in developing nations and the results presented in the thesis may prove to be valuable.

Chapter 3.
A Model to Evaluate Local Content Decisions

This chapter proposes a model to analyze the effects of local content requirement policies on the behavior of economic agents and the welfare of a local economy. First it discusses the framework associated with the evaluation of the impact of foreign investments in local economies. Then it explains the decisions of private economic agents in the context of complete markets, how they may be affected by local content requirements, and the overall welfare implications of government and firm decisions. Third, it compares the domestic content requirements with polices such as tariffs and subsidies that are often used as alternatives. In the fourth section, the existence of external and learning effects and their implications to this policy are discussed. Finally, an extension of the model to account for risk averseness is proposed.

3.1. Valuing Investments in a Local Economy

Following chapter 2, the objective is to understand if it makes economic sense for a host country to enact requirements on an original equipment manufacturer (OEM) regarding the purchases of domestic components. As expected, the natural metric to judge the performance of projects and policies is welfare or surplus analysis. In general, welfare analysis entails a comparison of the benefits generated by an activity with those that would be created if the same resources were deployed elsewhere in the economy (Grossman, 1990). For the evaluation of the impact of domestic content requirements, a benchmark without such a policy and a mechanism to assess welfare changes resulting from its enactment must also be established.

Economists and policy makers have long been concerned with having methods to fully assess the impact of development projects on a local economy. Over the past few decades, several methods to evaluate the welfare impact of a project on an economy have been proposed. Social cost-benefit analysis was probably one of the initial and most comprehensive efforts to establish models and techniques for project appraisal (Brent, 1990; UNCTAD, 1996). In the late sixties, Little and Mirrlees established guidelines on the use of the method for evaluating of projects and policies in developing nations (Little and Mirrlees, 1968). Since then, a number of authors have addressed this issue, either detailing frameworks or evaluating specific projects, often with government participation (Little and Mirrlees, 1974; Lall and Streeten, 1977; Lal, 1978; Weiss, 1980; Warr, 1983; Brent, 1990; Curry and Weiss, 1993; Chitrakar and Weiss, 1995; Dinwiddy and Teal, 1996). Social cost benefit analysis is also one of the methods that has gained more acceptance and is currently used for assessing the costs and benefits of requirements and incentives associated with foreign investment in the developing world (UNCTAD, 1996).

In social cost benefit analysis, the various costs and revenues of a project are restated at their full economic costs and benefits (Little and Mirrlees, 1974, chapter 9). For example, if there is widespread unemployment, the economic opportunity cost of labor may be zero and the labor costs of a particular project are not considered. Likewise, interest rates, exchange rates and input costs are changed to their opportunity cost and output is restated at world prices. When evaluating the project over time, these costs and benefits are discounted using a national opportunity cost of capital.

The important issue associated with the evaluation proposed in this chapter is the fact, explained in Chapter 2, that foreign investment in developing or intermediate economies has the potential to generate industry and economy wide productivity increases that are not accounted in the decisions of private economic agents. The question is then how to incorporate these external effects in the welfare calculations of the impact of domestic content requirements. A basic approach acknowledges that it is difficult to understand the mechanism through which the external effects happen. Therefore, they are simply considered an additional output that can be estimated and added ad-hoc to the net benefits calculated assuming no external effects (Lal, 1978; UNCTAD, 1996). The obvious problem with this approach is that cannot be used to understand how externalities affect resource allocations.

An alternative approach includes externalities in the structure of the evaluation, enabling a better understanding of their role in the results of the project and the potential impact of any policies adopted by the government (Squire and Tak, 1975 chapter 2). If the mechanisms through which externalities affect the value of the project are established, then the model might incorporate them directly. This may happen, for example, if spillovers are a function of cumulative firm or industry output (see section 3.4.2). Nevertheless, as can be readily understood from the discussion of section 2.2, it is often the case that only the overall drivers of the external effect and not the precise mechanisms are known. This discussion of the previous chapter will be recalled in the next paragraphs to establish the relevant drivers that ought to be considered in a model to assess welfare implications of foreign investment and local content regulations.

The first mechanism to be considered is human capital augmentation. Labor training and skill acquisition translate into higher productivity within the firm and also contribute to increased productivity in the sector (Aghion and Howitt, 1998, chapter 6). This can be interpreted as a reduction in the social opportunity cost of the worker, which will be below the wage it is being paid by the hiring firm (Warr, 1983). This effect is as important for the workers directly associated with the foreign direct investment (FDI), as well as to those working in suppliers.

The second mechanism highlighted in section 2.2 is the complementarity associated with foreign capital, which increases the marginal productivity of domestic technology, particular within sectors or clusters of activity. Because of this external effect, alternative uses of the capital in unrelated domestic activity must have an opportunity cost below the returns of this application (de Mello Jr., 1995). Expenses in disembodied capital associated with issues such as patents, license or designs will be set aside. In fact, these are precisely the types of expenses that result in greater complementarities to existing technologies. Like the case of labor, this notion is also relevant for suppliers, which materialize the cluster characteristic often identified with increasing spillovers of FDI (de Mello Jr., 1997).

The social cost-benefit methodology entails an adjustment of the costs to reflect their true social economic value. Therefore labor, capital and technology costs are adjusted to account for the differences between social and private opportunity costs noted in the previous paragraphs. This approach will enable an understanding of how each of these factors contributes to spillovers that drive productivity increases generated by FDI.

Although most of the discussion so far has focused on the role of externalities, it is important to note that there are other reasons for differences between private and social costs on the resources used in the assembly and manufacturing of foreign investors and their suppliers. As concerns labor, traditional models have justified gaps between the two valuations based on unemployment, bargaining power of organized labor and efficiency wage issues, among others (see Dinwiddy and Teal, 1996, chapter 8). Private capital costs above social ones also arise from imperfections in capital markets, mostly as a result of shortsightedness of lenders or asymmetric information between these and the investors (Stiglitz, 1989; Grossman, 1990; Stiglitz, 1993). These factors can also push opportunity costs below the market prices paid by economic agents. A detailed analysis of the effect of FDI should take into consideration these aspects to distinguish external effects from other reasons.

Now that the underlying framework of analysis is established, it is possible to start laying out the model. Two levels will be explored. First, private decisions and valuations are analyzed, neglecting any external effects that may exist. This enables an understanding of the underlying decision mechanisms and welfare effects associated with the OEM sourcing decisions, as well as an evaluation of the impact of a LCR policy on economic agents. Second, the model addresses how the existence of a gap between private and social opportunity costs for employed resources may affect the decisions of the government and the welfare of the local economy. The situation of unaccounted spillovers and learning will be studied in more detail.

3.2. Domestic Content Policies and Private Sourcing Decisions

The analysis developed here is done at the firm level[15]. First, a foreign investor that has decided to set up a plant in a particular region is considered[16]. A good example would be the decision of an automaker to establish a new unit, say in Brazil, to supply the local market and eventually the whole of South America.

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[15] A project-based evaluation assumes that the initiative is not large enough to affect the overall economy and, therefore, general equilibrium effects can be ignored. This is not always true, as large project may create pressures on inputs prices –especially labor-- that impact costs for other firms in the economy.

[16] The assumption that the investment decision has already been taken is important because the model does not try to address the issue of competition between governments for the location of multinational investment. This is certainly an interesting extension of the model.

The foreign investing firm will be called an original equipment manufacturer (OEM). This company is a final goods producer. To manufacture its product, the OEM uses labor and capital, as well as the components that make up the product. For example, an automaker will employ workers and equipment for the final assembly of supplied components into the final product, a car. It may also benefit from subsidies from the government. The profit function for the OEM can be written as:

$$\Pi^{OEM} = q.\left(P - C(K, L) - S + t\right) \qquad (3\text{–}1)$$

where q is the quantity sold; P is the price of the good; C is the internal OEM cost as a function of the amount of Labor (L) and capital (K); S is the component sourcing cost and t is the potential unit subsidy awarded by the government.

To proceed with the analysis it is important to discuss the behavior of the demand side. The first aspect is the decision time frame, which the model will consider as long run. This is reasonable because the local content policies are enacted for long periods of time and affect decisions such as sourcing, which in turn influence firm costs over one or more years.

Products affected by domestic content requirements are often complex and with important differentiating features. Again, the automobile is the natural example. Consumers exhibit individual preferences for cars that result in long run downward sloping demand curves for each model, instead of the flat demand that corresponds to a perfect competition environment. Moreover, it has been shown that its own price elasticity of demand is less than –1 (Berry, Levinson et al., 1995). A similar argument can be made for other industries. Therefore, the most plausible scenario, which will be explored in the model, is to assume a long run individual downward sloping demand.

This less than competitive demand behavior confers the firm some monopoly power that results in pricing above marginal cost. The OEM will maximize its profits by equalizing its marginal cost to the marginal revenues. Assuming that the demand is sufficiently elastic (the price elasticity of the demand less than –1 is a standard assumption for monopoly pricing - Tirole, 1988 p. 66 - and it is verified for the auto industry application presented in chapters 6 and 7), the OEM will charge a price given by:

(3–2) $$P = \frac{C + S - t}{1 + \left(1/E_d\right)}$$

Where E_d is the point elasticity of demand at the maximum. Given this market structure, the OEM has an incentive to minimize the marginal cost. Since the interest in mostly in the effects associated with the purchasing behavior of the investing firm, the OEM's technology will be simplified by considering a constant unit cost of capital and labor $C(K,L)=c$[17]. Furthermore, t is determined exogenously. Under these assumptions, it is straightforward to recognize from (3–2) that pursuing a profit maximization objective is equivalent to minimizing the costs of purchased components.

3.2.1. The Natural Sourcing Decision

The proposed analysis diverges from what most authors have explored in the past. As described in chapter 2, most researchers addressing the problem of domestic content have considered the components purchased by the OEM to be a uniform good with a certain price in the local and foreign markets[18]. This assumption does not fit well with reality, since design rigidities do not allow this kind of substitution. A computer, a car or a television, not only require multiple components, but their design decisions regarding what to do in-house and what to subcontract are done up-front (often taking in consideration the developed world), so that it is not possible to reverse them after the design is complete. Therefore, following Hollander (1987), the problem considers that multiple components are being sourced, as opposed to one uniform good[19].

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[17] I could assume the possibility of substitution between capital and labor, but this aspect would not change the general conclusions of the model and would make the analysis much more difficult.

[18] Grossman (1981) did consider the possibility of multiple components, but he also assumed that substitution between components was possible. He shows, not surprisingly, that this situation is equivalent to the unique good result. If substitution is possible then all components are used until the ratio of their marginal product to that of the primary good – usually labor - equals their relative prices. This enables the construction of a composite good that aggregates the individual components and whose price is determined by individual prices and level of local content

[19] The general setting of the model follows closely that of Hollander, although the purpose of the analysis diverges.

To achieve its cost minimization goal, the OEM requests quotes for each component and accepts bids from potential suppliers, both firms in the domestic industry and the world market. For each component, the OEM then chooses suppliers and corresponding prices, some in the domestic market, others imported from abroad. The tradeoffs determining the price of each component are illustrated in Figure 3–1. Close suppliers bring less risk of missed delivery due to idiosyncratic problems in the supply chain. But in a developing world environment, lower production scales, inexperience with the technology or poor macroeconomic environment (high cost of capital) may increase cost, even with wages that may be only a fraction of the developed world values. Local firms compete with foreign producers that, despite additional logistics cost and risk, are experienced with the technology and work at efficient scales, which is bound to translate into cost advantages. These aspects will be reflected in the suppliers' bids. It is likely that for some components, in particular those where wages and logistics costs are determinant, local suppliers have a cost advantage; while for others where scale and technical ability are the critical aspects, foreign suppliers will be more price competitive.

Figure 3–1: Sourcing Options for the OEM

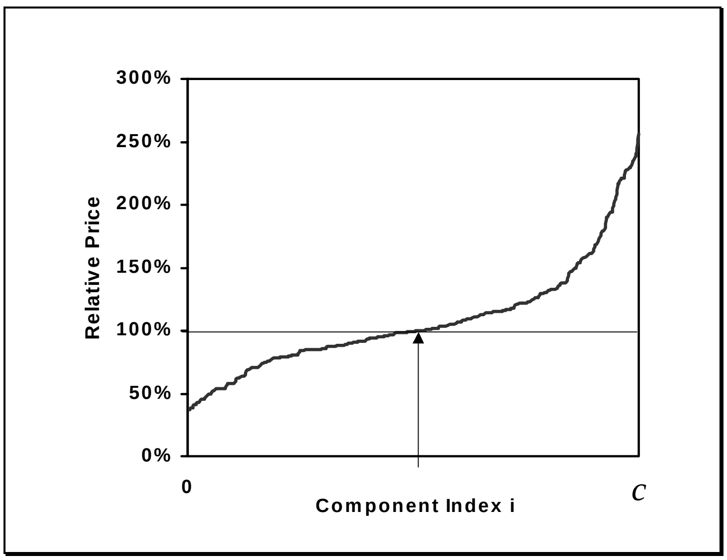
	Import Components from Home Market	**Source from Local Manufacturers**
Advantages	• Take full advantage of economies of scale in facilities located elsewhere • Source from efficient manufacturers	• No additional logistics costs • Favorable environment for being awarded subsidies
Disadvan-tages	• Expensive logistics costs • Less favored by the local government	• Low scale of production generates additional cost • Inefficiency of local plants

The profit function for each supplier of a component *i* is:

(3–3) $$\Pi_i(q) = q.\left(P_i - L_i.w_j - K_i.\left(r_j + d_j\right) - M_i - G_i - I_i\right)$$

where marginal unit cost includes a certain amount of labor *L* that gets paid at the wage rate *w* of the region ($j=D$ for domestic and $j=F$ for foreign); rental of capital *K* at rate *r* and with depreciation d; some materials and subcomponent costs M; logistics costs G as well as intellectual property costs I. As can be readily understood, all the inputs are treated as variable costs. This is a reasonable assumption because contracts are usually negotiated with sufficient lead time for the supplier to adjust its capital structure to the requirements of the demand (e.g. buy some new equipment that may be needed, train the people, etc). Equation (3–3) also reflects the assumption that component production is done by a constant returns to scale technology within the relevant production ranges. Component prices come from fierce bidding from potential suppliers, so that the price charged for both foreign and domestic producers of each component is assumed to be equal to marginal cost. As a result, normal profits are equal to zero.

Figure 3–2: Ordering Components Through the Sourcing Index



For purposes of analytical tractability, the model assumes that all variables are continuous. Nevertheless, the results are equivalent to a discrete version of the continuum analysis[20]. Components are indexed by a variable i_c and belong to a continuum $i_c \in [0,c]$. Since the focus of the study is on local content decisions, an important distinction will be made: the best bid for a particular component coming from a supplier in the domestic market is given by $P^D(i_c)$[21]; and

[20] Instead of a continuum of prices, there is a discrete set, with integrals replaced by sums and minimization through derivatives equal to zero replaced by numerical minimization methods.

[21] No distinctions associated with ownership are made. Local bidders may include foreign firms that make greenfield investments in the region with the purpose of supplying the investor

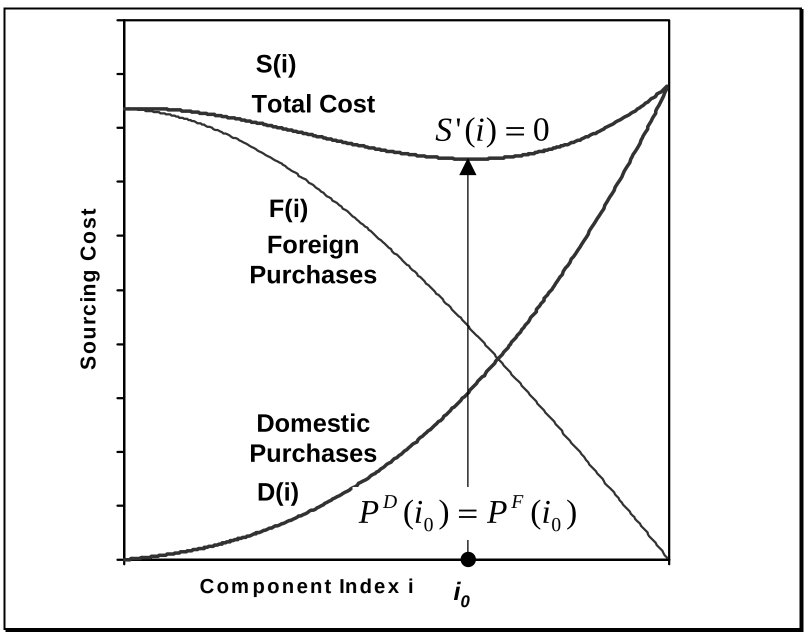
the top bid from foreign suppliers is given by $P^F(i_c)$. These prices are the result of maximizing the profit expression presented in equation (3–3).

The index of components is organized to enable an intuitive analysis of the sourcing decisions of the investor. As shown in Figure 3–2, they are indexed so that $r(i_c) = P^D(i_c) / P^F(i_c)$ is a non-decreasing function in i_c. As a result, the components where the domestic price is furthest below the foreign price in relative terms are indexed with the lowest values of the index. With this arrangement, if components in the interval [0,*i*] are produced in the host country and those in the interval [*i*,c] are imported, unit sourcing cost for the OEM is given by:

(3–4) $$S(i) = D(i) + F(i) = \int_0^i P^D(s)ds + \int_i^c P^F(s)ds$$

Figure 3–3 illustrates the sourcing cost and its two components as a function of the index *i*.

Figure 3–3: OEM Sourcing Cost as a Function of Component Sourcing Index



The benchmarking scenario assumes that the OEM is free to decide the level of local content. Since its objective is minimizing sourcing cost, it will choose *i* so that:

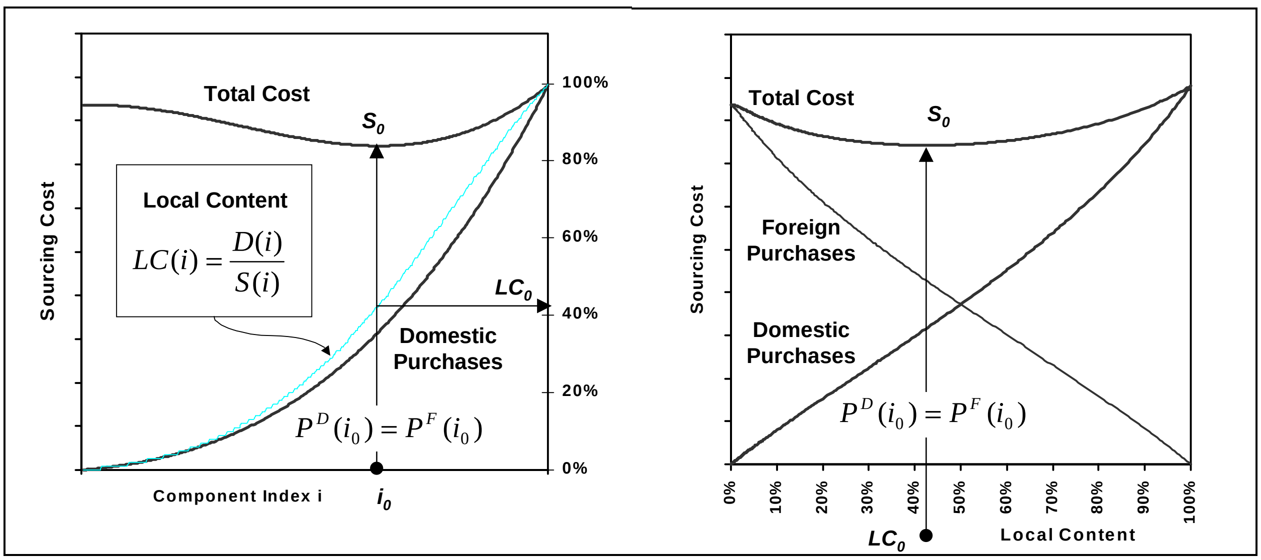
(3–5) $$S_0 = S(i_0) = \underbrace{Min}_{i} S(i) \Leftrightarrow \frac{dS(i)}{di} = 0 \Leftrightarrow P^D(i) = P^F(i)$$

This intuitive formula indicates that, for each component c_i, the investor will compare best practices in both the local and foreign business environments, choosing the firm with the lowest cost. The equality between $P^D(i)$ and $P^F(i)$ comes from our ordered set and means that local components are incorporated until their price is matched by the price of foreigner suppliers. This corresponds to the index i_0, with an associated Sourcing cost S_0, as represented in Figure 3–3.

Among all the components bought by the firm, those that are sourced in the local economy generate a certain domestic content. This level of local content, represented by *LC* which can be calculated from equation (3–4) dividing the total purchase value in the local economy by the total component sourcing cost associated with the final good:

(3–6) $$LC(i) = D(i)/S(i)$$

Figure 3–4: Correspondence between Index and Domestic Content Level



Equations (3–4) and (3–6) define the key variables that enable a calculation of the impact of decisions and policies on the OEM cost structure. An important aspect of these equations is that the function *LC(i)* is monotonically increasing with *i* and, therefore establishes a unique correspondence between the index and the level of local content[22]. As a result, each *i* has a specific level of local content *LC(i)* associated with it, and the sourcing cost can therefore be

[22] To see this, note that d.LC(i)/d.i is always positive

represented also as a function of the level of domestic content. It also generates a 'natural level' of local content $LC_0=LC(i_0)$. This correspondence and the representation of the sourcing cost as a function of the domestic content are represented in Figure 3–4.

3.2.2. The Effect of Domestic Content Requirements

What happens if the local government requires the OEM to have a certain level of domestic purchases? The intuitive result, detailed below, is that enacting content requirements will increase the sourcing cost of the OEM. Because of monopoly pricing, this additional cost will also result in an increased price for the final good and a reduction in the quantity sold. Both effects reduce the welfare of the local economy.

When facing local content requirements, the foreign investor will select the components across the universe of potential suppliers that meet the local content requirement with the least aggregate cost. Using l as the level of requirement, and considering equations (3–4) and (3–6), this means that the sourcing decision must verify $LC(i)>=l$. The new cost minimization objective of the OEM can be written as[23]:

(3–7) $$i_l = \underbrace{\arg\min}_{i} \{S(i) \text{ subject to}: LC(i) \geq l\}$$

The solution to (3–7) establishes that, for a given level of domestic content requirement l demanded by the government, there will be a set of components in the interval $[0,i_l]$ that will be locally sourced inputs and remainder $i \varepsilon (i_l,c]$ imported. Clearly, the level of local content requirements only makes a difference to the economy if $l \geq LC_0$. If this is the case, the constraint in (3–7) is binding and defines the index i_l. Moreover, because of the monotonicity of $LC(i)$, this relationship is unique and $i_l \geq i_0$. The new index also defines the sourcing cost as $S_l = S(i_l)$.

[23] This is a definition based only in non-labor input value. Alternatively, the definition could also include labor inputs, profits and taxes as domestic content; a definition based on part count has also been used (see Grossman, 1981)

The sourcing cost of the investor will always be penalized by the extra price of the domestic components across the distance [i_0,i_l] that needs to be incorporated to meet the domestic requirements. This implication can be seen graphically in Figure 3–3 or Figure 3–4. As either index or local content is moved from the level corresponding to the minimum cost towards the right, the sourcing cost increases. From the definition proposed in equation (3–4), the sourcing cost difference $\Delta S = S_l - S_0$ can be simplified to:

$$(3\text{–}8) \qquad \Delta S = \int_{i_0}^{i_l} P^D(s) - P^F(s)ds$$

A change in the OEM sourcing cost will result in a price change following the pricing behavior described in formula (3–2). For small changes around the maximum, the price correction is given by $\Delta P = \Delta S/(1+(1/E_d))$[24]. This change will also affect the quantity sold and the profit of the investing firm according to:

$$(3\text{–}9) \quad \Delta q = qE_d \frac{\Delta S}{c+S-t} \text{ and } \Delta\Pi^{OEM} = -q\Delta S\left(1+\frac{E_d}{1+E_d}\frac{\Delta S}{c+S-t}\right) = -q\Delta S\left(1+\frac{\%\Delta MC}{1+\left(1/E_d\right)}\right)$$

Consumer surplus will also be affected. Without loss of generality, the inverse demand function is assumed to be approximately linear within the relevant price difference region (this assumption will also be used in all further calculations of changes in consumer surplus). As a result, one obtains:

$$(3\text{–}10) \quad \Delta CS \cong -\Delta P\left(q+\Delta q/2\right) = -\frac{q\Delta S}{1+\left(1/E_d\right)}\left(1+\frac{1}{2}E_d\,\%\Delta MC\right)$$

where the marginal cost is given by $MC=c+S-t$.

The profit change presented in equation (3–9) has two components. The first is profit erosion due to additional souring cost and the second is the adjustment due to the change in price and quantity arising from the monopolistic behavior of the investor. This means that, for levels of elasticity below -1, quantity sold is reduced and the profits of the investing firm decrease. Likewise, consumer surplus is reduced both due to the increase in price and the reduction in quantity. Total welfare, measured through the profits of the firms[25], consumer surplus and government revenue is clearly reduced. This can be written as:

(3–11) $$\Delta W = \Delta\Pi^{OEM} + \Delta CS + \Delta\Pi^{SUP} + \Delta GS < 0$$

The first two terms are given by equations (3–9) and (3–10) respectively and are negative for elasticity less than -1. As explained in section 3.2.1, normal profits of suppliers in the domestic supply chain are always zero, which results in the third term of (3–11) also being zero. Because there are no direct revenues to the government the last term is not changed with the alterations due to domestic content requirements.

This conclusion that domestic content requirements on the investing firm (above the natural level of decision) increase the price of the intermediate goods – the components – and, consequentially the price of the final good, therefore reducing welfare is accordance with what most previous authors in the area have also found. Nevertheless, these findings have a crucial dependence on the assumptions regarding perfect markets, i.e. that all factors are being paid exactly their marginal cost. As detailed in the next sections, in a developing nation this may not be always the case. As a result, the welfare implications of the policy may be different from the standard evaluation presented in the previous paragraphs.

3.3. Benchmarking Domestic Content Policies

The previous section presented the base situation for domestic content requirements, concluding that such a policy had negative effects on OEM profit and overall country welfare. Although a subsequent section shows that there may be situations where this policy can be welfare

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[24] Significant variations in cost will shift the firm maximization point enough to alter the value of the point elasticity in the denominator. As a result, the new price would be calculated with the new elasticity and the formula wouldn't hold. This situation adds complexity to the calculations offering no additional benefit in intuition.

enhancing, this section compares domestic content requirements with two other situations that have been as prevalent in the developing world as a means to protect the local industry: tariffs and subsidies to producers. The relevant conclusion detailed in the next sections is that local content requirements are potentially superior to tariffs and subsidies as ways to increase the share of domestic purchases by an OEM. By setting a standard and letting the foreign investor make the decisions on how to comply, the government benefits from the firms' ability to minimize potential negative impacts on its cost and, as a result, the overall economy.

3.3.1. Are Domestic Content Requirements Better Than Tariffs?

The first relevant issue is a comparison of domestic content requirements and tariffs. The idea is that the government would like to know if reaching a certain level of domestic purchases leaves the local welfare better (or less worse off) if it is accomplished through a policy requiring the OEM to achieve this predetermined level of national content or, alternatively, through the enactment of tariffs on imported components that would displace them in favor of local ones. To study the problem, a base sourcing structure, cost and natural local content that result from the minimization process described in (3–5) are assumed. These are represented, respectively, by i_0, S_0 and L_0. What will be shown is that the following proposition holds:

> *Proposition. A domestic content requirement policy is weakly preferable to a uniform price based tariff policy when measured in terms of welfare of the local economy.*

Tariffs create a cost penalty on imported components that does not exist for the case of domestic content requirements. Moreover, this additional burden on sourcing cost is aggravated by the monopoly pricing of the OEM, further reducing domestic welfare

If the government option is to enact a domestic requirement policy, the result is defined directly by the mechanisms presented in the previous section. A requirement LC_l results in a sourcing structure i_l and cost S_l, both defined by equation (3–7). Likewise, the cost penalty $\Delta S_l = S_l - S_0$, is

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[25] For simplicity, assume that all profits remain in the country

given by equation (3–8) and the impact on quantity and welfare by the subsequent formulas. The total welfare impact of this policy is named as W_l.

Now, instead of the domestic content requirement, consider a tariff that covers all foreign components equally on a percentage of their purchase price. The calculation of the new sourcing structure is similar to finding the natural level of local content, but with the foreign price adjusted by the tariff level. This requires each foreign component price in equation (3–4) to be replaced by the new sourcing price: $P^F(s) \rightarrow (1+\zeta)P^F(s)$, with ζ being the tariff schedule.

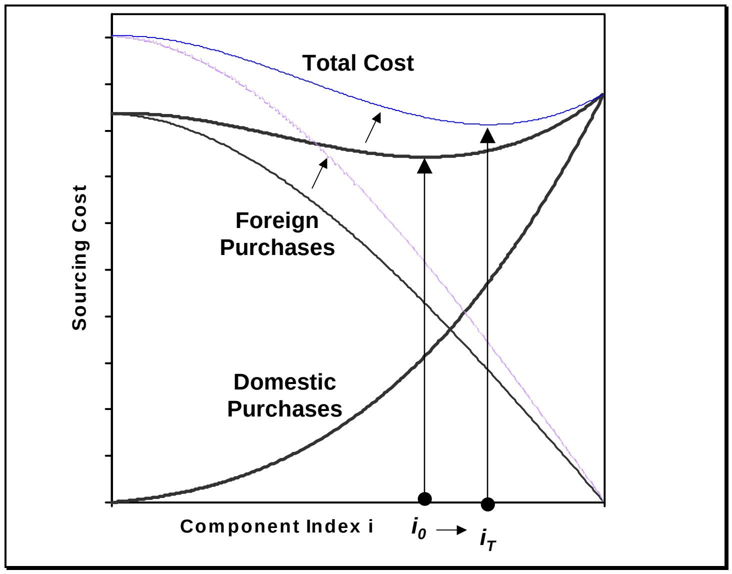
Using equation (3–5), the result of the minimization process is implicitly given by $P^D(i_T) = (1+\zeta)P^F(i_T)$, with i_T and S_T representing the sourcing structure and associated cost. Moreover, since the objective is to compare this policy with the domestic content policy, the government will set the tariff level ζ to make sure that i_T is equal to i_l, assuring that the same level of 'true' domestic content is achieved[26]. This results in $\zeta_l = P^D(i_l) \big/ P^F(i_l) - 1$. The new sourcing cost is now:

$$S(i_l) = \int_0^{i_l} P^D(s)ds + (1+\zeta_l)\int_{i_l}^{c} P^F(s)ds \text{ and}$$

(3–12) $$\Delta S_T = S(i_T) - S(i_0) = \int_{i_0}^{i_T} \left(P^D(s) + P^F(s)\right)ds + \zeta_l \int_{i_T}^{c} P^F(s)ds\,; \quad \text{defining } T = \zeta_l \int_{i_T}^{c} P^F(s)ds$$

Comparing equations (3–12) and (3–8), it is easy to note that there is an important difference in the cost penalties that the OEM is subject to in the two policies. As it can be seen in in Figure 3–5, charging a tariff shifts both the foreign and total cost curves upwards. Since the tariff can be set so that $i_T = i_l$, the domestic content is the same as if $LC(i_l)$ would be demanded by the government. Nevertheless, the new sourcing cost is higher than before, with $\Delta S_T = \Delta S_l + T$. This is because all foreign components in the interval $[i_l,c]$ that are still bought also pay the tariff, contrary to the situation of the domestic content policy. The *T* term on the cost change section of equations (3–12) reflects this idea.

Figure 3–5: Effect of a Tariff on Purchasing Decisions



The question now is how the tariff and local content requirement policies compare in terms of domestic welfare. On one hand, the new OEM sourcing cost penalty is greater by the amount *T*, resulting in less OEM profits and reduced consumer surplus, as calculated by equations (3–9) and (3–10). On the other hand, the value *T* generated through the tariffs is additional revenue for the government. A calculation of the overall welfare effects as defined in equations (3–9) to (3–11), including the government surplus arising from the tariff revenues, results in:

(3–13) $$\Delta\Pi_T^{OEM} = -q(\Delta S_l + T)\left(1 + \frac{1}{1+(1/E_d)}\frac{\Delta S_l + T}{MC}\right)$$

(3–14) $$\Delta CS_T = -q(\Delta S_l + T)\frac{1}{1+(1/E_d)}\left(1 + \frac{1}{2}E_d\frac{\Delta S_l + T}{MC}\right)$$

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[26] 'true' means that the level of domestic content is measured as a share of the original sourcing cost before the enactment of the tariff. This value is different from the result of the ratio of domestic cost to total cost with the enactment of the tariff because of the increase in the prices of the foreign components.

(3–15) $\Delta GS_T = (q + \Delta q)T = qT\left(1 + E_d \dfrac{\Delta S_l + T}{MC}\right)$

If the effects in the previous formulas are added, it can be shown that the corresponding total welfare effect is given by:

(3–16) $$\Delta W_T = \Delta W_l - \frac{qT}{1 + \left(1/E_d\right)}\left(1 + \frac{\Delta S_l - T.E_d/2}{MC}\right)$$

Where ΔW_l is the welfare effect obtained through the domestic content policy. Since the elasticity of demand is negative and below minus one, it is straightforward to see that tariffs penalize the economy beyond the effect of domestic content requirement, demonstrating proposition 2.

There are two aspects driving this result. The first is that the extra cost penalty on the imported components, represented by T, does not exist for the case of domestic content requirements. Second, this additional burden on sourcing cost is aggravated by the monopoly pricing of the OEM, further reducing profits and consumer surplus. The additional government revenues never compensate for this effect. As a result, a requirements policy is preferable to the enactment of tariffs.

The reason why domestic content requirements are only weakly preferable to tariffs comes from the fact that the tariff policy can be set to replicate the effect of the requirement policy. If the government gives the tariff revenue back to the OEM in form of a subsidy, then the cost penalty T is removed from the profit equation and the increase in sourcing cost is reduced to ΔS_l, the same as in the case of the domestic content. As a result, the pricing does not change and the welfare effects of the two policies will be equivalent. This result can also be used to assess the how policy makers can replace one policy by the other.

The intuitive reason leading to the superiority of the content requirement policy is the ability of the government to use the knowledge of the OEM in choosing components. By imposing the standard and leaving the component sourcing decision to the company, the government knows that it is in the firm's best interest to reach the desired level of domestic purchases with minimal sourcing cost. This behavior also minimizes any potential negative impact on domestic welfare.

On the contrary, a uniform tariff penalizes all components, even those that have the largest gap between domestic and foreign production. This extra unnecessary cost creates an additional welfare burden on the local economy.

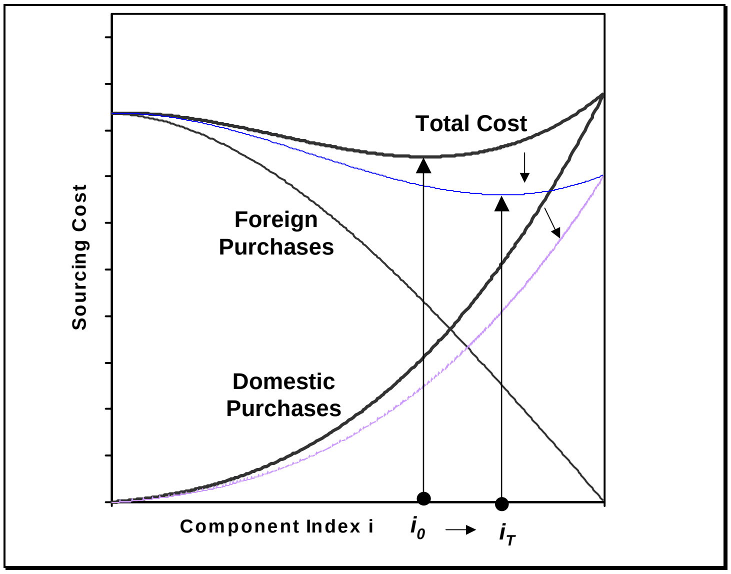
Governments have tried to mitigate this problem by establishing selective tariff policies, with differentiated levels depending on the component (Krueger, 1975; Bennet, 1986; Shapiro, 1993). Ultimately, if the government would be able to target the components at the margin with tariffs that compensate exactly for their difference between domestic and foreign production costs, it could obtain the same result as the one reached though the content requirements policy. The problem is that governments do not have the necessary information to establish the appropriate targeting. Moreover, even if that would be possible at one point in time, local market conditions change over time with new local supplier investments, typically at a faster pace than the government can follow. As a result, it becomes impossible in practical terms to use tariffs as an alternative to content requirements without further reducing welfare.

3.3.2. Subsidies and Domestic Content Requirements

Now the objective is to compare domestic content requirements with a policy of awarding a uniform subsidy to all local manufacturers. The analysis of the domestic content requirements is similar to what was shown in the previous section. Nevertheless, unlike the analysis of the tariff policy, it will not be possible to reach an overall conclusion on the comparison.

A direct subsidy based on a percentage σ of the component cost is considered. Since domestic suppliers will be pricing at the new marginal cost, the new price for each component is replaced by $P_i^D \to P_i^D(1-\sigma)$. Using (3–4) and (3–5), the OEM minimizes the sourcing cost so that $(1-\sigma)P^D(i_S) = P^F(i_S)$, with i_S and associated S_S representing the sourcing structure and associated cost. This scenario is very close to the one analyzed in the previous section for the case of tariffs. The major difference is that, instead of moving the foreign components cost curve upwards, the domestic components cost curve is shifted downwards, generating a new equilibrium. This situation is presented in Figure 3–6

Figure 3–6: Effect of a subsidy on Purchasing Decisions



Since, like in the case of tariffs, the objective is also to reach a level of domestic content identical to a direct restriction, the subsidy level is decided so that i_S = i_l. This results in $\sigma_l = 1 - P^F(i_l) / P^D(i_l)$. The new sourcing cost is now:

$$S(i_S) = (1-\sigma_l)\int_0^{i_S} P^D(s)ds + \int_{i_S}^{c} P^F(s)ds \text{ and}$$

$$(3\text{–}17)\quad \Delta S_S = S(i_s) - S(i_0) = \int_{i_0}^{i_T}\left(P^D(s) + P^F(s)\right)ds - \sigma\int_{i_s}^{c} P^F(s)ds; \quad \text{defining} \quad B = -\sigma\int_0^{i_s} P^D(s)ds$$

Analyzing this equation, one can see that that its structure is identical to the analysis that was performed in the case of tariffs. Therefore, equations (3–13) to (3–16) can be directly applied in this context, replacing T by B[27]. The problem with the new calculations is that, because B is negative, the numerator of the right hand side term of equation (3–16) can be either positive or negative, depending on the relative values of the parameters. As a result, little can be said regarding which of the two policies hurts the economy less. Moreover, this evaluation is bound to become even more complex if one considers that there may be additional costs associated to

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[27] In the government surplus calculation, a cost of raising the money might have to be added.

raising the subsidy money, and that not all the profits of the OEM are retained in the domestic economy.

3.4. Externalities and the Social Evaluation of Domestic Content

As discussed in detail in chapter 2, the prospect for local companies in developing nations to participate as suppliers of components for complex products such automobiles, capital goods or electrical units is often unique and seen as a critical opportunity to gain the experience and recognition that will enable the local industry to increase overall productivity[28]. This situation may generate a gap between the social and private cost of the resources that are employed in suppliers, with their social opportunity cost below the private cost. This is the key difference to the situation analyzed in previous sections.

In a free market environment the OEM will choose the lowest (quality adjusted) price for each component. This generates the base sourcing structure i_0, a sourcing cost S_0 and a resulting natural level of local content, represented by LC_0. This natural local content generates surplus to the domestic economy, designated by W_0. If the government enacts local content regulations then, the company makes the least cost supplier choice subject to the LCR policy, resulting in a new sourcing structure of the firm i_l, sourcing cost S_0 and welfare W_l.

The issue is to understand the conditions under which these regulations are beneficial to the country, focusing on the economic welfare effects of the policy[29]. Welfare calculations include producer surplus, both generated by the OEM (OSP) and the suppliers (SSP), consumer surplus (CS) and government surplus (GS). Therefore, welfare can be written as:

(3–18) $W = OSP + SSP + CS + GS$ and $\Delta W = \Delta OSP + \Delta SSP + \Delta CS + \Delta GS$

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[28] A similar reasoning can be made if the foreign OEM induces foreign suppliers to invest in the country instead of contracting local firms, since foreigners often bring unique knowledge that may partially spillover to the local economy

[29] if one is to abstract from political effects

Following the discussion of section 3.1, two different analyses are presented. The first investigates how government should consider local content requirements in the presence of a generic gap between the social and private opportunity costs of the resources used in the industry. The second models a situation where industry spillovers exist based firms and industry experience, but they are unaccounted by private firms. It will be shown that, if a foreign OEM investing in a developing economy generates unaccounted learning and spillovers effects that depend on the breadth of the supplier structure, local content requirement can improve welfare as long as the unaccounted benefits of the components sourced beyond the OEM market decision are above the cost penalty associated to them.

3.4.1. Differences in Private and Social Opportunity Costs

The key idea of this scenario is that, although OEM and suppliers have to pay input factors according to their private cost, this value is above their social opportunity cost. This also reflects the major difference between this model and the work of other authors, since previous research has mostly neglected the possibility that factors may not be paid their social marginal cost.

Section 3.1 explained how external effects can be interpreted as a reduction in social opportunity costs below the values paid by the private agents. The relevant factors included labor and capital, as well as disembodied technology, which will be associated with development expenditures. Since it is difficult to have accurate estimates of the opportunity cost for the resources allocated to a particular project, they will be made parameters. Based on equation (3–1) and (3–3), the following corrections are considered:

- The social opportunity cost of each unit of labor is given by $(1-\lambda).w$
- The social opportunity cost of each unit of capital is given by $(1-\phi).r$
- The social opportunity cost of intellectual property is given by $(1-\pi).I$

Following the social cost benefit approach, the welfare effect of a project is reassessed by considering the social opportunity cost of the resources, instead of the private cost. Taking into account the profit function presented in equation (3–1)[30], annual surplus for the OEM can now be written as:

(3–19) $OSP = \tau\Pi^{OEM} + q\left(Lw\lambda + Kr\phi - t\right)$, with τ as the tax rate

In addition to the OEM surplus, purchases of components in the local economy also generates producer surplus. Like the investor firm, the contributions of these firms are potential profits and the social value of the factor inputs used in production. Using the profit equation (3–3), the surplus that each domestic firm *i* can generate if included as a supplier is:

(3–20) $SSP(i) = \Pi(i) + q\left(L(i)w\lambda + K(i)r\phi + \pi I(i)\right)$

where $\Pi(i)$ represents normal profits that are zero for the supplier behavioral assumptions that have been described before. The total surplus derived from the participation of local suppliers is:

(3–21) $SSP = \int_0^i SSP(s).ds$

The government surplus is also affected through the subsidies that are awarded to the firms. What is important to reflect on is that the opportunity costs for government funds is often greater than its monetary value. The reason for this situation is the fact that these funds have to be collected through taxes that distort the economic decision making (Laffont and Tirole, 1993, chapter 2). As a result, government surplus is now given by:

(3–22) $GS = -q(1+\psi)t$

where ψ is the additional cost penalty of raising government funds.

These adjusted calculations for producer and government surplus, added to consumer surplus (that does not have to be adjusted because of the differences in opportunity costs noted above) result in the new value for the total welfare of the local economy. As noted before, since this

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[30] This evaluation can be further refined by considering the negative effect of expending foreign exchange.

research addresses the effect of domestic content requirements, the focus is on variations of welfare from the base decision with no content requirements, as opposed to a calculation of absolute welfare values.

Section 3.2.2 explained that an OEM that is prevented from buying components from less expensive foreign manufacturers because of domestic content requirements will have higher sourcing costs. As shown in equations (3–9) and (3–10), this leads to lower profits and diminished consumer surplus. Under social cost benefit analysis, these negative surplus calculations have to be balanced against the positive surplus generated by the difference between social and private valuations of the resources, reflected on the right hand side terms of equations (3–19) and (3–20). This is the key tradeoff that becomes relevant to analyze.

The analysis of this tradeoff is greatly simplified if it is assumed that the government uses subsidies to compensate the OEM for the higher sourcing costs. If this happens, the OEM cost remains equal before and after the enactment of the local content requirements. As a result, the final good price will also remain constant and so will the quantity produced, the OEM profits and the consumer surplus. As seen below, the advantage of assuming this compensation is that it allows the mathematical simplification while retaining the characteristics of the key tradeoff that is the focus of this section. Moreover, Chapter 4 shows that the strategy of compensation can be an optimal solution for the problem from an incentive perspective. Therefore, for the remaining of the section, it will be assumed that the government pays any penalty that results from its content policies.

Under this simplification, the new welfare changes resulting from a local content policy can be written as:

$$(3\text{–}23)\quad \Delta SSO = 0\,;\ \Delta SSP = \int_{i_0}^{i_l} q\big(L(s)w\lambda + K(s)r\phi + I(s)\big).ds\,;\ \Delta CS = 0\,;\ \Delta GS = -(1+\psi)q\Delta t$$

and $\Delta t = \Delta S$ to offset the increased cost from greater incorporation of local suppliers.

These new surplus changes used in equation (3–18) result in:

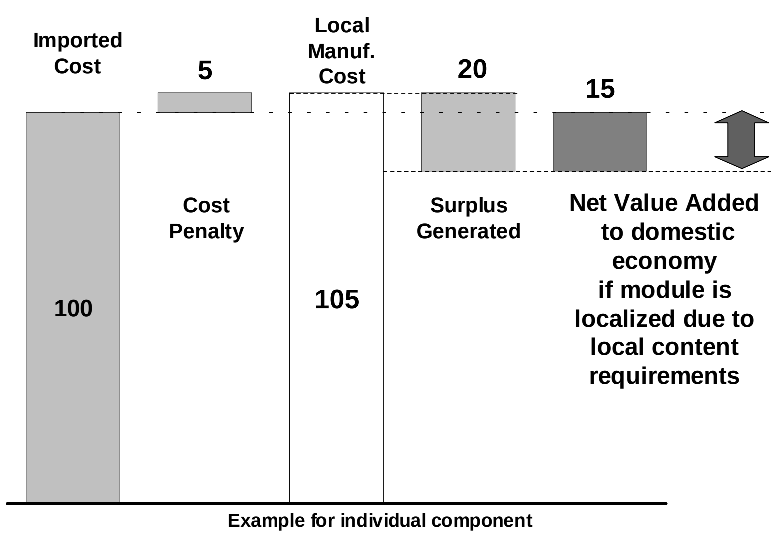
$$(3\text{–}24)\qquad \Delta W = q.\int_{i_0}^{i_l} \upsilon(s) - (\psi + 1)\left(P^D(s) - P^F(s)\right)ds \text{ , where } \upsilon(s) = L(s)w\lambda + K(s)r\phi + \pi I(s)$$

Where the variations in social value and cost penalty are given by:

$$(3\text{–}25)\qquad \Delta\upsilon = \int_{i_0}^{i_l} \upsilon(s)ds \quad and \quad \Delta S = \int_{i_0}^{i_l} (\psi + 1)\left(P^D(s) - P^F(s)\right)ds$$

This formula shows that welfare change is governed by the balance between the sourcing cost penalty and what Grossman (1990) called an externality-from-entry. It tells us that local content policies generate economic benefits to the local economy as long as the components that are localized as a result of the policy generate more social value than the cost penalties associated with higher domestic prices.

Figure 3–7: Example of Positive Surplus from Forced Localization



This idea that a decision to force local sourcing may result in a benefit to the local economy is represented in Figure 3–7. For any component, the OEM will always choose the smaller price. It has no incentive to choose otherwise, even if the cost difference is small compared to the component price. As a result, the component will be imported. Nevertheless, if one believes that the social value associated with the manufacturing of the component in the local economy is greater than the cost penalty, the economy would be better off if this difference would be subsidized to allow domestic purchase. This is precisely what the policy on local content requirements coupled with the government subsidies to offset the cost penalty does.

A careful analysis of the expression (3–24) describing the welfare effects of a policy requiring domestic content also shows that there is an optimum associated with the enactment of such a policy. In fact, a sound administration of the policy should require an investing OEM to localize components not while the welfare change is positive, but rather while welfare is growing. Differentiating expression (3–24) with respect to i_l, one gets[31]:

(3–26) $$Max.\Delta W \Leftrightarrow \frac{d\Delta W}{d.i_l} = 0 \Leftrightarrow \upsilon(i_W) = (\psi + 1)\left(P^D(i_W) - P^F(i_W)\right)$$

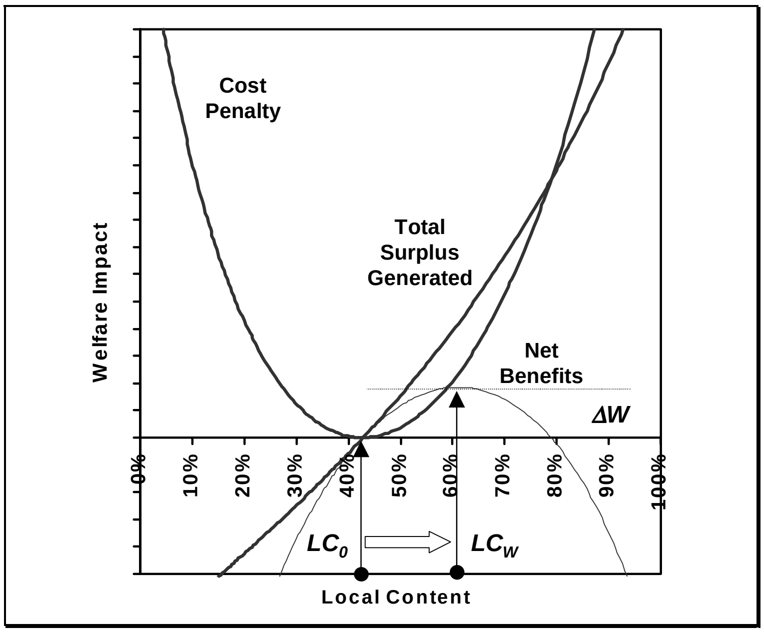
Equation (3–26) is intuitive and tells that local components should be added until the cost penalty of the marginal component reaches its social value. This is equivalent to localizing components until the marginal return to the government equals the marginal cost to the firm. This equation also enables the following proposition:

> *Proposition. In the presence of a gap between private and social valuations of the resources employed in potential suppliers of an OEM, a small domestic content requirement policy coupled with an OEM subsidy for the cost penalty can be welfare enhancing.*

To see why this has to be true, equation (3–26) is rearranged as $P^D(i_W)\big/P^F(i_W) = 1 + \upsilon(i_W)/(\psi + 1)\,P^F(i_W)$. This implicitly defines the index that maximizes welfare when there is some extra social value to the local economy. Since, both the index and the level of domestic content increase with the ratio $P^D(i_W)\big/P^F(i_W)$, any positive value of $\upsilon(i_W)$ moves the index towards the incorporation of more local components, i.e. $i_W > i_0$, with i_0 corresponding to the decisions with $\upsilon(i\ ) = 0$. Therefore, any $l<LC(i_W)$, with $LC(i)$ defined as in equation (3–6), will increase welfare.

For this case with no quantity effects, the welfare implications can easily be seen using a graphic representation similar to the one presented in Figure 3–4, where again the effects are presented as a function of the degree of local content instead of the component index for easier understanding. Figure 3–8 illustrates the behavior of the relevant variables: the sourcing cost penalty, the surplus generated by the entry of domestic component manufacturers and the net result of the effects[32].

Figure 3–8: Welfare Effects of Local Content Requirements



Whenever there are external effects that generate a valuation of the resourced used by the suppliers beyond their private cost, there will be benefits from enacting a domestic content requirements policy. Nevertheless, there is a limit to which this policy can work. As the figure shows, requirements much beyond the natural level will have very negative effects in the economy, rendering any potential benefits small in comparison.

The figure above also helps to understand why it is less likely that we find content requirements and incentives being awarded in more developed regions (UNCTAD, 1991). In these regions markets are functioning well and differences between private and social opportunity costs are

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31 Maximization is possible only under reasonable regularity conditions. I need to have $\Delta S'' > 0$ and $\Delta V'' <= 0$

32 The exact matching to equation (3–24) is done on the added surplus from the natural level of local content. The analysis with total surplus is similar, but cleaner because it moves this line away from the origin.

usually much smaller. Therefore, the surplus curve will be shallow and its slope will rapidly match the slope of the cost penalty, limiting the region where there may be positive benefits from enacting domestic content requirements.

3.4.2. Learning and External Effects

So far all costs and prices have been constant regardless of the sourcing decisions of the OEM. Nevertheless, given that the issue that is at the core of the thesis are spillovers in the supply chain, it is important to address how they may change the conclusions that have been reached so far. If the hypothesis is that local firms learn with experience and that there may be external effects present in the decisions, it is important to address those directly in the formulation. The interest is to understand how learning changes the ability of the local government to demand local content requirements. To perform the desired analysis, the standard base case with no learning is compared against several learning patterns to understand how the sourcing structure and, more importantly, the welfare impact changes with the rate of learning.

First, firm *learning-by-doing* is explored. Experience with a particular manufacturing technology renders improvements in efficiency that eventually result in cost improvements. The influential paper by Arrow (1962) established this issue as critical in the economics and management literature. Since then, this hypothesis has been explored in the literature, both at a theoretical (Lieberman, 1987; Mody, 1989) and an empirical level (Lieberman, 1984; Lamoreaux, Raff et al., 1999; Sinclair, Klepper et al., 2000). Virtually all of these studies report that cost decays exponentially with cumulative output of the company over time.

The second type of learning that will be considered is *learning-by-spillovers*. The idea is that manufacturing costs of individual firms may be reduced as the presence of other related companies in the region increases. Factors such as the ability to exchange information and solve technical problems in common, share workers among companies and the development of regional technical centers are all bound to have a positive effect in the manufacturing capability of the firms and, therefore, on their cost. Like the case of the learning by doing, most authors have suggested that the appropriate representation of the phenomenon is an exponential driven by the cumulative output of the relevant industry.

Given previous work, the following formula can used to represent these two effects:

(3–27) $C_{ti} = \alpha_i X_{it}^{-\beta} Y_{it}^{-\gamma}$

Where C_{it} is the cost of component *i* at time *t*, X_{it} is the learning-by-doing index and Y_{it} represents learning-by-spillovers. The interest is in finding an appropriate way to model these in the context of the problem under analysis. The main complication arises from the fact that a monopolist whose costs change due to learning should have a strategic behavior, charging less than the monopoly price in initial stages to increase output and take better advantage of the learning effect (Lieberman, 1987; Tirole, 1988, p. 72). This strategic effect makes the analysis much more complex, with no substantial gains in terms of intuition or the overall magnitude of the results. Therefore, a simplified version of this problem is considered. The simplifying assumption is to have quantity decided before the investment takes place, so that it can't be changed throughout the project[33]. This eliminates the effects of strategic behavior and monopoly pricing. If this is the case, then output quantity is constant. What might change depending on the relative cost structure and government policy is the relative share of components that are produced by local and foreign suppliers.

Within these assumptions, measuring firm internal learning is rather straightforward, with the learning-by-doing index established as $Y_{it} = q.t$. This representation is equivalent to having cost as a function of firm cumulative output, as seen in the studies mentioned before. The above representation results from the fact that yearly production is assumed constant. The formula means that doubling the value of cumulative output reduces cost by $2^{-\gamma}$. For example, if γ is equal to 0.1, the cost reduction is 93%. This number is often treated in the literature as the slope of the learning curve.

Following the previous literature, learning spillovers will be an exponential function of industry cumulative output. Since quantity is constant, the number of components manufactured in the domestic market will drive this indicator. Therefore, the learning index can be written as

[33] Generalizing the analysis to include strategic pricing will part of future research

$X_{it} = q.i.t$. This representation means that every additional component sourced locally adds to the industry cumulative output and makes an equal contribution to the learning index. Likewise, every year adds to the index the output corresponding to the total number of domestic components manufactured in the region.

Once the two indeces are substituted in equation (3–27), and adjusting for the appropriate α, the result is:

$$C_{ti} = C_{0i}.(t.i)^{-\beta} t^{-\gamma} \text{ , t>0}$$

The quantity is dropped from the formula because it is assumed to be constant throughout the periods[34]. Taking in consideration that the suppliers' price is equal to cost, learning can be accounted in the decision of the OEM by making the following substitution in (3–4):

(3–28) $\int_0^i P^D(s)ds \rightarrow (t.i)^{-\beta} t^{-\gamma} \int_0^i P^D(s)ds$ [35]

The new OEM cost structure depends on time. But, so far the model set-up is static and therefore not directly amenable to the incorporation of a time framework. Therefore, to fully consider this issue, the project is assumed to have a certain time horizon over which a net present value is calculated.

Like the case of quantity discussed above, an optimal solution is described by equation (3–5) with the replacement indicated in (3–28), taking in consideration strategic effects that influence monopolistic pricing. Once again, all decisions regarding domestic content will be done before the project. Nevertheless, while a constant quantity is an important simplification of the real situation, an up-front decision on suppliers is actually likely. Due to search and approval times

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[34] This has another underlying simplification that the base quantity manufactured every year does not influence the rate of learning. Therefore, a firm producing 35,000 units will see its cost decrease from the base value at the same rate as another firm manufacturing 70,000 units. The base cost of the two firms will obviously be different.

[35] Note that the exponential is left out of the integral to make sure all the components are equally affected by the external effect. If it would be inside, each component would have its cost reduced as a function of its individual position in the ordered index.

and processes (see Veloso, Henry et al., 2000, chapter 3 for the case of the auto industry) there are usually important switching costs associated with changing a supplier. As a result, the most likely situation is to consider that the sourcing structure has to be decided up-front and will be maintained for the duration of the project.

Given the set of assumptions described in the previous paragraphs, the cost structure with learning effects can be represented through a variation of equation (3–4) according to the following formula:

$$(3\text{–}29) \qquad ST(i) = \sum_{t=1}^{n} (1+\delta)^{-t+1} \left(\int_0^i P_t^D(s)ds + \int_i^c P_t^F(s)ds \right)$$

Where δ is the yearly discount rate; $P_t^F = P^F$; $P_1^D(s) = P^D(s)$ and $P_t^D(s) = (t.i)^{-\beta} t^{-\gamma} P_0^D(s)$ for t greater than 1; *n* is the number of years of the project. An analysis of this equation rapidly shows that the above formula yields a scenario that is close to the calculations and the solution for the case of subsidies discussed in section 3.3.2.. The difference is that the discounting in equation (3–29) interacts with the learning effect in each period.

With a complete decision before the project, the solution for the new sourcing problem results from the minimization of *ST*(*i*) with respect to *i*. The problem is that the new equation does not have an obvious closed form solution. As a result, numerical methods have to be used to find the appropriate distinction between domestic and foreign components, and the associated i_L. In any case, given that domestic cost decreases over time, the solution for this new problem leads to more local sourcing than the static no learning calculation. Therefore, the new equilibrium value i_L will be to the right of the original decision i_0 presented in section 3.2. This means that the OEM will source more domestic components. Eventually, this minimization will also be subject to domestic sourcing requirements.

If the OEM recognizes that learning is taking place, then it will follow the formulas described above and incorporate them into the decision making process. As a result the government will have no role to play and domestic content will at most hurt the industry. The problem is learning effects may become external to the OEM and suppliers decisions, often because firms can't anticipate the patterns of individual and collective learning. If this is the case, the local content resulting from the firm private decisions will be below the socially desirable outcome. As a result, the government may intervene. It can either subsidize local firms in anticipation of the difference between private and social costs, or subsidize the OEM while enacting domestic requirements that bring the share of domestic purchasing to the socially desirable level.

Comparison of these scenarios and the implication of the rate of learning are discussed in the model application presented in chapter 7. Several values of the parameters β and γ will be tested, aiming to understand how learning may affect the OEM sourcing decisions and the need or opportunity for government regulation. As we will see in the numerical calculations these two types of learning are important and can reinforce the perceptions put forward in the previous sections, whereby a gap between private and social valuations of the resources used in the supplier sector may justify government intervention through domestic requirements and subsidies.

Despite these results, both learning paradigms considered in this section are generally unintended consequences of the activity, i.e. they are more of a side result rather than a consequence of purposeful activities. This leaves out another crucial component of learning, the one that results from purposeful activities that the company undertakes to be able to excel at a particular area. The problem is that a careful analysis of these issues requires a full dynamic environment with an incentive structure for the investment in learning, as well as a mechanism for that to happen. This will be considered as future research.

3.5. Model Extension: Cost Uncertainty and Risk Averse Managers

The previous analysis considered that all prices put forward by the suppliers are deterministic, or that they correspond to the expected value of a random variable, with the OEM being a risk neutral player. This section investigates what happens if the costs of local suppliers are a random variable and the decision maker is risk averse.

Although firms are often considered risk neutral in the economic literature, managers are not. In the context of the model explored in this chapter, this becomes an issue if a risk averse purchasing manager makes the OEM sourcing decisions. The problem is that suppliers in a developing region often have less control over the manufacturing process than their foreign counterparts. This may lead to unanticipated cost overruns, quality and delivery problems, among other problems. Any of these have negative impact on the financial outcome of OEM operations. For simplicity reasons, it is assumed that any problems associated with sourcing from a domestic supplier have a sourcing cost equivalent that is factored in by the OEM as the perceived domestic cost. Given the risk averse behavior, it is clear that this manager would prefer to source from a foreign supplier that he knows will provide a certain cost for sure (e.g. because of past supply experience) than from a local supplier whose expected cost might be the same as the foreign supplier, but still has a positive probability of generating costs overruns.

To model this situation the usual assumptions in the literature in terms of the shape of the utility function and the cost distribution are used. The price of the imported components P_i^F will be the same and assumed with certainty. The value of local components are now considered a random variable $V_i^R = P_i^D - \varepsilon_i$ with the random component ε representing cost overruns from the expected value. ε is considered to have a normal distribution with mean zero and variance σ_i^2. The sign is reversed in ε because the manager values less cost. The value can then be represented as $V_i^R \sim N(P_i^D, \sigma_i^2)$.

The manager has a utility function that represents its attitude towards cost savings and cost penalties. The shape of the utility function is assumed as a constant absolute degree of risk aversion, represented by $u(x) = -e^{-r.x}$, where x is the level of value savings ($x = V_i^R$) and r is a parameter that measures the degree of risk aversion. Since x is assumed to have a normal distribution, it has been shown[36] that the expected utility of the local components cost can be represented by $E[u(x)] \equiv \bar{x} - r.\sigma_x^2 / 2$. If the definitions given above are used, the cost of each of the local parts can be replaced by $P_i^D \to P_i^D + r.\sigma_{\varepsilon_i}^2 / 2$. With this new representation, the impact of potential management risk averseness in the sourcing options of the firm can be addressed.

[36] See for example Varian (1992), p. 189

The risk averse behavior is equivalent to having the foreign manager demand a price premium from local suppliers to hedge for the fact that they may have or cause cost overruns. This is actually a situation that many local suppliers, potential entrants in the industry complain about, often feeling discriminated against when compared to established firms (Veloso, Henry et al., 2000). The manager base sourcing structure i_0 and cost S_0 that result from the normal risk neutral choice can be compared with the risk averse result i_R and corresponding S_R. It is easy to notice that $S_R > S_0$ because the 'adjusted' perception of the manager is that local suppliers are more expensive than their expected price. This is equivalent to shifting the domestic supply cost curve presented in Figure 3–3 upwards. As a result he will substitute some components that would be sourced by a risk neutral manager in the local market with those produced by a foreign supplier that are more expensive for sure. This will hurt both the OEM and the local industry.

Here the government could intervene and establish a preemptive domestic content requirement. Imagine that the government recognizes that there may be risk averseness from the management. As a response it establishes a level of domestic content that is exactly $l=LC_0$. Faced with this new constraint, the risk averse manager has to go back to the sourcing options that would be made by the risk neutral manager. The domestic content counters the risk averse behavior of the manager.

The idea is that by enacting local content requirements but compensating these with subsidies, the government is acting as an insurer of the investor. The reason why the government needs to intervene is because there is an external cost. The OEM does not want to pay the insurance cost because it has alternative suppliers in the foreign market at no extra cost, and the individual firms' local suppliers may not be willing to pay for it because they may not acknowledge or be aware that this risk exists. As a result, government intervention may be the only solution.

This section provides an important conclusion to policy makers: establishing domestic content objectives during the contract negotiation stage can be important to minimize the impact of potential risk averseness from the managers in charge of sourcing decisions. It is likely that high-level decision makers negotiating the project with the government within the global portfolio of the company have a behavior that is closer to risk neutrality than the manager that ends up in charge of negotiating specific contracts.

3.6. Summary

This chapter proposes a model to benchmark the effects of a local content requirements policy on the investment of a particular OEM and on the welfare of the economy. Impact is measured based on welfare or surplus generated by the project, including the effects of any restrictions, comparing the benefits generated through the investment to those that would be created if the same resources were deployed elsewhere in the economy. The model is explored at two levels.

First, competitive decisions are analyzed. This enables an understanding of the underlying decision mechanisms associated with OEM sourcing decisions and a benchmark evaluation of the impact of a LCR policy on economic agents and on welfare. The analysis includes a comparison with alternative policies, in particular tariffs and subsidies. The relevant conclusion is that content requirements is a superior policy to tariffs and subsidies as a means to increase the share of OEM domestic purchases. By setting a standard and letting the OEM make the decisions on how to comply, the government benefits from the firm's ability to minimize potential negative impacts on its cost and, a result, on the overall economy.

Second, the model studies how the existence of gaps between private and social opportunity costs of the resources employed in the OEM and its suppliers affects the impact of LCR on the domestic economy. The analysis shows that local content requirements can improve welfare as long as the opportunity cost gap of the components sourced beyond the OEM market decision is above the cost penalty associated with them. The key idea underlying the model is that a foreign OEM investing in a developing economy generates unaccounted learning and spillovers effects that depend on the breadth of the supplier structure. This effect generates an externality-from-entry associated with domestic suppliers that drives the gap between social and private valuation.

The model also describes an extension related to risk aversion from the OEM. It is shown that a foreign manager may demand a price premium from local suppliers to hedge for the fact that they may have cost overruns, which decreases domestic sourcing. Content requirements can help to avoid the behavior of the manager and improve domestic welfare.

Chapter 4.

Performance Standards, Information and Content Decisions

Chapter 3 discussed a set of conditions that could engender the need or opportunity to establish domestic content requirements. As explained, in the presence of differences between social and private opportunity costs of the resources used by domestic suppliers, or external learning effects, the domestic economy would be better off if an OEM is forced to source more domestic components than it would choose if the decision was market based. This chapter analyzes the mechanisms that can be used by the government to induce the OEM to choose the level of domestic purchases that yield maximum welfare to the local economy. In particular, it explains how content requirements coupled with subsidies may be used as performance standards that drive the OEM to make this optimal choice for the economy. The first section explains how content requirements and subsidies may work together as performance standards and discusses the intuitive mechanism that supports the interplay between the two aspects. The second section describes the formal incentive model, both with full and asymmetric information. The third section presents policy implications.

4.1. Content Requirements and Subsidies as Performance Standards

4.1.1. Understanding Performance Standards

Governments in industrializing nations have been aware that long-term economic growth requires local firms to master the technologies of the developed world. chapter 2 explained that attracting foreign firms to invest locally and promoting the exposure of domestic companies to international markets is likely to be important for this development process. Nevertheless, coordination problems, learning and spillovers lead to differences between social and private opportunity costs for the resources that may result in under-investment by both local firms and foreign investors in the types of skills and technologies that are critical for industrialization. The model explained how, under a set of conditions, the optimal sourcing level for the OEM might be less than what would be optimal for the domestic economy. As a result, the enactment of some degree of local content requirement could improve domestic welfare.

The discussion of chapter 2 shows that governments in most late industrialized nations intervened in the economy whenever they perceived the potential for a gap between private and social costs. Nevertheless, intervention appears to have been more successful in regions such as Korea or Taiwan, where requirements related to domestic content (but also to other activities such as exports or technology purchases) were coupled with subsidies and other non-pecuniary benefits granted to the companies affected by the policy. These policies established incentives based on reciprocity principles, capable of enhancing learning and development in the economy. Likewise, case studies on the impact of domestic content policies suggest that these seemed to have had a better effect whenever used in a discretionary form and bundled with incentive packages. This articulate effort of coupling requirements with incentives is what will be labeled as using performance standards for targeted development, which is the focus of this chapter.

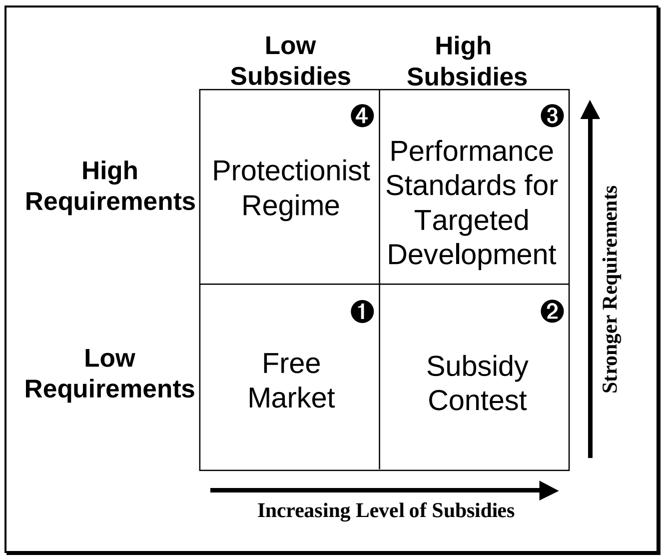
Although policy studies reviewed in Chapter 2 have shown that incentives and requirements on foreign investment are often used together, researchers have mostly considered this juxtaposition as ambivalence from local governments and not as a deliberate policy mechanism. Therefore, it is not surprising to note that the reviewed research work on domestic content requirements has not considered the possibility of balancing subsidies with requirements. Figure 4–1 helps to understand how the dominant perspective on the role of incentives and requirements (the focus is on domestic content) does not encompass the idea of performance standards. As the explained below, the third quadrant has often been left out of any discussion in the subject[37].

Most research labels policies related to high levels of requirements as protectionist mechanisms for inefficient domestic industries, placing them in the fourth quadrant. This has been particularly prevalent in what concerns domestic content policies. Papers studying the problem consistently describe models where the critical feature is the fact that the marginal costs of the critical inputs become greater in the host country than in the international market as a result of the content

[37] Guisinger (1989) considers both restriction and incentives, but his focus is on measurement of the joint impact on profitability rather than on the welfare to the local economy

requirement policy. Given these characteristics, the economic distortions of the content policy become obvious. Nevertheless, the failure of these policies only happened in some cases, while in most cases the policies have worked. Moreover, successful interventions seem to correspond to situations where governments established requirements according to reciprocity mechanisms to achieve clear developmental objectives. According to this view, the objective of limiting the use of requirement policies is to move from quadrant four to quadrant one, a reasonable conclusion within the limited perspective of the left hand side of Figure 4–1.

Figure 4–1: A Framework to understand Performance Standards



A separate line of work has studied subsidies, often considered as a second best mechanism to correct for gaps between private and social results of projects, much in line with the argument for content restrictions developed in the previous chapter (UNCTAD, 1996). This viewpoint has mostly considered the lower section of the figure, which includes the first and second quadrants. The critical issue that research on this subject has pointed out is the fact that governments in industrializing nations are vigorously competing for foreign investment based on high profile subsidy contests, sometimes offering more than the benefits of the investment. In fact, one could speculate that a failure to consider the third quadrant might be driving this subsidy race. Reducing the ability of governments to demand restrictions that would tailor projects to local conditions leaves them exposed to outright auction type situations where the project goes to the region that offers greater subsidies. Economic theory predicts that this will result in the investor capturing the whole surplus generated by the project[38].

This work specifically addresses the third quadrant, evaluating conditions for a successful use of incentives and requirements to enhance learning and improve development. The government wants to solve the problem of under-investment by creating the right incentive structure for local firms and foreign firms entering the country. It sets targets and requirements to firms in the domestic market that may improve social welfare, and is willing to commit the resources to compensate the negative effect that its policies may create in economic agents. The argument explored is that subsidies and requirements coupled through reciprocity principles act as incentive and screening mechanisms that lead the firms to perform the desired social objectives by aligning their decision with the optimal for the economy. As before, the focus will be in the enactment of domestic content requirements.

Within the context of these ideas, one might think that the model discussed in chapter 3 justifies protectionist measures for a particular context. Yet, section 3.4.1 notes that the government pays the OEM for any cost penalty associated with the domestic content requirement. This is the critical assumption that frames the problem as an interplay between requirements and incentives rather than a mere protectionist policy. In fact, the conclusion of the model is precisely that, within an optimal incentive contract, the government should pay the OEM exactly its sourcing cost penalty.

4.1.2. Using Performance Standards to Establish Incentive Contracts

The idea is that the government may use both restrictions and incentives to account for the difference between the private and social opportunity costs to maximize welfare. The technological characteristics of a project will determine different cost structures for domestic and foreign components, as well as for the external benefits associated to domestic purchases. As a result, each project will vary, both in the natural level of domestic purchases, as well as in the

[38] Considering the effect of competition between governments for the project is an interesting extension of the model presented in this chapter that will not be pursued in the thesis.

cost penalty resulting from a content level beyond its natural level. It is in government's interest to demand requirements and award incentives to the firm according to the cost of responding to the social objective function. A project with higher costs to increase domestic content will need greater subsidies to respond to an equivalent level of social objectives than another with lower costs.

In a standard model, both the company and the government are aware of each other's objective functions, costs and how they vary with domestic content (this was the case for the model in Chapter 3)[39]. Therefore, it is intuitive to think that a reasonable approach is for the government to demand content requirement beyond the natural level and to compensate the company for this extra effort until the marginal social benefit equals the marginal cost. What will be shown in the next section is that the optimal incentive contract is for the government to offer the OEM a subsidy that varies according to the level of domestic content that it chooses. This contract can be set up so that the OEM chooses the content level that is optimal from the point of view of the domestic economy and receives a subsidy that will match the cost penalty due to the extra domestic purchasing. An important conclusion is precisely the fact that the optimal subsidy is equivalent to the cost penalty, the assumption considered for the model of Chapter 3.

In the real world, a government facing a potential investment may not be sure of how costly it is for the OEM to increase domestic content beyond the natural level. It also may not know exactly what benefit it derives from increasing domestic sourcing. Therefore, it becomes difficult to establish the optimal contract. Suppose that, upon entering a negotiation with a prospective investor in the region, the government is unable to know ex-ante the cost to the firm of an increase in the level of domestic content. Nevertheless, lets consider that costs will be either high or low and that the government knows the probability of each of them. Now imagine the government proposes an optimal contract (with a schedule of subsidies and a corresponding level of domestic content) that is aimed at the expected costs and benefits of the average firm. If the company faces a low cost to increase domestic content, it will gladly take the offer, since subsidies will cover more than its cost. On the other hand, if the company has a cost of

[39] The specific intuition described from here onwards is formalized in the model presented in the next section

compliance above average, it will under invest, or may choose not to invest at all if the level of content demanded becomes more costly than the subsidies given out by local government. This situation is what the economics literature generically describes as an adverse selection problem. The superior information of the firms, in particular the ability of the low cost firm to mimic the behavior of high cost one generates a rent for the low cost or under investment from the high cost firm.

To better understand this problem a case where the intrinsic value of the project is rather important (even with no externalities), and the government wants to make sure that the investment takes place for both the high and the low cost firms, is assumed. This is a rather plausible scenario for a large OEM investment in a developing country. If government doesn't know the true cost for the companies to comply with content requirements (but knows the cost distribution) and can only offer one bundle of requirements and incentive, the solution is to offer the bundle directed at the high cost firm, that has less domestic content requirements and also awards less money. Under these circumstances the firm with high cost will take the offer. But so will the low cost one, for which it is less costly to respond to the regulation. The problem is that this solution is not efficient because the government could be better off with a different arrangement in content requirements and incentives directed at the low cost firm.

The adverse selection problem highlighted above can be minimized (although not eliminated, as seen below). The government can offer a menu of two bundles, letting the firm choose the one it prefers. The menu should have both a strong domestic content requirement coupled with a large incentive, and a small requirement with an associated limited incentive. Moreover, the values can be adjusted so that the bundle with demanding requirements and a large incentive looks more attractive to the low cost firm than the lower requirements with corresponding low incentives. Faced with this menu of choices, the firms self-select themselves when maximizing their profits. For the firm with the high costs of compliance with content requirements, the best choice is to choose the bundle with low content requirements and small incentives, while for the low cost firm the natural choice is the aggressive requirement and large incentive. In this situation, the allocation is more efficient than before where only one bundle was offered.

4.2. *The Formal Model*

The ideas outlined above can be formally expressed through a variation of the adverse selection model well established in the literature (Laffont and Tirole, 1993; Mas-Colell, Whinston et al., 1995, ch 14.; Salanié, 1997, ch 2). The government wishes to maximize local returns from the investment of a particular company in its country or region. The idea is that these returns depend on the type of company and its level of effort expensed in tailoring its operations to fit the needs of the local economy. In many ways, the model presented below can be thought of at as an extension of the one developed in chapter 3. Nevertheless, the regularity conditions that have to be imposed here are much stronger. Therefore, the analysis is treated as stand-alone and the necessary parallels to the work presented in the previous Chapter are drawn whenever necessary to understand the links between them.

This model also adds to the growing body of literature that explores the role of asymmetric information on strategic trade policy. Existing models have addressed the effects of the asymmetric information in Brander and Spencer (1985) rent-shifting trade type models (Qiu, 1994; Brainard and Martimort, 1997; Kolev, 1997). They concluded that information problems weakens the ability of the government to gain domestic welfare advantages through subsidies, with the degree of this effect depending on the influence of the actual characteristics of the market. The conclusions of the model presented here follow a similar pattern.

The objective of the firm is to maximize profits. These include two components. The first is the intrinsic value of the project, which corresponds to the original motivation to undertake the investment. For the purpose of our study, this is considered to be the profit associated to the basic project, labeled as Π^0. The second component is the net result of the incentive given by the government minus the additional costs faced by the project as a result of the extra level of domestic content demanded by the government (equivalent to the ΔS described in equation (3–8) of Chapter 3 multiplied by the quantity sold). These costs depend on the effort demanded through the level of content requirement, as well as on the type of firm. So, one gets:

Firm additional profit: $\Pi^E(e,\beta) = t - S(e,\beta)$

Where e represents domestic content requirement beyond the natural level, β represents firm type and t is the subsidy awarded from the government to the firm.

The marginal cost of compliance with additional content requirements is assumed to increase with the firm inefficiency in increasing content level. This can be written in mathematical form as $S(0,\beta)=0, S_e^{'}(0,\beta)=0, S_e^{'}(e,\beta)>0, S_{ee}^{''}(e,\beta)>0, S_{\beta}^{'}(e,\beta)>0, S_{e\beta}^{''}(e,\beta)>0$. For the above assumptions to be coherent, a larger β will be associated with a firm facing higher cost of compliance with domestic content requirements.

Following the ideas developed in chapter 3, the domestic economy will receive a certain surplus associated with increasing local purchases (equivalent to the supplier surplus defined in equation (3–24) of chapter 3). This can be represented as:

Government revenue: $V(e,\beta)$

Where revenue grows with content level e, but with diminishing returns, i.e. $V_e^{'}(e,\beta)\geq 0, V_{ee}^{''}(e,\beta)\leq 0$.

The government also has a cost. This is the cost of any subsidy it pays the firm to make sure it achieves the extra content desired (the government surplus in the same equation 26). Like before, this cost is corrected to account for the penalty of raising money from taxpayers. Therefore, the cost is represented as:

Government cost: $C=(1+\psi)t$,

Where t is the subsidy paid to the company and ψ the additional burden of raising money.

The full expressions for both the government and the firm are:

Firm: $\Pi(e,\beta,t)=\Pi^0+t-S(e,\beta)$

Government: $G(e,\beta,t)=V(e,\beta)-(1+\psi)t$

4.2.1. Base Case: First Best

Now the objective is to understand how the relationship between the two parties is established. First, a base case is established, against which any relevant variations will be evaluated. In the base case the types of firms and content levels are common knowledge. This is the traditional neoclassical problem. The government will maximize surplus minus cost, subject to the participation constraint (PC) of the firm (i.e. the firm will only invest if the offer of the government is better than an outside option with value Π^0). This is equivalent to:

$$\underset{e,t}{Max}: G(e,\beta,t)$$

(PC) s.t. $\Pi(e,\beta,t) = \Pi^0 + t - S(e,\beta) \geq \Pi^0$

or, assuming that the restriction is binding,

$$\underset{e,t}{Max}: V(e,\beta) - (1+\psi)t - \lambda(t - S(e,\beta))$$

Differentiating with respect to *e* and *t*, the result is, respectively:

$$V_e^{'}(e,\beta) = -\lambda S_e^{'}(e,\beta) \text{ and } -(1+\psi) = \lambda$$

The result is:

(4–1) $$\frac{V_e^{'}(e^*,\beta)}{1+\psi} = S_e^{'}(e^*,\beta)$$

This result tells us that the government should choose a level of domestic content so that the marginal cost for the firm to comply with the requirements equals the marginal benefit for the government. To assure that the firm chooses the appropriate level of effort, the government offers the firm the following contract:

(4–2) $$t(e,\beta) = S(e^*,\beta) + \left(\frac{V(e,\beta)}{1+\psi} - \frac{V(e^*,\beta)}{1+\psi}\right)$$

The profit maximizing behavior results in the government awarding the firm $t = S(e^{*}, \beta)$, and the firm responds with the level of domestic content *e** defined in equation (4–1). When this is the case, the participation constraint (PC) will be binding. This result also matches the conclusion presented in equation (29) of Chapter 3. In addition, it shows that the optimal solution is indeed to pay the OEM exactly the additional cost it has to endure to comply with regulation, leaving it indifferent between the new solution and the original contract.

This initial result provides us some additional insights:

- Linear incentive contracts may be efficient. It is usually difficult for the government to assess the complete value curve *V* of the project for society. Nevertheless, it is straightforward to see that if the value curve $V(e, \beta)$ in equation (4–2) is replaced by $e.V_e^{'}(e^*, \beta)$, the result will be the same. This means that the information the government may need is reduced, requiring it to know the level of content requirement it wants to achieve, the value of these benefits at the maximum and the slope of the variations around this optimal level. Under these circumstances, the government will offer the firm a contract of the form $t = a + b.e$. This shows that very simple linear performance standard contracts can be efficient from the point of view of the firm and the domestic economy.

- In more developed regions it is less likely to find content requirements and incentives being awarded. In more developed regions, a particular investment project is one of many others. Therefore, the government is more likely to be mostly concerned with having the project happen, but has little or no value for additional effort. Therefore, its returns can be interpreted as containing the firm profit, with a marginal benefit from the additional effort likely to be very small (i.e. $V(e, \beta) = \Pi(e, \beta) + M(e, \beta)$, and $M(e, \beta) \to 0$; this implies $V_e^{'}(e, \beta) \to 0$). As a result, both *e** and *t(e*)* will go to zero. This conclusion is in line both with the conclusions of chapter 3 and earlier findings on this issue (UNCTAD, 1991).

- It is not surprising to see governments establishing similar incentives schemes for similar projects. When the government learns the structure of the cost of compliance with domestic content requirements, it can anticipate the reaction of the firms and, therefore, offer the corresponding incentive schemes.

- Tax collection affects the ability of the government to improve domestic welfare. Equations (4–1) and (4–2) indicate that the level of content demanded from a firm and the compensation offered by the government are affected by the cost of raising government funds (the parameter ψ). Therefore, higher costs of government funds will reduce its ability to offer incentives and will mean that a lower level of content will be demanded from a given firm.

- The uniqueness of the investment opportunity affects the ability of the firm to demand incentives to compensate demands of higher content. If the government becomes aware that the outside option of investment is below the opportunity in its region (i.e. PC becomes $\Pi(e,\beta,t) = \Pi^0 + t - \psi(e,\beta) \geq \Pi^0_{out}$ and $\Pi^0 > \Pi^0_{out}$), then the government can reduce its incentives by the same amount of the difference between the base result for the firm in the region and elsewhere.

4.2.2. Asymmetric Information: Second Best

Now the situation where the government is not aware of the firm type at the time of negotiation is analyzed. For simplicity, two possibilities for the types of firms are considered. The first will face a lower cost to comply with domestic content regulations while for the other it will be more costly to respond[40]. This is can be written as:

$\underline{\beta}$: Low cost

$\overline{\beta}$: High cost

Since the government knows it may be dealing with two types of firms, it will generate different offers, which consist of bundles of incentives and content requirements. These will be called $(\underline{t},\underline{e})$ and $(\bar{t},\bar{e})$, considering that the first set is aimed at firms with type $\underline{\beta}$, while the second tries

[40] This can be generalized for a continuum of types. See for example Salanié (1997)

to respond to the type $\overline{\beta}$ company. Moreover, although the government is not aware of the firm type, it will have a prior probability that it is facing either a low cost or high cost firm. The distribution considered is:

ξ = Prob. (β= $\underline{\beta}$)

1-ξ = Prob. (β= $\overline{\beta}$)

The government maximization problem can now be considered. Given the assumptions outlined above, it will maximize the expected value of its result:

(4–3) $$\underset{\underline{e},\underline{t},\bar{e},\bar{t}}{Max}: \xi\left[V(\underline{e},\underline{\beta}) - (1+\psi)\underline{t}\right] + (1-\xi)\left[V(\bar{e},\overline{\beta}) - (1+\psi)\bar{t}\right]$$

This maximization will be subject to a set of constraints. These include the participation constraint for each firm. The new versions of equation PC presented above are:

(PC1) $\Pi(e,\underline{\beta},t) = \underline{\Pi^0} + t - S(e,\underline{\beta}) \geq \underline{\Pi^0}$

(PC2) $\Pi(e,\overline{\beta},t) = \overline{\Pi^0} + t - S(e,\overline{\beta}) \geq \overline{\Pi^0}$

In addition to these, there are two additional constraints. These are called incentive compatibility constraints (ICC). The idea is that whenever a firm chooses a contract, it should be better off with the particular level of requirement and incentive it chooses, and would prefer to pretend to be the other type of firm and get its contract. If the model specification is considered, this means:

(IC1) $\underline{t} - S(\underline{e},\underline{\beta}) \geq \bar{t} - S(\bar{e},\underline{\beta})$

(IC2) $\bar{t} - S(\bar{e},\overline{\beta}) \geq \underline{t} - S(\underline{e},\overline{\beta})$

It can be shown that the solution for this problem is (see Appendix 9.1.1 - calculations for asymmetric information):

(4–4) For $\overline{\beta}: \dfrac{V_e^{'}(\overline{e}^*, \overline{\beta})}{1+\psi} = S_e^{'}(\overline{e}^*, \overline{\beta}) + \dfrac{\xi}{1-\xi}\Phi^{'}(\overline{e^*})$

(4–5) For $\underline{\beta}: \dfrac{V_e^{'}(\underline{e}^*, \underline{\beta})}{1+\psi} = S_e^{'}(\underline{e}^*, \underline{\beta})$

Where $\Phi^{'}(e) = S_e^{'}(e, \overline{\beta}) - S_e^{'}(e, \underline{\beta}) = \int_{\underline{\beta}}^{\beta} S_{e\beta}^{''}(e, \beta)d\beta$

So, the optimal strategy for the government is to offer the firm a menu of contracts with two bundles $(\underline{t}^*, \underline{e}^*)$ and $(\overline{t}^*, \overline{e^*})$[41] that are determined by the equations (4–4) and (4–5). If the new equilibrium solutions are compared with (4–1), it is possible to see that they yield an efficient level of effort from the low cost firm, coupled with a positive rent, as well as underprovision of effort from the firm with higher cost to comply with regulations. Because the low cost firm may mimic the behavior of the higher cost firm, the government gives up some rent if it wishes to have the firm with high costs also investing in the region.

Like before, there are some additional implications of the results:

- If the government is aware that the firms are either mostly low cost or high cost, then contracting becomes efficient. This means that ξ–>1 or ξ–>0, respectively. As a result, one goes back to the situation where the government is aware of the characteristics of the firms. It also builds a case for the developmental government to have a good understanding of an industry. The better it understands it, the better it can tailor the menus.

[41] Alternatively, it could offer two contracts with $t(e, \hat{\beta}) = t^*(\hat{\beta}) + (e(\hat{\beta}) - e^*(\hat{\beta}))S_e^{'}(e^*(\hat{\beta}), \hat{\beta})$, $\hat{\beta} = \{\overline{\beta}, \underline{\beta}\}$

- The more dissimilar the types of firms, the more inefficient contracting can get to be. This is due to the structure of *Φ'(e)*, where increasing differences in the type characteristics (i.e. $\overline{\beta}$ - $\underline{\beta}$), or a steep marginal cost difference between the two firm cost type (i.e. $S''_{e\beta}(e,\beta) >> 0$) forces the government to further lower the level of content requirement demanded from the high cost firm to give more rent to the low cost firm.

4.2.3. Deviations From Optimal Behaviour

First, the study considers what happens if the government is limited in its ability to demand performance requirements. This is a crucial aspect because there is increasing pressure from the WTO for the developing world to drop performance requirements it has traditionally demanded from certain types of investments.

- If content requirements are prohibited, the firm extracts incentives from the government until project benefit is zero or there will be no offer from the government.

For any of the firm types, the best strategy is to demand the subsidies upfront announcing that it will endure the content level desired by the government and then set extra content to zero and still keep the government funds. To see how this may happen consider that, without an effort provision, the return for the government is a tax α on firm profit minus the cost of incentives given out to the firm[42]. Under these circumstances, the firm will maximize: $\underset{e,t}{Max}:\Pi(e,\beta,t)=\Pi^{0}+t-S(e,\beta)$ s.t. $V(e,\beta,t)=\alpha(\Pi^{0}+t-S(e,\beta))-(1+\psi)t\geq 0$. The solution for this problem is to set $e=0$ and demand $t=\alpha\,\Pi^{0}/(\psi+1-\alpha)$. So $V=0$, and $\Pi>\Pi^{0}$. Nevertheless, the government may anticipate that the firm will not comply with the desired content level if it is not forced to and may decide not to offer any incentive at all.

- If the government is not able or allowed to discriminate between firms and can only offer one type of contract, two things may happen. The contract will either be tailored for the high cost firm and there will be underprovision of effort, or the government will offer the bundle aimed

[42] Formally this means that we have to consider that V(0,β)>0

at the low cost firm, which will deter the high cost firm from investing (all calculations presented in Appendix 9.1.2).

Lets assume that the government maximizes the expected value of the returns, subject to participation constraints of the firms[43].

$$\underset{e,t}{Max}: \xi\left[V(e,\underline{\beta})-(1+\psi)t\right]+(1-\xi)\left[V(e,\overline{\beta})-(1+\psi)t\right] \text{ s.t. } \Pi^0+t-S(e,\beta)\geq\Pi^0,\ \beta=\underline{\beta},\overline{\beta}$$

The solution is for the government to offer a contract so that:

(4–6) $$V_e^{'}(e,\overline{\beta})+\xi.B(e)=(1+\psi)S_e^{'}(e,\overline{\beta}),$$

with $B(e)=-\int_{\underline{\beta}}^{\overline{\beta}}V_{\beta e}^{''}(e,\beta)d\beta$ being the additional marginal utility that the government gains from having a the low cost firm deriving the effort. Therefore, the exact solution depends on the structure of B(e).

- If it is only the level of domestic content that drives the benefit, i.e. $V_{e\beta}^{''}(e,\beta)$=0, then *B(e)=0* and one gets $V_e^{'}(e_1^*,\overline{\beta})=(1+\psi)S_e^{'}(e_1^*,\overline{\beta})$. Therefore, the government will choose a contract that is optimal for the high cost firm. The low cost firm will respond by mimicking the high cost one, and extract the extra rent derived from the fact that complying with domestic content is less costly to it.

- If the marginal result for the government increases with firm efficiency, i.e. $S_{e\beta}^{''}(e,\beta)<0$, then B(e)>0 and the result is $V_e^{'}(e_2^*,\overline{\beta})+\xi.B(e_2^*)=(1+\psi)S_e^{'}(e_2^*,\overline{\beta})$. Comparing this result with the one of the previous paragraph, it can be concluded that $e_1^*<e_2^*$. The government increases the content requirement with increases in the likelihood of a low cost firm and the difference between marginal benefits.

43 Without differentiated offers, there is no incentive compatibility constraint. It's a take it or leave it offer.

- But the government will choose to shut down the high cost firm if the expected benefits of having this type of firm doing the project are below the result the government is giving away for the other type. In this situation, the government will always require a high level of content commitment, offering the appropriate high incentives. In this situation, the project will only happen if the firm is of the low cost type, but the effort of the firm will be efficient. This happens either because the revenue of the high cost firm is too low, or because the rent derived by the low cost firm is too high. Mathematically, this effect is driven by a very large difference in marginal benefit between low and high cost firms.

In any of the cases, it is obvious to see that the inability of the government to observe or to demand different performance requirements to the firms dampens their level of commitment to the economy and, as a result, the benefits that the government derives from their investment.

4.3. Summary

This chapter analyzes the mechanisms that can be used by the government to induce the OEM to choose the level of domestic purchases that yield maximum welfare to the local economy. Subsidies and content requirements coupled through reciprocity principles act as incentive mechanisms that align OEM decision with the optimal choice for the domestic economy. When offered the adequate options with bundles of content requirements and subsidies, companies will self-select themselves in an optimal way while correcting for the gap between social and private benefits and costs. Nevertheless, the analysis also shows that uncertainty on how the enactment of content requirements affects the cost structures of the firms reduces the ability of the government to enact efficient incentive contracts and to improve domestic welfare.

The incentive model described in this chapter works as an extension of the work presented in chapter 3 (although stronger regularity conditions are necessary for the formal proofs). In fact, for the case with full information, the conclusions of both models converge, and the incentive contract results provide the necessary justification for the assumption used in chapter 3 of having the cost penalty of the investing firm paid by the government.

These results also provide a good understanding for some of the findings of earlier studies mentioned in chapter 2, which suggest that, despite its pervasive presence, performance standards do not greatly affect in the decisions of investing companies (UNCTAD, 1991). In fact, given the results exposed above, firms that choose to enter a market with performance standards, where subsidies and requirements are used to correct for coordination problems and external effects, are doing so because it is optimal for them and for the local economy.

Chapter 5.
SCM - System Cost Modeling

As seen in previous chapters, understanding the decisions of investing firms and local governments in what concerns domestic content depends heavily on component cost structures in the relevant market contexts. In particular, it is important to know how the manufacturing conditions in the developing nation contrast with those found in the world market to be able to investigate on the trade-offs between local and foreign sourcing. The problem is how to assemble cost information for all the relevant components that are subject to the OEM sourcing decisions. For an automobile, for example, this could mean hundreds of components, for which price information from two locations would have to be gathered. Even if it would be possible to find these prices, they would pertain specific manufacturing condition and would not allow sensitivity analysis to changes in relevant variables such as volume or cost of capital.

The alternative solution is to model the cost for these components. The establishment of a cost structure for all the components that takes in consideration their use of factor inputs such as materials, labor and capital, would enable an analysis of the OEM sourcing decision. Moreover, if it would account for aspects such as factor costs, logistics conditions and production volume, it would also enable the desired examination of the influence of regional manufacturing conditions on cost and, consequentially, on the local content decisions and policies.

To be able to make this assessment, this chapter proposes a methodology to evaluate the cost of complex systems with a large number of individual components and subsystems. First it describes the existing techniques for estimating cost and their relative advantages and disadvantages. Then it describes a new methodology called Systems Cost Modeling (SCM) that proposes a number of simplifications that enable it to be used to build bottom-up cost structures, starting at the level of the individual component and aggregating cost to the subsystems and system level. The main advantage of this approach is that it requires relatively few inputs per part making the task of estimating cost of large numbers of parts more manageable.

5.1. Manufacturing Cost Modeling

The issue of manufacturing cost estimation has long been a source of concern for managers and researchers (see Sims, 1995 for a full review of issues associated to manufacturing cost estimation). Several techniques have been proposed to estimate cost. While initial ones were rather crude and served mainly to provide rough orders of magnitude, increasing cost and profit pressures in the industry during the later part of this century have generated the necessity for more precision in the estimates. This section reviews the main techniques that have been used to assess manufacturing cost, discussing their main objectives, characteristics and limitations.

Rules of Thumb

The best known techniques for evaluating the cost of manufacturing processes are simple rules of thumb. Designers or engineers with experience with the relevant technologies and processes usually develop rules of thumb (Busch and Field III, 1988). They are often based on two of the core cost drivers of any manufacturing activity: materials cost and cycle time.

- Markup over materials cost. In many manufacturing processes, materials are an important share of the total cost. Experience in a particular industry enables experts to accurately predict this share and suggests the development of rules that are easy to understand by everyone and provide results that are sometimes close to the actual cost of the component. For example, the material costs for steel stampings is expected to be something between 50% and 80% of the total cost, depending on part geometry (see for example German, 1998; Veloso, Henry et al., 2000).

- Materials cost plus shop time burden. This technique acknowledges that, in addition to materials, processing time is another major cost driver for manufacturing. Processing time cost is then characterized through a burden associated with part production cycle time. This burden can include an estimated machine and tool rent, cost for the workers associated with the production process, etc.

There are three major problems with these rule of thumb techniques. First, they rely heavily on historical data and previous experience. Therefore, they have strong limitations in environments of rapid change in materials, technologies and customer requirements. Second, they assume linear relationships between factors driving cost. This leads to misleading results as in most situations these relations are fundamentally non linear. Third, these are black-box techniques that do not allow the manager to understand the interplay between the several factors that are driving cost, nor do they allow experiments to understand potential cost savings. As a result, relying on rules of thumb to make important technical or managerial decisions can be extremely misleading and costly to the company.

Accounting Principles

Cost estimation by accounting principles uses current accounting data and practices in the plant to estimate manufacturing cost. A particularly popular application of these principles is activity based costing (ABC), which attributes direct and overhead costs to products and services on the basis of the underlying activities that generate the costs (Cooper and Kaplan, 1988). When successfully applied, ABC has enabled a better understanding of the cost drivers and more accurate decisions of pricing and marketing decisions. It may also provide accurate estimates of equipment and workers burden rates (Anderson, 1995). Nevertheless, it has been of limited help to engineers and designers concerned with improving the manufacturing lines or choosing between alternative materials. The reason for this situation is that ABC is based on historical and descriptive information, and seldom incorporates any engineering control variables. Therefore, it retains some of the fundamental ex-post characteristics of rules of thumb, hampering the possibility to establish predictions for new manufacturing systems, materials or part characteristics.

Econometric analysis

This estimation process involves assuming a predetermined functional form for production, either stemming from a theoretical proposition or empirical observations, and then regressing the dependent variable (cost or quantity) on the relevant independent ones (regressions are typically linearized forms of non-linear relationships).

Econometric estimation has been used to study a wide variety of aspects, including economies of scale on production, monopolistic pricing, productivity differences and quality of labor and capital efficiency measured by embodied technical progress, among many others (Pesaran and Wickens, 1997). The analysis, nevertheless, looks at the industry or sector aggregation level, with individual firms as an observation for the regression. Therefore, while this technique has provided economists with relevant information to understand aggregate behavior, it provides limited predictive information in situations of changes in the underlying technological process, and it does not facilitate the individual decision makers in the firm. Moreover, although some attempts to include relevant engineering information in economic production functions have been made (Wibe, 1984), the economic and engineering professions have mostly become more far apart, and limited work integrating the two perspectives has been tried.

Technical Cost Modeling

The problem with the previous techniques is the fact that they offer very limited power for estimating the effects of departures from observed conditions in manufacturing cost. These limitations led to the development of Technical cost modeling (TCM) methodology at the Massachusetts Institute of Technology in the late seventies (Busch and Field III, 1988; Clark, Roth et al., 1997; Kirchain and Clark, 2001). TCM is related to the activity based costing idea of accounting principles, but uses engineering, technical and economic characteristics associated with each manufacturing activity to evaluate its cost.

TCM analysis starts with an identification of the relevant process steps required to manufacture a particular component. The fender of a vehicle, for example, may start as a steel sheet that is blanked, then stamped, and later painted. For each identified step, all cost drivers are estimated. TCM evaluates fixed and variable costs separately. This division reflects the fact that variable costs can be directly associated with the production of one unit of output, thus increasing roughly linearly with production volume. On the contrary, fixed costs remain constant until production capacity is reached, whereupon more equipment is required. These categories are then subdivided into variable costs of material, direct labor, and energy; and the capital costs of main and auxiliary equipment, tooling, building, maintenance and overhead. These items reflect those used in classical accounting methods in order to maintain consistency with conventional views on cost. The critical difference with the accounting approach is that values underlying each of the categories are a reflection, not of accounting information gathered at a plant, but of how engineering process knowledge influences each of these cost accounts.

TCM is a flexible tool to analyze the manufacturing cost implications of different strategies, business conditions and product characteristics. The models enable wide experimentation and analysis, critical to evaluate relative strengths and weaknesses of alternative paths, or to pinpoint critical engineering or economic factors affecting cost, particularly in early stages of design. TCM and other techniques that are closely related, provide rather accurate estimates of the manufacturing cost and have been used with success in a number contexts (Boothroyd, Dewhurst et al., 1994; Humphreys and Wellman, 1996; Clark, Roth et al., 1997; Ulrich and Pearson, 1998; Kirchain and Clark, 2001).

Because the systems cost model that is the object of this chapter relies heavily on the TCM approach, a more detailed explanation of this method is presented, which is then used to ground the SCM explanation presented in section 5.3.

5.2. Technical Cost Modeling

As noted above, TCM uses engineering knowledge to estimate relevant cost drivers associated with relevant cost drivers for each processing step required to manufacture a particular component. This section explains the TCM approach used to calculate each of these drivers and how technical knowledge is incorporated in the calculations. The division between fixed and variable costs highlighted above is used, followed by a discussion of the equally important concept of time usage of equipment. At the end, a discussion of the limitations and extensions of TCM is presented. More detail on the method can be found on Busch (1988), Clark (1997) or Kirchain (2001).

5.2.1. Fixed Costs

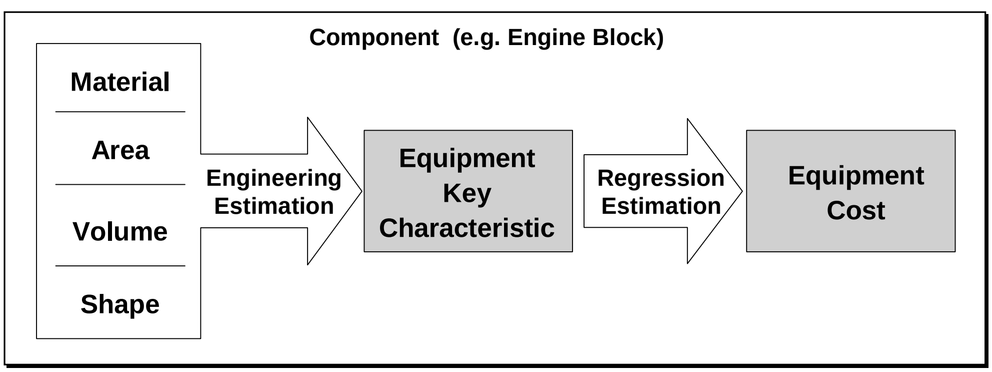
Fixed costs are associated with aspects of the process that cannot easily be changed within the time frame relevant for the analysis, and are independent of the level of our control variables or the rate of inputs or outputs. Even if nothing is to be produced, these costs will still exist. Typical examples of fixed costs are the building or the machines used for production.

Fixed costs extend beyond the one-year time frame currently used for analysis. Therefore, all investment is annualized, considering a level of discount rate and a capital recovery period. As a result, each of the fixed cost drivers described below has an annual equivalent that is used in the evaluations. This annual cost can be analyzed on a unit cost basis dividing year values by the annual production volume. The calculation of fixed costs in TCM typically includes main equipment, auxiliary equipment tooling, building, maintenance and overhead.

Equipment Cost

The technical estimation of equipment costs is often done in two steps. First, the features of the component to be formed are used to identify the required characteristics of the equipment to be used in the manufacturing process. This decision, illustrated in Figure 5–1, is often achieved using engineering estimation techniques. In the second stage, the cost of the equipment with the necessary characteristics is determined, either by direct inquire with suppliers, or by regression techniques that associate the key characteristics of the equipment with cost.

Figure 5–1: Equipment Cost Estimation Techniques for Technical Cost Modeling



For each manufacturing process, the main equipment that is used to achieve the desired transformation process is usually characterized by one major feature (see Kalpakjian, 1995, for detailed explanations of these features and their importance). For example, in the injection molding process, this key characteristic is the machine Clamping Force. The Clamping force is applied by the machine to keep the dies closed during injection of molten plastic in the mold cavities. Since there are typical pressures inside the mold necessary to assure the desired part characteristics, the clamping force determines the maximum size of the part. Likewise, die casting machines also have the force that keeps the die closed as the limiting factor. Therefore, they are also characterized and rated as a function of the clamping force. For other processes such as stamping, sheet-molding compound or forging, the punch force they can apply to material being shaped is the critical equipment characteristic. Blow molding is characterized by the air pressure blast into the mould cavity to form the part. Other manufacturing processes have their own key characteristics.

This key characteristic can often be estimated from component features such as volume, material, and shape that will exist from component design specifications. The example of injection molding will be used again to explain this derivation. This manufacturing process is achieved through a machine that melts the plastic material and injects it into the cavity of a mold. When injection molding, physical laws dictate that clamping force required to hold the dies closed during mold filling must be greater than the force generated normal to the plane of die separation. This force can be related to the filling pressure and the cross section in that plane of the part being produced. With enough information, the relationship between the clamping force and these design parameters can be modeled to an extreme level of detail. For the purpose of cost calculations, a reasonable approximation to these relationships can be calculated through regression on existing injection molding parts. This approach results in a definition of press clamping force as (Busch, 1987):

$$ClampForce = SectionArea\left(\frac{224}{\sqrt{MaxWallThickness}}\right) + 172kN$$

The next step is to find the cost of the equipment from the computed key characteristic. For this example of injection molding, the required clamping force can used to gather information regarding machine prices directly from equipment suppliers. Alternatively, information for different forces and associated costs can be gathered from a number of suppliers, and a statistical relationship between the force and the investment in equipment can be established (Busch, 1987; Boothroyd, Dewhurst et al., 1994, Chapter 8).

This type of relationship is much more powerful than an accounting estimate since it enables a rather accurate estimate of the relevant cost driver from related design variables across a wide range of conditions. Moreover, this type of estimation method can be performed for virtually any technology, with the relevance of each design parameter depending on the particular process under consideration (see Han, 1994; Kirchain, 1999 for a discussion of the multiple applications of TCM). If instead of injection molding, the above consideration would be for stamping, the relevant component features to estimate the punching force would be material, area and the depth to length ratio.

The equipment cost estimated through the steps described above usually has to be adjusted to take in consideration two aspects. First, auxiliary equipment cost may have to be considered. Quotes from equipment suppliers often do not include complementary machinery such as fixtures, conveyors and workbenches, among others. Because it extremely difficult to have an accurate estimation of these costs, they are usually considered as a percentage of the investment in the main equipment, with ranges depending on the level of automation that will be used to loading, unloading and conveying. These values are usually gathered directly using industry estimates. The second correction is for installation costs. Any industrial equipment requires careful installation, ranging from electrical power and dedicated supplies to precise positioning in the building and training of the workers. These are relevant additional costs beyond the equipment value. Like auxiliary equipment, they are difficult to estimate and are usually considered to be a fixed percentage of the equipment cost.

Another important element of equipment cost is tooling. *Tooling cost* is probably the most difficult value to estimate because it is unique for each part that is produced. The main difficulty arises from the inability to completely describe tool complexity using only limited and standard component description inputs. A small geometric detail can make a tool extremely difficult to produce and, therefore very expensive. The approach used with more success is to regress tooling cost on certain material, geometric, durability and conformability characteristics of the tool, based on historical information for each relevant process (Busch, 1987; Busch and Field III, 1988; Boothroyd, Dewhurst et al., 1994, chapter 8 to 10).

Although tooling is also considered an annualized investment, it will be dedicated to a specific part. Therefore, the recovery period is the life time of product, and there is no weighting against other part utilization, as in the case of equipment.

Other Fixed Cost

In addition to equipment costs, there is a set of other factors such as building, overhead and maintenance that only have a weak correlation to the engineering aspects of a particular process. Therefore, they are often incorporated as a function of machine and tooling cost.

Building Cost depends directly on the equipment that is necessary to assure the manufacturing process. On the one hand, more equipment requires more space; on the other hand more complex equipment may require greater care with the surrounding environment (e.g. precision leveling of the floor), both resulting in greater building cost. Therefore, this cost can be treated as share of equipment cost. It can also be estimated given the amount of space that the equipment will occupy, with the surface area value for industrial operations obtained from industry or real estate sources.

Maintenance Cost is considered as a fixed percentage of the cost associated with equipment, tooling and buildings. Although formal stochastic models of machine failure and maintenance schedules exist (Gershwin, 1994), this level of sophistication is often not helpful when the object of the analysis is cost and not specific shop floor planning. The ratio to equipment cost approach is used because maintenance expenses are often correlated with the cost of the original equipment.

Overhead labor costs consist of supervisors, janitors, accountants and other personnel not directly involved in the production process. This is a value for which it is impossible to have an accurate estimate since it depends on the human resources practices of each company. Because of the high variability, it is assumed as fixed percent of direct labor. *Fixed Overhead* includes all other fixed costs of the company, including the equipment used in the administration and management. It is valued as a percentage of the equipment cost.

5.2.2. Variable Costs

Variable costs depend on the rate or volume of production. They are measured based on either inputs or outputs of production. Typical examples of this cost are raw materials or energy consumption. Some of these costs can be directly attributed to a particular part (e.g. raw materials), while others (e.g. energy) have to be converted through some common metric, usually time.

The major drivers of variable cost are:

- *Material cost* is one of the most important cost drivers. This cost depends on the quantity of material that is bought, mostly driven by the weight. Nevertheless, an accurate treatment of the material cost has to take in consideration rejects and scrap that result from the different steps of the production process. Because there is a market for scrap, the amount sold has also to be deduced from material costs.

- *Direct labor cost* is a function of the man-hours per year used to produce the part and the wages (and benefits) they are paid. This calculation takes in consideration the intrinsic characteristics of the technologies chosen to perform the relevant operations, particularly in what concerns automation, but it also depends on time allocation patterns chosen by the management of the company.

- *Energy Costs* are simply a function of the price of energy, the machines consumption rates and the number of hours that they work.

- *Inventory Cost* results from having raw materials, work in process and final goods immobilized in the company. This involves an opportunity cost tied to the value of the immobilized product, as well as costs related to storage and potential negative implications to the company organization (Womack and Jones, 1996). This cost is often evaluated by evaluating material flow in the company or through accounting techniques.

5.2.3. The Process Time Use of Resources

The methods described in the previous section establish the methods that lead to an evaluation of the cost of the resources required to manufacture a particular component. But previous sections have not discussed how the time it takes to manufacture an individual component, or to reach a particular annual production volume, affects its cost. In fact, while time this is certainly not important for material costs, it becomes critical for fixed costs, which are associated to resources (e.g. equipment) with a useful life that extends beyond one year and sometimes to variable costs. Therefore, it is important to establish the concept of *Process Use Time (PUT)*. The idea of PUT is that the cost of resources may be determined by the cost of using them for the amount of time required to reach the desired production volume. PUT becomes a critical control variable in a manufacturing system because increasing process use time is associated with the use of more equipment, additional workers and energy utilization and, as a result, accrued cost (Sims, 1995).

The critical variable determining time usage is *Cycle Time*, the time between two consecutive parts coming out of a production line. Because of its importance, Cycle Time is calculated using information on the technological constraints that determine processing time. To explain how TCM addresses this issue, the Injection molding example is used one more time. Molding cycle time can be effectively divided into three separate segments: injection of filling time, cooling time, and mold resetting time. Given a particular mold design and machine clamping force, these times can be calculated through an analysis of polymer flows in the mold cavity. Precise estimates using computational models can be achieved using specific software (Clark, Roth et al., 1997). A more expedite solution for an approximate result with cost estimation objectives may be, once more, to establish a statistical relationship between critical variables. Previous work (Busch, 1987) has established that cycle time can be regressed with a good degree of confidence on cooling time and weight of a particular part. Part geometry and material characteristics are enough to establish weight and, using transport theory, calculate the required cooling time for the part (Ballman and Shusman, 1959). These values are then inserted in the statistical relationship to have an estimate of the cycle time. Other technologies will have equivalent procedures (see Busch and Field III, 1988; Han, 1994; German, 1998). Given cycle time information, the time required to manufacture a certain annual volume is achieved multiplying both variables.

Nevertheless, it is important to recognize that an accurate account of how time use affects cost should also take in consideration *Idle Time* of relevant resources. Manufacturing processes are planned to respond to objectives in terms of production volume within a given period of time, typically one year. Therefore, non-operative periods of time represent a foregone opportunity to produce a certain number of components. Factors leading to idle time can be both planned and unplanned and typically include:

- *Set Up Time*. Time spent preparing equipment to run a new batch of parts.
- *Planned down time*, during which the line is attended but it is not producing, and can involve rest periods or scheduled maintenance
- *Unplanned breakdown time*, during which the line is down due to unplanned problems

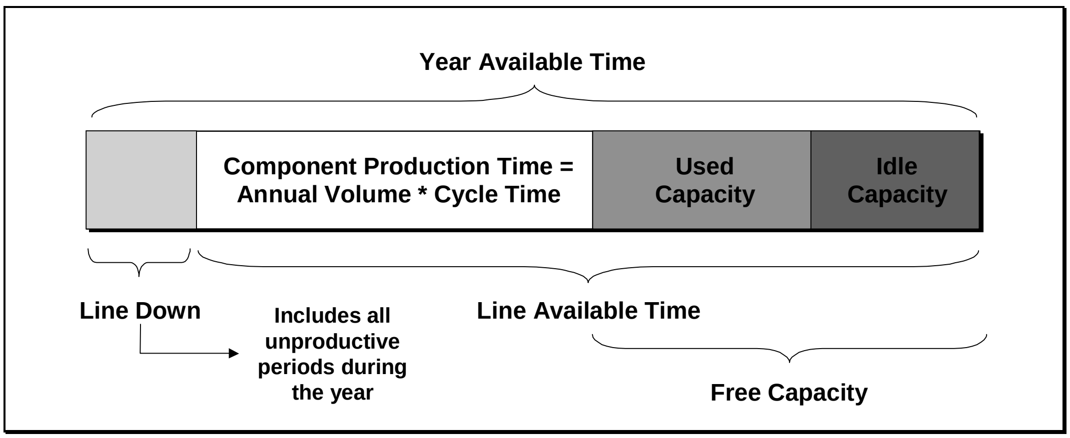
These times are usually assessed by making direct inquires regarding industry practices. Values may depend on process, equipment characteristics as well firm or regional conditions.

Following the process use time logic, cycle time and idle time information can be combined to estimate *Unit Fixed Cost*. The first aspect to note is the fact that the fixed costs estimated through the methods described in the previous sections are investment costs. Therefore, to translate these costs into a unit component cost, it is necessary to annualize them. The approach used is the economic notion of opportunity cost. Investments in fixed capital, including items such as equipment and building, could have been applied elsewhere in the economy rendering a reference annual income during the period of the investment[44]. This foregone income is then the *Annual Fixed Cost (AFC)* associated to the manufacturing activity.

If the equipment is solely dedicated to the manufacturing of the component under analysis, the unit cost can easily be calculated dividing the annualized cost by the annual production volume. The difficulty is that equipment is often used to manufacture different components. As a result, the appropriate unit charge should be calculated according to the relative time during which the capital equipment is used for the relevant component.

Process Time Use (PUT) is defined as the ratio between *Line Utilization Time (LUT)*, which corresponds to the amount of time needed to manufacture the required volume of components and *Line Available Time (LAT)* that indicates the amount of time that the manufacturing equipment is available for operation. The later indicator is the result of company operating policies, including number of shifts, holidays and planned line down time (for aspects such as maintenance, meals or rest), as well as line and demand characteristics, that affect issues such as unplanned breakdowns and die change time, among others. For the purpose of this study, all factors leading to unproductive periods in a manufacturing plant are condensed into a *Line Down* variable. The converse variable, obtained by subtracting line down from the total available time in one year defines the *Line Available Time*.

Figure 5–2: Critical Relationships in Line Utilization



Line Utilization Time is given by the sum of the time needed to manufacture the required volume of components, or *Component Production Time (CPT)* and a burden associated with unused equipment time. The CPT usually does not take up all the line available time[45]. The remaining time is *Free Capacity* that can either be used to manufacture other components (*Used Capacity*), or kept as *Idle Capacity* if no alternative use is found. If it remains unused, this *Idle Capacity (IC)* has to be charged to the components being manufactured in their relative proportion.

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[44] For example it could be loaned to someone at a market rate, or invested in a portfolio of securities.

[45] It may also happen that the Component Production Time is greater than the annual available time for a given equipment. If this is the case, several lines are bought, and the Free Capacity variable represents the remainder time in the less than fully utilized equipment.

Figure 5–2 illustrates the relationship between these variables. Since CPT can be calculated by multiplying *Cycle Time* and *Annual Production Volume (Vol)*, the *Unit Fixed Cost (UFC)* can be written as:

$$(5\text{–}1) \qquad UFC = PUT\,\frac{AFC}{Vol} = \frac{LUT}{LAT}\,\frac{AFC}{Vol} = \frac{Vol * CT * \left(1 + IC/(LAT - IC)\right)}{LAT}\,\frac{AFC}{Vol}$$

$$UFC = \frac{CT}{LAT}\left(1 + \frac{IC}{LAT - IC}\right)AFC$$

The utilization of free capacity is important because it influences the unit cost of the component under analysis. On the one hand, if free capacity is fully utilized, then idle capacity is zero and the second term on the right hand side of equation (5–1) drops to zero. As a result, unit cost is only the relative share of cycle time on the overall production time available in the year. On the other hand, it is easy to see that if the idle capacity is large, the unit cost will be mostly determined by the entire line cost and not the individual component production time.

Cycle time and idle time information, together with fixed and variable investment cost calculations detailed above, provide a rather accurate estimate of the cost associated with an individual part. Moreover, since calculations are based on engineering estimates, it is possible to understand how variation in the characteristics of the part may affect manufacturing cost.

5.2.4. Technical Cost Modeling Extensions

The previous sections, following the approach of traditional TCM analyses, described the problem of cost modeling from the perspective of individual processes. In fact, the initial research that led to the development of TCM aimed at estimating cost implications of adopting alternative materials in a particular process; or comparing the manufacturing cost of a particular component when using different processes. Good examples of these two applications are the investigation of Busch (1987) on the economic impact of using different polymer resins in injection molding, or the work by Busch and Field (1988) comparing injection molding with blow molding, thermoforming and structural foam molding for the manufacturing of panels.

Most applications of TCM since its inception follow a pattern similar to the one described in these two studies: a limited number of parts are modeled in one or more competing individual processes to understand the economic implications of changes in process or in critical design parameters (e.g. material, production volume, factor condition) (Clark, Roth et al., 1997). Nevertheless, the large majority of today's products are the result of a complex combination of parts that require numerous operations in their manufacturing as well as a substantial assembly effort. The seat of an automobile, for example, may require 40 different individual parts and more than 10 different processes. As a result, there has been a growing demand for the use of TCM to estimate more complex products (Han, 1994; Kang, 1998; Kirchain, 1999).

Evaluating the cost of complex products using TCM requires the combination of a significant number of different models. For each of them, part and processing information has to be gathered and processed. Because of the high level of detail associated with TCM, combining a large number of technical cost models will require large amounts of information. For the seat example mentioned above, given that an average model may require the introduction of 25 descriptive variables (Kirchain, 1999, chapter 2), more than 10,000 variables would have to be accounted for. This makes the estimation process extremely complex.

The initial problem resulting from an increase in the number of variables is handling the information. Traditional TCM have been implemented in spreadsheets, with the user responsible for the introduction of the variables and the establishment of the necessary links to calculate aggregate cost from individual models and parts. Entering and manipulating large number of variables in spreadsheets is not only very time consuming and inefficient, but it also very prone to errors. An obvious solution to this problem is to migrate the models from the spreadsheet environment into a more sophisticated modeling environment. To address this problem, Kirchain (1999) developed an application to support the use of TCM in an object-oriented database environment. The computer tool created a uniform data structure that describes each part in a system and the procedures that emulate the behavior and interrelationship of those parts. A case study of the automobile recycling infrastructure was used to demonstrate the applicability of the tool.

As in many other problems, the use of computer tools facilitates the TCM problem associated with manipulating and processing large amounts of information. Nevertheless, as the complexity of the product to be modeled increases, the problem is not only data manipulation, but also data collection. Gathering or constructing detailed design and processing data for a large number of parts is very difficult. A problem that may exist at the onset is access. As products become complex, detailed design and processing information required as input to TCM is also likely to be scattered among various persons and departments in a large organization. Furthermore, the supply chain may become disperse, with various firms responsible for different components. As a result, data may be very difficult to gather. In addition, even if it would be possible to have all the required information, inputting and analyzing such a detailed data set can become unmanageable.

For a manufacturing firm, a high level of detail in cost estimation can be very important for rigorous competitiveness assessment, particularly at the manufacturing stage. If this is the case, companies assemble large teams of engineering and purchasing people devoted to estimating the cost of each individual part. Automotive is a good example of an industry where this is often the case. However, for the overall assessment of a system in early stages of development, or to investigate the generic impact of changes in factor conditions, such a level of detail is not desirable or sometimes even possible to achieve. In addition, such a large effort is impossible to replicate in an academic environment. Therefore, it is important to find methods to approximate the estimations. At one extreme it is possible to go back to techniques based on rules of thumb. However, it is reasonable to expect that solutions that reduce data requirements without compromising the logic and the mechanisms underlying TCM are possible to find.

A potential approach to this problem is the extrapolative method, proposed by Han (1994) and developed by Kang (1998), to estimate the cost of the body-in-white (BIW) of an automobile. Instead of modeling approximately 150 parts existing in a BIW, a set of categories were determined and a representative part to be modeled in detail through TCM was chosen for each category. The categories were determined according to differences in part geometry, size and forming complexity. The rest of the parts in the BIW were assigned to each of the categories. Assuming that all parts were formed in a similar fashion, their cost was estimated using weight ratios and identical processing conditions to those used for the representative part in each category.

The two applications show that the extrapolative method can be extremely useful when the parts have similar processing conditions and common characteristics that can be used to establish the relative differences. The method may not be so accurate if processing technologies and conditions are very diverse. A good example of this situation is the attempt to model the whole 3000 components of a car. Unlike the BIW, there is little common ground between components except the fact that they are all manufactured according to a number of processes. While the BIW uses only stamping and welding, the 3000 parts of the car require over 20 processes. The approach for these more complex cases may be still to model all the components, but to reduce the requirements in terms of the information and the modeling detail associated with each component. This is approach of the systems cost modeling methodology described in the next section.

5.3. Systems Cost Modeling (SCM): Estimating the manufacturing cost of complex systems

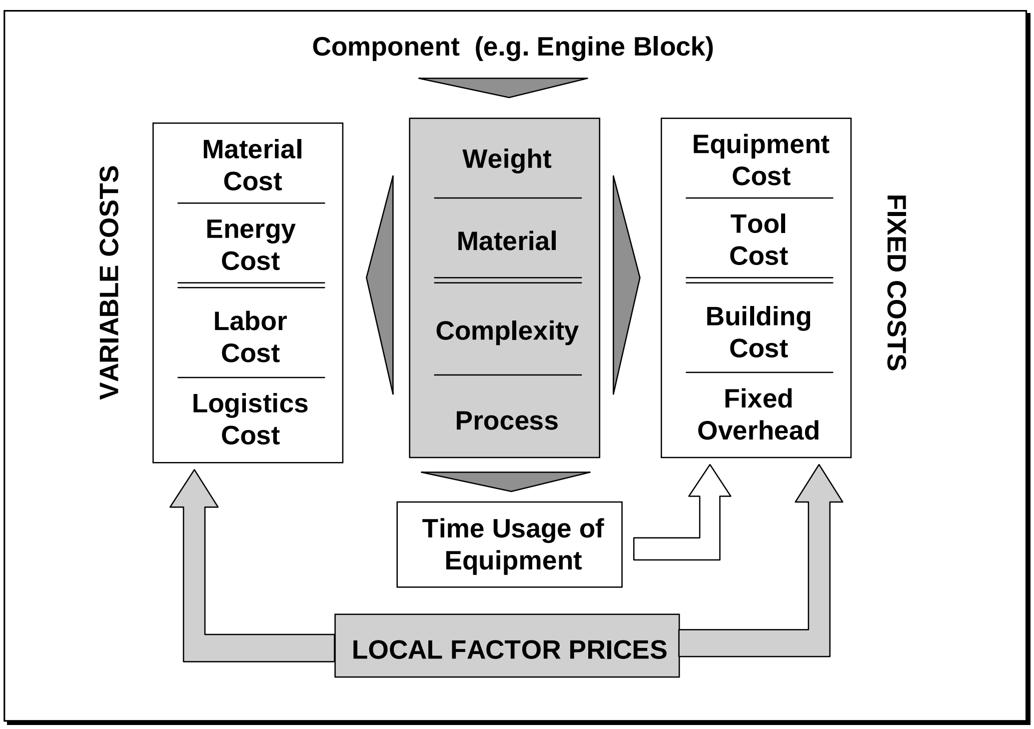
The SCM method aims at establishing a systematic way to estimate cost functions for complex systems, such as the interior or the chassis of a car, where multiple processes and diverse components are present. The cost function is grounded in engineering based approximate estimates of the manufacturing and assembly cost of its individual components, aggregated over subsystems. Unlike most existing cost estimation methods, that aim at obtaining an accurate evaluation of the manufacturing cost at an individual component level, SCM focuses on providing reliable calculations of the overall system cost and the influence of key parameters (such as volume and factor input costs), on the cost behavior.

When comparing manufacturing costs at the individual component level, accuracy and detail in the estimates is crucial for the relevance of a particular methodology. This is precisely the objective of TCM. SCM reduces the information intensity when compared to TCM, but it also provides less precision in cost estimates. Therefore, although SCM provides individual component cost, values at this level will only be on the right order of magnitude, limiting the ability to establish comparisons between technologies or manufacturing environments. Nevertheless, when comparing system costs, the level of idiosyncrasies is high enough that order of magnitude and trend are the relevant parameters that a researcher or practitioner may be concerned with. A typical application of SCM is the evaluation of the impact of wages or capacity utilization on a system cost, but not to compare the use of aluminum versus steel in the manufacturing of a car door.

SCM is based on a systematic evaluation of individual component costs. It is important to detail how this evaluation is done and how the individual and aggregate costs are established. As mentioned in section 5.2, cost estimation requires a careful evaluation of two aspects:

- The cost factors involved in a particular manufacturing process.
- The process time use associated to a particular technology and component

Figure 5–3: Estimating Component Manufacturing Cost Through SCM



The individual SCM approach to component cost estimation is a simplified version of the TCM methodology described above. As noted above, the problem is that TCM requires very detailed information regarding individual characteristics of the component and associated processing technology. Therefore, they are particularly useful when comparing designs or material solutions for individual or small groups of components. But they become less practical and sometimes infeasible when trying to model several hundred components. SCM solves that problem by estimating each of cost factors and process use time with limited information and using simple rules. The level of data detail is reduced, but cost estimates are also less precise.

The critical SCM approach to simplify traditional technical cost modeling techniques, illustrated in Figure 5–3, is to use four simple metrics as the basis for establishing all the cost drivers of an individual part. The metrics considered in the analysis are:

- Weight. This indicator is readily available for any component, making it a very natural choice. It's important for the material cost estimate and serves as a proxy for the volume of the component, often a major factor determining the characteristics of the required processing equipment and tooling.

- Material. Information is usually directly available for each component, even when several materials are a mixed together. Moreover, it is critical to estimate the material cost, which is often a significant portion of the total.

- Complexity. Detailed information regarding shape, thickness and other factors used to calculate equipment characteristics are substituted by a three level complexity factor, estimated by judgment. Level 1 corresponds to simple components where their size is the major factor affecting processing; higher levels of complexity imply more detail or additional features that require more complex (and therefore more expensive) equipment.

  An example is a convoluted injection molded part, which would require (a) a more complex and therefore more expensive tool; (b) higher pressures to cope with the complex mold that result in a larger more costly machine; (c) longer times to fill the cavity, affecting time utilization of equipment as well as labor; (d) greater scrap losses due to engineering trim or rejects.

- Process. To manufacture each component, a particular process is assigned. This process is either provided or determined knowing the material and analyzing the role the component in the overall system.

These metrics are used directly to determine equipment cost, tooling cost, labor usage, cycle time and material needed for the relevant manufacturing of a component. Following the TCM logic, the costs are derived from these core estimates. Unlike TCM that uses detailed component characteristics together with engineering and statistical relationships to determine cost, SCM uses published and collected information on the ranges of costs and capabilities of equipment, tools and labor for every process and proposes functional relationships between the four simple metrics described in the previous paragraph and cost. Each of the items is discussed in detail in the following sections.

These estimations, together with local factor conditions enable an evaluation of the fixed and variable costs associated with each component. The cost estimations over individual components are aggregated considering also the assembly costs. These are calculated using estimates from published information on insertion and manipulation of components. The following sections detail the method of calculating the costs.

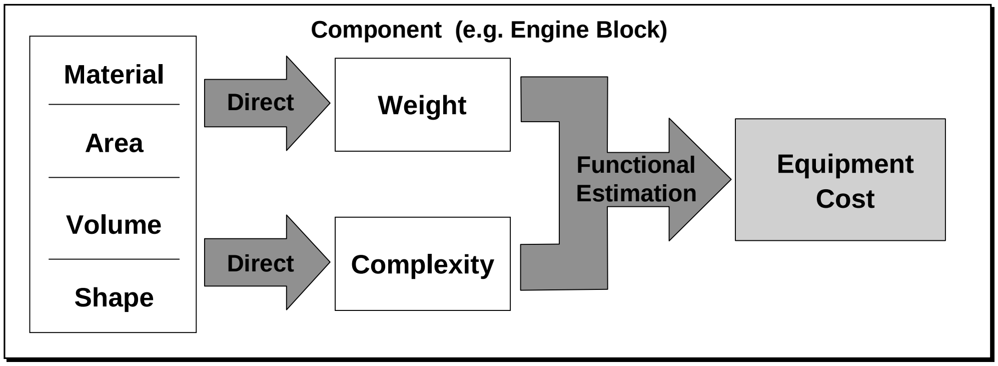
5.2.1. Estimating Fixed Cost Drivers

To explain the estimation process, the order of the cost drivers described in section 5.2.1 is used. The initial one is equipment cost, followed by tool cost, building and other fixed costs.

Equipment Cost

The SCM approach to estimate equipment cost involves two critical simplifications from traditional technical cost modeling techniques. The first is to aggregate detailed component information associated with physical characteristics into the four simple metrics discussed above. The second is to establish a direct relationship between these metrics and equipment cost, bypassing the step of estimating the key characteristic of the equipment described in section 5.2.1.

Figure 5–4: Equipment Cost Estimation Process for SCM



The simplification is illustrated in Figure 5–4 and the differences to traditional cost modeling can be perceived by comparing it with Figure 5–1 shown before. Instead of using detailed geometrical characteristics to estimate equipment cost, SCM relies on component weight and complexity. For the particular process assigned to a component, these two metrics are used to derive equipment cost. SCM proposes a functional form to relate component features and equipment cost following a logarithmic:

(5–2) $$Cost = A.(Weight)^b \, (Complexity)^c$$

This functional form is a generalization of previous work from several authors on the area of cost estimation (Busch and Field III, 1988; Boothroyd, Dewhurst et al., 1994; Han, 1994; Humphreys and Wellman, 1996). The use a logarithmic relationship to scale costs based on a key parameter, in this case weight, has been widely used in the chemical industry (a recent summary of several work done in this area can be found in Humphreys and Wellman, 1996, chapter 1). But unrelated manufacturing cost estimation research shows that logarithmic relationships between component weight and equipment cost seems to hold in a number of other circumstances.

Table 5–1 illustrates how the relationship between weight and equipment cost becomes logarithmic due to composite effects of a linear and a logarithmic function on the estimation steps from weight to equipment key characteristic and then to equipment cost. This type of behavior is observed for diverse technologies, suggesting the generic choice made in (5–2). The end term on the right hand side of the equation is used as a modifier to account for the impact of complexity on the capabilities of the equipment and, therefore on its cost.

Table 5–1: Generic Functional Relationship Between Weight, Equipment Key Characteristic and Cost

Process	Weight →	Key Charact →	Eq. Cost	Source
Injec. Molding	*Logarithmic*	Clamp Force	*Linear*	(1)
Die Casting	*Logarithmic*	Clamp Force	*Linear*	(2)
Stamping	*Linear*	Press Force	*Logarithmic*	(3)
Machining	*Linear to Logarithmic*			(4)

Sources: Own calculations based on (1) Boothroyd, 1994, Chapter 8; (2) Chapter 10; (4) Chapter 7; (3) Han, 1994.

Assuming that the relationship proposed in equation (5–2) holds, the relevant parameters *A*, *b* and *c* have to be estimated. Following previous examples, an obvious estimation method would be to perform regressions of observed equipment cost on the relevant parameters for a number of parts and processes. Unfortunately, given the pioneer stage of the method, data for such estimation is still not available. Therefore, the choice was to have an initial estimate of the three coefficients in the proposed relationship based on a three-point estimation.

While any three points can be used, the particular evaluation that was selected follows the procedure described below:

1. Identification of extreme points. The choices for two of the points were the extremes. For a range of components for which equipment cost is to be estimated, the extreme points are such that the component with minimum weight (*Min_Weight*) and complexity equal to one is associated with the minimum equipment cost (*Min_Cost*), and the component with maximum weight (*Max_Weight*) and complexity level equal to three corresponds to the highest equipment cost (*Max_Cost*). This uses the weight and complexity information for the set of parts manufactured with the relevant technology. Equipment costs for the extreme parts is gathered either from published sources or directly from equipment suppliers.

2. Mid point estimation. An additional point is required to complete the estimation. The strategy was to choose a point that would define the relative importance of complexity and weight in establishing equipment cost. The mid point chosen corresponds to a simple part (complexity equal to one) with maximum weight defines the share of the maximum equipment cost that is

defined by the weight as opposed to complexity. If the equipment cost for this part is close to the maximum cost, then most of the cost is defined by weight; if its closer to the minimum cost, then complexity is the determining factor. To have this tradeoff explicit, equipment cost for this point is presented as a share of the difference between the values gathered for the extreme points defined before, instead of an absolute value. This share value is labeled as a weight *Factor*.

Given this methodology, the parameters *A*, *b* and *c* in equation (5–2) are then defined through the following equations:

(5–3) $Min\_Cost = A(Min\_Weight)^b (1)^c ; Max\_Cost = A(Max\_Weight)^b (3)^c$ for the extremes

(5–4) $Min\_Cost + (Max\_Cost - Min\_Cost) * Factor = A(Max\_Weight)^b (1)^c$ for the mid-point

Where *Factor* is the share of the cost difference explained by the complexity level. Solving these equations results in:

(5–5) $b = \log\left(\frac{Max\_Weight}{Min\_Weight}\right) \Big/ \log\left(1 + \left(\frac{Max\_Cost}{Min\_Cost} - 1\right) Factor\right)$

(5–6) $A = Min\_Cost / Min\_Weight^{b}$

(5–7) $c = (\log 3)^{-1} \log\left(Max\_Cost / A.Max\_Weight^{b}\right)$

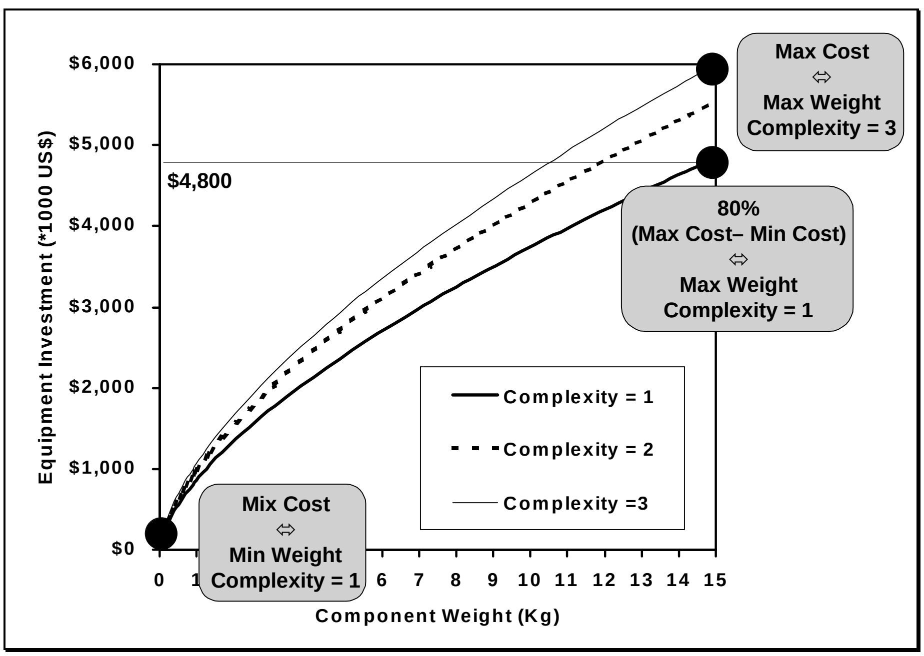
These estimation steps become clearer with an application to a particular technology. Stamping will be used as an example. Imagine that the objective is to model all the components in a car. With a complete analysis of the breakdown of the car at the individual part level, it would be possible to single out that 1000 of these that are stamped. For each of these, a level of complexity from 1 to 3 is assigned and weight is determined.

1. Extreme point identification. An observation of the parts reveals that weights range from a few grams to 15 kg. Eliminating the parts below 100g whose cost is mostly material driven, stamped parts will have a weight ranging from 0.1kg (*Min_Weight*) to 15kg (*Max_Weight*)

and complexities from 1 to 3. Literature on stamping and direct interviews with equipment suppliers establish that a line of tandem presses required to handle components weighting 0.1kg and with minimal complexity costs approximately US$200,000 (*Min_Cost*). The cost of a press line to stamp a 15kg part of high complexity was estimated to be US$6,000,000 (*Max_Cost*). These values establish the extreme points used in the estimation of (5–2).

2. <u>Mid point estimation</u>. To establish the mid point, it was assumed 80% of the cost difference is determined by weight (this is equivalent to having Factor = 80%), while only 20% is determined by part complexity. In other words, a part weighing 15kg with a complexity level of 1 requires a press line that costs approximately US$4.84 Million (80% of the way from $200,000 to $6M).

Figure 5–5: Three Point Estimation of Equipment Cost



With this information, equipment cost can be mapped to the component characteristics using equations (5–5) to (5–7), resulting in $A=865$, $b=0.64$ and $c=0.2$, for results in thousands of dollars. The evaluation for the example of this stamping technology is represented in Figure 5–5. With this evaluation method, a moderately complex stamped part (with complexity level equal to 2) weighing 8kg needs a press line that costs approximately US$3.76 million.

As explained in section 5.2.1, calculations for the base equipment cost are corrected to account for auxiliary equipment and installation costs, usually as a percentage of the equipment cost. This practice will be maintained here . The share of auxiliary equipment cost considered is 25%. For installation costs the value gathered from industry quotes is 15%. With these values, the 8kg stamping example would require an additional $940,000 in auxiliary equipment and $564,000 for installation.

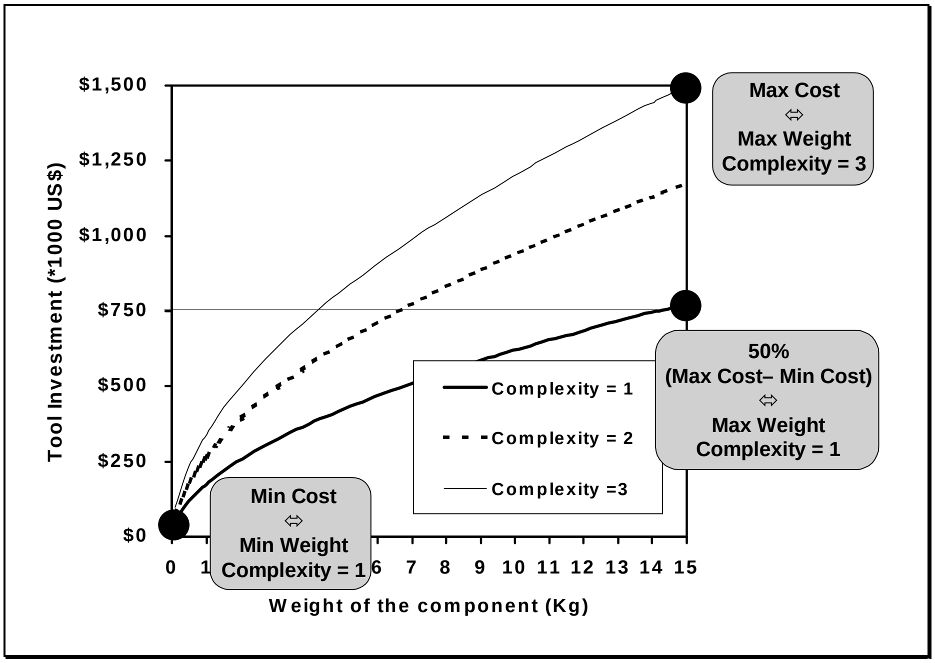
The steps to calculate the base equipment cost and the corrections associated auxiliary equipment and installation determine the equipment fixed costs represented in Figure 5–3. This process described in detail for the stamping equipment is then replicated for all other technologies considered in the analysis. The description of relevant cost ranges and parameter values for all other technologies is presented in Appendix 9.2.

Tooling Cost

Equipment cost is one of the key cost drivers affecting overall manufacturing cost. The other major fixed cost in a manufacturing activity is tooling costs. The process used to calculate tool cost is similar to what was described for equipment cost. Again a logarithmic relationship between component weight and tool cost of the type presented in equation (5–2) is assumed, using complexity as a cost modifier. This functional form is reasonable because the major driver for tool cost is its surface area (Busch, 1987; Boothroyd, Dewhurst et al., 1994) and weight is directly proportional to the volume. This argument is similar to the one used in the chemical industry to size cost as a log function of capacity (Humphreys and Wellman, 1996, chapter 1).

The difference is related to the effect of complexity on overall tool cost. Complex components require the tool to have particular characteristics that can substantially change its cost. In stamping, for example, a tool with moving parts to accomplish a particular component feature may cost as much as two times that of a component with similar size but with a simple shape (Han, 1994). A similar fact happens for casting or injection molding (Busch, 1987). Therefore, when considering equations (5–3) and (5–4) for estimating tool costs, the Factor value that determines the relative importance of complexity in the cost will be different, assigning greater relative importance for complexity.

Figure 5–6: Three Point Estimation of Tool Cost



Like before, calculating individual tool costs requires the steps described for the case of equipment costs: the range of component weights and complexities has to be registered, information from suppliers on the equivalent range of tool costs has to be collected, and new three point estimation is performed, with the new values and assumptions regarding the weight factor value. Given this information, the parameters *A*, *b* and *c* in formula (5–2) can be calculated from equations (5–5) to (5–7). The visual representation of these calculations for the example of stamping is presented in Figure 5–6, where the base value for the factor considered in the estimation is 50%, dividing equally the importance of weight and complexity level. Similar steps are taken for all other relevant technologies.

Other Fixed Cost

The remaining costs associated with a particular manufacturing technology can be calculated from equipment and tooling costs:

- *Building.* Consultation with industry and previous studies has placed building cost as 4% to 8% of equipment cost. The base value considered for the study is 6%.

- *Maintenance.* Equipment, tools and buildings need to be carefully maintained to assure an adequate operation in a manufacturing environment. This cost is normally considered to be a share of the value of the item under consideration. A 10% value was used.

- *Overhead*. The values assumed were 50% of overhead labor over the direct production labor cost (detailed below) and 25% equipment cost for fixed overheads.

5.3.1. Variable Costs

One of the major cost drivers in industrial processes is *material cost*. This cost includes not only the quantity of material that embodies the final component, but also the material that is scrapped, mostly as a result of trimming and rejects. The major aspect influencing the levels of scrap rate in a component is its complexity. Therefore, the approach was to link the level of complexity associated with each component to a given percentage of material that is scrapped (for each good unit produced). The values considered are 15%, 30% and 45% for levels of complexity of 1, 2 and 3 respectively. Total material cost involves the weight of each component summed with the respective share of scrap, both multiplied by unit material cost that was gathered from published sources. The unit costs for each material considered are presented in Appendix 9.2.

Another important variable cost is *labor cost*. This cost includes the workers that are needed to operate the equipment required in the relevant manufacturing process, as well as those that assemble individual parts and components into systems. The methods for calculating the number of workers needed for manufacturing and assembly are different.

A logarithmic relationship similar to (5–2) is also used to estimate manufacturing labor costs. The important difference is that the number of workers and not their cost is written as a function of component characteristics:

(5–8) $$Number\_of\_Workers = A(Weight)^b(Complexity)^c$$

To understand the difference in the approach it is important to note that the market for equipment is global, with the same suppliers quoting similar prices regardless of the location of the plant. This makes it possible to establish the unique relationship between equipment cost and part characteristics proposed in formula (5–2). On the contrary, labor market is local. Therefore, it is not reasonable to write labor cost as a function of part characteristics. But workers required for the relevant manufacturing activity are directly associated with processing equipment. In fact, information on equipment characteristics often includes ranges for the number of workers required to operate it depending on the characteristics of the component being manufactured. This leads to the modeling choice to have the number of workers as a function of component characteristics.

The solutions to equation (5–8) can also be given by (5–5), (5–6) and (5–7), provided that the necessary adjustments are done. This means that the values of maximum and minimum cost are now associated to the maximum and minimum number of workers, while part weight and complexity are the same as before. *Factor* values determining the relative importance of complexity and weight for labor utilization have also to be chosen for each technology. Manufacturing labor costs are then calculated multiplying the worker estimates by the unit wage of the region.

Table 5–2: Time Required for Joining Processes

Joining Process	Layed Fit Press Fit	Adhesive Snap Fits Spring Release Clips Clamp Stitching Rings	Heat Pins
Time	3 sec	5 sec	10 sec

Assembly labor cost is treated differently. Estimates are based on information regarding joining processes used to assemble individual components into larger systems. This information could be used to derive detailed assembly times for each group of components. The problem, like before, is that detailed estimation of assembly times for a large number of components is very time consuming. Therefore, the solution was to use average values on handling and insertion times associated with major assembly processes. The values, adapted from Boothroyd (1994) are presented in Table 5–2 and Table 5–3. Total labor assembly cost is calculated multiplying the time needed to assemble each component and system by the unit wage cost.

Table 5–3: Handling Time for Components

Weight	W < 10g	10g < W< 50g	50g < W < 5000g	W > 5000g
Handling time	8 sec	5 sec.	2 sec.	15 sec.

Energy consumption cost is estimated as a percentage of Material cost. Values gathered from detailed cost estimation placed the range of values for this share as 2% to 5% of material cost (own calculations based on Kang, 1998; Veloso, Henry et al., 2000). *Development costs* are estimated as a share of total sales using industry averages gathered from published information.

5.3.2. Valuing the Process Use of Resources

The previous sections characterized the approach proposed by the SCM methodology to evaluate resources needed in the relevant manufacturing activity, detailing methods to assess drivers for *Fixed and Variable Costs*. Nevertheless, as noted in section 5.2.3, unit cost estimation also requires an evaluation of the *Process Use Time (PUT)* of these resources and the cost associated with this usage.

The calculations depend both on plant operating conditions that lead to yearly plant available time and line down time estimates, as well as on the component *Cycle Time*, that has to be estimated. In detailed technical cost modeling, *Cycle Time* is calculated from the component physical characteristics through engineering and statistical principles. As explained in section 5.2.3, the cycle time for the example of injection molding is determined by the filling, packing and cooling stages of the process, all of which can be estimated using flow equations together with data on mould dimensions and material characteristics. As mentioned on several occasions, the objective in this study is to develop methods of estimating these parameters that require less detailed information. Therefore, an alternative simpler method is proposed.

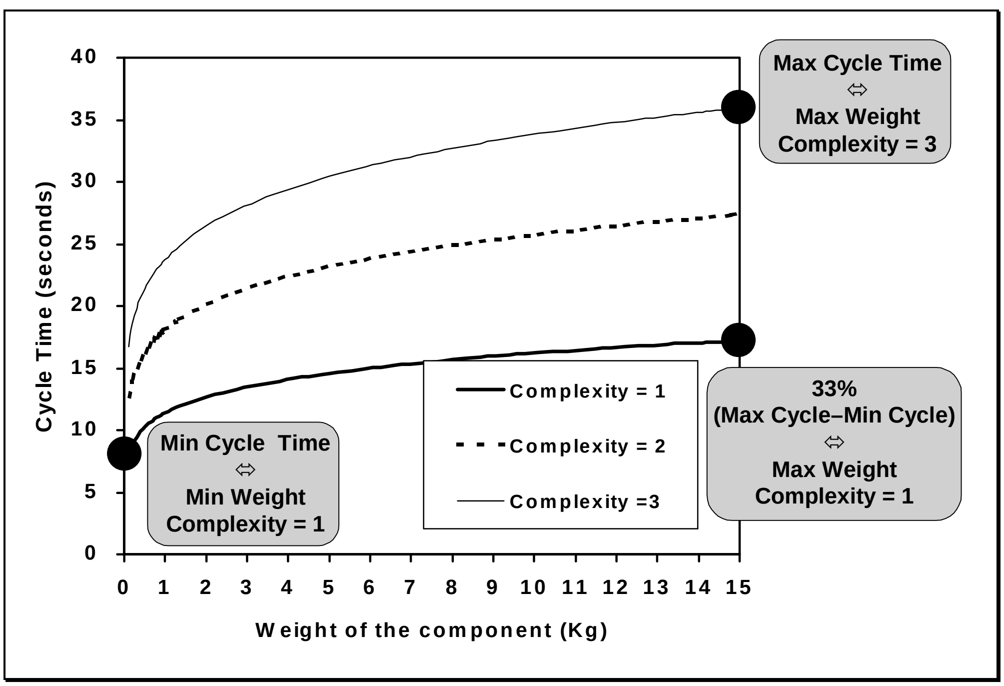
Like before, the objective is to establish a simple functional relationship between the four component characteristics described in the beginning of section 5.3 and the relevant variables, in this case cycle time. Interestingly, previous research shows that the functional form that better describes the type of relationship between weight, complexity and cycle time for a given process also takes a generic log form (Boothroyd, Dewhurst et al., 1994, chapters 7,8,10; Kang, 1998;

calculations based on Veloso, Henry et al., 2000). Given this relationship, the new equation replicates (5–2), substituting cost by cycle time:

(5–9) $$Cycle\_Time = A.(Weight)^{b}(Complexity)^{c}$$

The values for parameters *A*, *b* and *c* are estimated by gathering information from suppliers on ranges of cycle times for different levels of complexity and weights of the components being processed and applying formulas (5–5) to (5–7), where cost is replaced by cycle time in all instances. The characteristics of the intermediate point used in the calculation, which determines the relative importance of complexity and weight and has been labeled as *factor*, is also different from before. In fact, the level of complexity and not weight is usually the critical aspect determining cycle time. Figure 5–7 presents the results of the estimation process for the same example of stamping, with a base value for *factor* chosen to be 33%. Appendix 9.2 presents the values estimated for the remainder technologies.

Figure 5–7: Cycle Time Estimation for Stamping Example



The cycle time estimate presented above together with information on manufacturing practices associated to line down and capacity utilization in a particular region enables a calculation of the process use time. As explained in equation (5–1), the process use of resources establishes the link that enables the calculation of the unit fixed costs associated with the manufacturing activities.

5.3.3. Logistics Costs

While most of the cost is driven by the fixed and variable components, logistics may also play an important role, in particular when considering supply over very large distances. SCM evaluates logistics cost at two levels. For individual components, an overall baseline logistics cost is calculated based on published information for the industry as a percentage of the product value. At the subassembly level, SCM evaluates transportation for the regional shipping scenario under analysis. First packaging volume and weight for each subassembly is estimated. Second, the packaging volume is used to calculate all categories contributing to the overall logistics costs.

Packaging volume is the minimum volume needed for the component when being safely transported. Because information on this measure does not often exist, it is estimated from the information available on each component through:

(5–10) $$Pack\_Volume = DF * Weight / Density$$

As noted before, weight and material data are usually easy to gather for any component. Through the division between its weight and density, it is possible to have a base estimate of the component volume if it would be a solid cube. The problem is that components often have odd shapes that make the packaging volume much greater than this simple calculation. The solution was to assign each component a *Density Factor (DF)* that establishes the share of packaging volume that corresponds to its weight. This information is then used to calculate how many components can fit in standardized containers that are transported in trucks or boats.

Logistics costs include a number of issues. Those considered for the present study include:

- Packaging cost. The cost of placing components in containers and the cost of the container.
- Truck Cost. This includes procurement, loading and unloading as well as cost per mile.

- Shipping Cost. The whole cost of sending a container on a boat between ports, including loading and unloading.

- Inventory Cost. The cost associated with the idle components during the transportation process.

All these costs, except the last, are a function of container or truck size and are gathered from published information on trucking and shipping transportation sizes, time and cost. Inventory costs are considered as charge based on the value of the components held in transportation and the interest rate. For simplicity reasons, the study only considers a direct transportation scenario. This would be equivalent to having all components and subassemblies delivered to a warehouse that organizes the Just-In-Time delivery to the OEM.

5.4. Summary

This chapter describes a methodology to evaluate the cost of complex systems with a large number of individual components and subsystems. This methodology, called Systems Cost Modeling (SCM) is based on the Technical Cost Modeling technique that has been widely used to assess manufacturing cost of individual or small groups of components. The problem with TCM is that when the number of components increases, the amount of information to be collected and processed rapidly becomes unmanageable.

The SCM approach involves critical simplifications from traditional technical cost modeling techniques. It proposes simple metrics and rules that enable it to be used to build bottom-up cost structures for large number of components. Four simple characteristics associated with each component (weight, process, complexity and material) are inputs to parametric estimates of fixed and variable costs, as well as process use time of relevant resources. These estimates are then used to calculate individual component that are then aggregated to the relevant subsystems and system level.

Unlike most existing cost estimation methods, that aim at obtaining an accurate evaluation of the manufacturing cost of an individual component level, SCM focuses on providing reliable calculations of the overall system cost and the influence of key parameters (such as volume and factor input costs), on the cost behavior. This precisely the objective associated to the domestic content decision question that the thesis addresses.

Chapter 6.
Modeling Cost in the Automotive Supply Chain

The economic models described in chapters 3 and 4 and the cost model presented in chapter 5 can be applied to a number of industries with complex supply chains, ranging from capital goods to electronics or automotives. Nevertheless, it is important to show whether the issues become relevant in a particular business and policy environment. The choice was to explore the models in the context of the automotive industry. This sector has traditionally been one where performance standards such as domestic content requirements have been present and are still very active. Moreover the influx of investment in the coming decade towards the developing world is expected to grow significantly, making this issue more important for governments and firms.

This chapter has two sections. First, it assesses the global trends in the industry and the purchasing policies in particular. Second it describes the car manufacturing costs in both a developed and developing region, exploring the tradeoffs and the potential sourcing decisions of the OEM. These calculations are based on the SCM methodology described in Chapter 5.

6.1. The Automotive Supply Chain

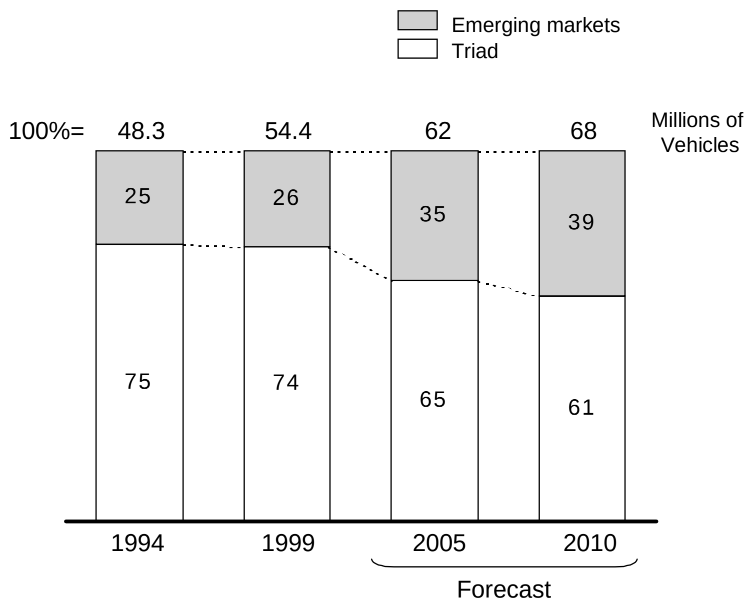
6.1.1. Global Trends in the Auto Industry

One of the major competitive factors is the pattern of demand for new cars. In any of the Triad regions (Western Europe, Japan and the US) original equipment manufacturers (OEMs) have been facing a mature market for the past 10 years, with stagnant demand, product proliferation and stiff price competition. The demand for new cars has been growing on average less than 1% per year during the past ten years and this trend is forecasted to continue.

A flat demand is aggravated by increased competition in the product market. During the past two decades, most OEMs have invested heavily in plants outside their home market to better reach local consumers. As a result, market shares of incumbent players have become thinner. In the

US, domestic automakers have lost more than 20% market share to Japanese and Korean automakers in the past two decades. Europe has experienced a similar trend, although ameliorated by the stricter regulations on the participation of Japanese OEMs that were in place until recently.

Figure 6–1: New Vehicle Sales in Triad Versus the Rest of the World



Source: Automotive News, McKinsey

Sales growth is now coming from developing regions, with South America, India, China and Eastern Europe leading this trend (see Figure 6–1). Sales of automotive vehicles outside the Triad surpassed 14 million vehicles in 1999, representing around 26% of total new sales. Although this number is only slightly up from the 25% of sales just half a decade ago, mostly due to the recent economic crisis in the developing world, it could go up to 40% in less than ten years. The leading growth region has been South America. Until 1998, when a severe financial crisis hit Brazil and Argentina, sales in that area of the world were growing an average of 10% per year, led by an astounding 15% growth in Brazil (Automotive News). As the economic growth in these regions picks up, the strong pattern of sales growth is expected to continue.

In India and China the evolution will be slower because their levels of economic development are far behind those of Brazil. Nevertheless, the size of their population is still making them important markets. The rest of Asia is also recovering faster than expected. Large sales growth forecasted for the ASEAN countries and Korea before the 1997 financial meltdown turned out to be severe market contractions. Nevertheless, some of these nations recovered rapidly and are now back to levels of economic growth only slightly below those levels seen before the crisis. As a result, analysts are reviewing demand estimates monthly, with all the corrections upward. Another booming area is Eastern Europe. Deprived of car imports during the era of the Soviet bloc, these nations are using their recent improvements in living standards to buy more cars. Sales in Eastern Europe (Poland, Hungary, The Czech Republic, Slovakia and Slovenia) reached one million vehicles, in 1999, double the figure of 1994 (Automotive News).

The evolution of consumer demands, the need to have a global presence and the fast pace of technological change place important requirements on the participants in the automotive industry. OEMs have been the players directly affected by these trends. Nevertheless, the strategies they have pursued as a response to these challenges are having far-reaching effects on the whole supply chain. The industry is undergoing a period that could be characterized by four major trends: Globalization, Standardization, Disaggregation and Consolidation.

The first clear characteristic of today's auto industry is Globalization. Through the end of the eighties, despite some overseas presence of OEMs, competition was mostly within regional brands. This picture changed completely during the nineties. A growth of transplants during the beginning of the decade led to the presence of all competitors in virtually every region (Sturgeon and Florida, 1999). This has become particularly important in emerging markets, where all OEMs are fiercely competing for market share as the market grows. As a result, automakers are now planning operations on a global scale. This means having similar models launched at the same time in different locations with similar standards.

An intense degree of similarity in the vehicles manufactured across regions has led automakers to try to replicate successful existing supply chain structures in new locations. This often means inviting, or sometimes demanding, their suppliers to be present in regions where OEMs are investing. Suppliers have often seen the OEM globalization trend as an excellent opportunity to improve their market presence and expand sales volume. As a result, they have followed the OEMs by expanding into new regions. Nevertheless, suppliers are still far behind any of the

OEMs as true global players. Most of these firms have either total sales or total installed capacity of less than 50% outside their home markets (Global Interest Group, 1998).

The second critical issue that affects the evolution of the auto industry is standardization. Declining sales and continuous restyling of models prevent automakers and suppliers alike from reaching economies of scale in manufacturing, with important adverse impacts on cost. The solution has been to share components and systems across models and OEMs. This involves the development of common platforms, the deployment of common processes and the use of common systems (Lung, Chanaron et al., 1999).

The idea of 'common platforms' that homogenize basic structures of the car (like the Golf/A3 VW platform), while allowing adaptations of exterior body is now a prevailing concept among OEMs. Another important aspect of standardization is the construction of plants able to produce multiple and varied models, thereby being able to respond to sudden shifts in consumer demands, or to easily fit in a global capacity management strategy. A similar logic is applied to components. Suppliers are trying to market systems such as the ABS or the seat frame across car models and even different OEMs. This possibility could yield important returns, not only due to scale efficiency, but also because the costs associated with the development of challenging innovative solutions can be split among several automakers and a much larger number of manufactured units.

The third aspect that characterizes the industry is value chain disaggregation (Clark and Veloso, 2000). OEMs are focusing their attention on designing and marketing vehicles, as well as servicing the customer. They wish to reduce the asset intensity of their operations to boost shareholder return on assets, while improving quality and reducing manufacturing cost. Their strategy has been to transfer increased responsibilities to existing suppliers and generate opportunities for the emergence of suppliers with new roles. Part of this transfer of responsibility involves manufacturing tasks that were previously done by the assembler. The stamping of doors and fenders are a good example of an activity the OEM has traditionally done, but that is increasingly being considered for outsourcing. Another dimension of the disaggregation trend is the divestiture of assemblers from supplier units, which have grown to be full-fledged businesses of their own. While Visteon and Delphi are the most prominent examples, there are also a myriad of other smaller players that were spun off from OEMs.

The other industry characteristic, consolidation is directly coupled with the concept of value chain disaggregation. The need to be present all over the world, the increasing regulatory and consumer requirements and the need to continuously tackle new technologies, all of this at low cost, created a tremendous financial pressure on the automakers. As a result, a vast wave of consolidation is happening among automotive assemblers. It is estimated that, within the next 5 years, less than 10 independent automakers may survive. As OEMs integrate and shed their involvement in manufacturing, they also concentrate their efforts on working with a smaller number of players. The new direct suppliers are large global firms, which are either specialized in complex systems, or integrators of several simpler subsystems. They are expected to have a substantial responsibility in the design and engineering of these systems and to coordinate the supply chain necessary for their manufacturing and assembly.

Traditional suppliers were not equipped to respond to this new set of challenges. They were mostly regional, focusing on particular components, and had limited resources to withstand financial outlays on product development for up to 3 years before receiving returns on investment. As a result, during the past few years, the supplier industry has also been undergoing increasing consolidation. The number of US suppliers with sales between 1 and 5 billion dollars went from 28 firms in 1992 to 47 companies in 1998. Likewise companies with sales higher than 5 billion dollars increased from 5 to 13 in the same time frame (own calculations from Wards, several years). The value of merger and acquisition deals peaked at an astounding US$30bn in 1999, representing close to 7% of the total sales of the autoparts industry.

One of most interesting aspects associated with the recent trends in the auto supply chain is the fact that industry expansion and innovation is happening in emerging regions. OEMs and suppliers are expanding rapidly in areas like South America, Eastern Europe and Asia, where they are also trying some of the most innovative solutions in manufacturing and supply chain organization. For example, the most innovative modular supply approaches, where suppliers assemble entire modules directly in the OEM plant are happening in Brazil (Lung, Salerno et al., 1999). This means that, contrary to what has been observed in the past, multinational automotive companies are trying new solutions outside their core markets. It has also meant that local, often smaller firms have been active players in new areas of the auto supply chain. A good example of this situation is the Brazilian steel maker Usiminas. In 1993, Usiminas agreed with Fiat to take over most of its stamping operations. This agreement is part of a recent OEM trend to increase the level of outsourcing at the stamping level, an area traditionally done in-house by the OEM. The interesting aspect is precisely the fact that the early adopter was a local firm rather than a multinational.

6.1.2. Understanding OEM Purchasing Policies and Decisions

The significant changes that the auto industry is going through influence the purchasing policies of OEMs and their relationship with the suppliers. The critical issues are the OEM drive towards increasing supplier responsibility and sourcing practices that are associated with this tendency. The increase in supplier responsibilities is reaching impressive levels. Renault, for example, claims that 80% of vehicle value added comes from suppliers (EIU, 1999). Given the increasing complexity of the systems being subcontracted by the assemblers, there is a clear tendency to have a smaller number of large suppliers with important responsibilities in the vehicle. For example, the objective is for Renault to have only 350-400 suppliers by the year 2000 (Veloso, Henry et al., 2000, chapter 3).

Although there is a general trend towards increasing supplier responsibility and associated reduction in the number of direct suppliers, assemblers are pursuing different strategies (see Veloso, Henry et al., 2000 for a comprehensive discussion of these issues). Companies like Renault and Volkswagen have a more conservative policy strategy in what concerns supplier reduction, while Ford is being more aggressive. The strategy of VW and Renault could be described as the 2+1 suppliers. For each subassembly, the assembler forms a strategic partnership with key suppliers for each region where it is present. Two suppliers are considered privileged partners, with involvement since the early stages of the development process. A third one will follow closely, being given less responsibility, but enough for it to be ready to replace any of the existing suppliers.

Because the same cars are being sold in several regions of the globe, this partnership strategy is generating a tendency to have also the same suppliers around the world for a given part in a particular car. Since assemblers demand that car parts have the same characteristics in any given plant, suppliers often prefer to invest themselves near new the assembly units rather than transferring process and product knowledge to a local supplier if they don't follow into new regions.

The overall Ford-Europe supplier strategy is more radical. The tendency is towards increased use of entire modules rather than individual components or even subsystems. The ultimate (theoretical) goal is to have a single source for modules like the entire interior. Most current first tier suppliers are likely to become second or even third tier and this policy is inevitably going to lead to a drastic reduction in Ford's direct supplier count, but might also lead to an overall reduction in the size of the entire supply chain as consolidation occurs at lower tier levels. As admitted by Ford, their supply strategy is not the industry standard.

Given what was described above, choosing partners that are able to work with the assemblers in the development and manufacturing of the systems becomes crucial. Major criteria for the choice of suppliers include the standard cost and quality competitiveness criteria, and for parts with substantial logistics costs, location is also an issue. It is also increasingly dependent on R&D capacity of the first tier suppliers and closeness to the OEM major development centers. It is clear is that nationality is definitely not a relevant criterion. Another important aspect is that these first tier suppliers are expected to manage their own supply chain, deciding where they sourcing the individual components that enter the larger subassemblies that the OEM is buying from them.

Given the degree of requirements and the global presence associated with being a supplier to these assemblers, how do new firms get accepted as suppliers to the automotive industry? The typical system is presented in Figure 6–2 (that shows the example of VW) to illustrate how the process works. The idea is that virtually any supplier with the necessary cost, quality and development capabilities can be admitted in the supply chain. The admission process is as follows (Veloso, Henry et al., 2000, Chapter 3):

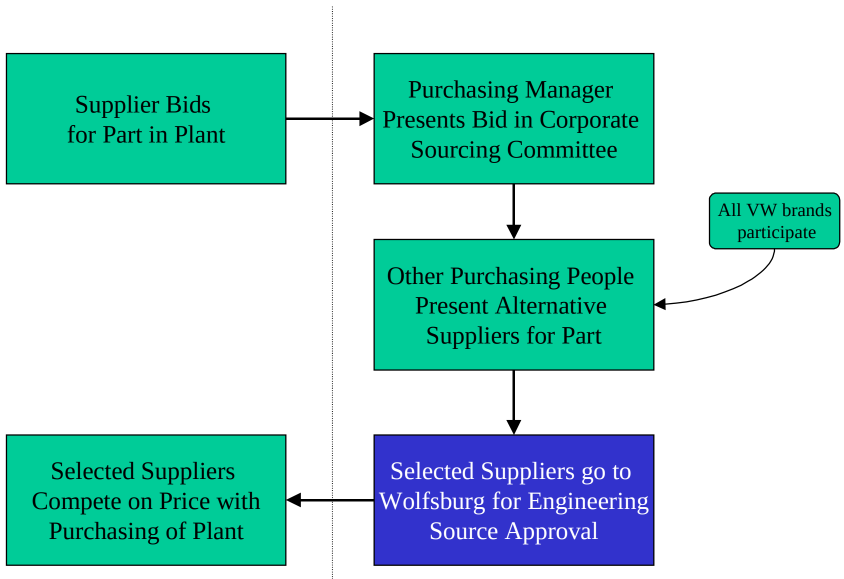
- Whenever there is new design or redesign of a car, a supplier presents a local bid for supplying it. (For most assemblers, QS9000 certification is demanded up-front);

- This bid is presented in Corporate Sourcing Committee, where other purchasing managers suggest alternative suppliers for the component. These suppliers are invited to present bids, and at number of them are selected for Engineering Approval.

- For most components, the OEM major engineering center has to approve both component specifications and overall company engineering capabilities.

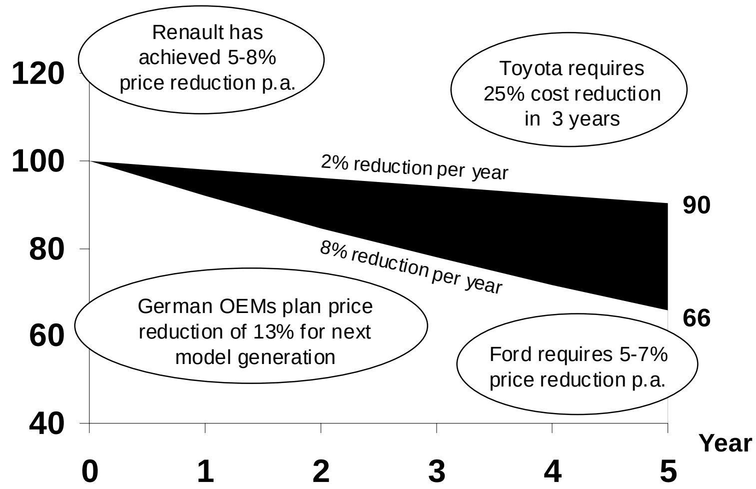
- Suppliers with engineering approval make final price bargaining at plant site.

Figure 6–2: Typical Supplier Approval Process for VW



Variation in the process described above among assemblers is mostly related to the steps required for engineering approval. While VW has a more centralized engineering process, in GM, for example, technical review are most likely to be done more on a regional basis, joining technical people from the plant and a regional development center. Ford is once again more at an extreme. Although they have had a full service supply accreditation program (the Q101/Q1), they believe that this is likely to diminish in importance with Ford's policy of limited first tier suppliers. The expectation is that their first tier suppliers will develop their certification program for their own suppliers in which Ford will have a limited role.

Figure 6–3: Price reductions demanded from Assemblers.



Source: Mckinsey, The Economist Intelligence Unit, Wards

More responsibility has often come with strings attached. In first place, all assemblers have very aggressive price reduction objectives towards their suppliers (see Figure 6–3); second, assemblers require suppliers of modules to have quality performance above their own, and with continuous improvement. This has meant that suppliers may need to improve rejects, scrap and rework by as much as 5-7% a year.

Given these characteristics of the auto industry, the tendency is to have a smaller number of suppliers delivering a limited number of subassemblies that make up the whole car. These suppliers compete fiercely around the globe for OEM contracts. As the market in developing areas expands, their role in the global auto supply chain also gains a new dimension. Suppliers and OEMs have to carefully decide what components should be supplied from where, carefully planning the location of their plants.

Literature in operations has analyzed these type of decisions in detail (see Arntzen, Brown et al., 1995; Cohen and Mallik, 1997; Vidal and Goetschalckx, 1997 for recent reviews on the subject; Pontrandolfo and Okogbaa, 1999; Schmidt and Wilhelm, 2000). The problem is that the research in this area treats local conditions as inputs (e.g. wages, transportation costs, taxes) or constraints that the company faces (e.g. local content requirements, mandatory exports) when making decisions. The focus is rather on the decision methods to choose optimal manufacturing configurations given a set of plant characteristics. Moreover, research work in this area has not considered the interaction of firm decisions with the social impact on host economies and, in particular, it has not addressed how may government policy effect firm decisions at a strategic level. This aspect has been particularly noted in a recent survey of the literature on global operations, which also referred the shortage of analysis focusing on the realities of developing nations (Prasad and Sunil, 2000).

The SCM proposed in Chapter 5 and its integration with the models of domestic content decisions and policies presented in chapters 3 and 4 aims at bridging research on global supply chain decisions with economic analysis of the implications and drivers of government policies in developing nations. This is done in the context of an industrial sector that is of growing importance for these nations. The remainder of this chapter presents an application of SCM to the automotive supply chain, explaining the characteristics of its cost structure and the influence of plant location.

6.2. Modeling Automotive Supply Chain Costs

As described in Section 6.1, manufacturing an automobile is an extremely complex and has strong interdependencies with the regional environment. This is precisely the reason why there are important interactions between investing OEMs and a multitude of stakeholders, that include local governments as well as local and global suppliers. These outcomes eventually shape the supply chain configuration, in particular the origin of the purchased parts and their cost. The most critical variable shaping the decisions is the cost of the operations, both assembly and manufacturing. This is the object of this section.

With more than 3000 individual components and as many as 300 sub-assemblies that perform integrated functions in the vehicle, the car is a clear example of a product for which it becomes extremely complex to have detailed cost estimations for all the components. In the business world, automotive companies and their suppliers have large teams of engineers and business people in charge of costing each sub-assembly during the design and purchasing stages. Despite this effort, difficult to replicate in the academic environment, information regarding individual components that compose each sub-assembly is often dispersed along the supply chain, making it difficult to have accurate estimates from the manufacturers. To be able to evaluate the sourcing cost structure of a car, the system cost modeling methodology proposed in Chapter 5 is used. As explained, SCM enables the estimation of manufacturing and logistics costs of systems with large number of components. Calculations for each component rely on simple metrics that can be gathered directly from manufactures, estimated by direct observation, or judged from reasonable criteria.

6.2.1. Unbundling the Car Structure

The cost estimation is based on a comprehensive list of components for a mid-size car of a major manufacturer[46]. An extended list, presented in Appendix 9.2, includes the most important of the 3090 individual components, excluding screws, bolts, pins and other small parts. These individual components are the basis of the system cost modeling estimation. For each of them, the weight, material, complexity and process information are gathered or attributed. For some, more than one process is considered[47]. For example the alternator housing, which is made out of aluminum, needs first to be die cast and then machined.

Although SCM calculations are performed at the level of individual components, this is not the relevant level of analysis. As noted before, the objective of the SCM is to enable the evaluation of cost at the system or subsystem level. Therefore, these levels have to be established for the object of our evaluations, the car. For this study, individual components are aggregated at two levels:

- <u>Sourcing</u>. This level clusters components according to sub-assemblies that reflect typical sourcing decisions for automakers. OEMs have to decide, for example, who will supply the oil pump, the fuel injection system, or the emergency brake, but not the wires, brackets, cases and other parts that make these subassemblies. This division yields 274 sub-assemblies, each with an average of 11 individual components.

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[46] The brand and model are not revealed for confidentiality reasons

[47] SCM considers up to three manufacturing processes per component

- Group. Sub-assemblies are gathered according to major groups. Following a typical division found among OEMs, eight groups are considered. They enable a good understanding of the relative importance of major areas of the car.

Table 6–1: Components and Sub-Assemblies by Group

Group	Number of Sub-Assemblies	Number of Components
Powertrain	43	442
Chassis	54	644
HVAC*	16	242
Interior	87	1017
Body	10	84
Exterior	41	396
Info & Controls	20	217
Electrical Power	3	48
TOTAL	274	3090

*Heating Ventilation and Air Conditioning

Table 6–1 describes how the total number of individual components is distributed over the two levels that are considered for this study. The interior is the part of the car that has more individual components as well as subassemblies, followed by the chassis and the powertrain. An important caveat is that the component breakdown presented in the table and the associated SCM does not consider body-in-white (BIW) at the level of individual components. A detailed evaluation of this subassembly would add about 65 to 70 more individual components to the component count. The reason for excluding BIW manufacturing from the analysis is the fact that these operations are usually done by the OEM and not subcontracted. Therefore, they are not affected by the local content policies.

There are two additional aspects related to the analysis of the automotive cost structure that are important to note. The first is that very simple and small components (less than 100g of weight) were not modeled through the regular SCM approach described in the previous chapter. Because of their simplicity a rule of material plus was considered (see section 5.1.1.), with other costs representing up to 30% of material cost. The second aspect is that the cost of electronic components was not modeled but rather gathered from suppliers and published sources. The manufacturing techniques used in electronics and the relative importance of design and software vs. manufacturing is not easily captured through the modeling techniques that have been proposed.

6.2.2. The Cost of the Auto Supply Chain

To illustrate the application of the SCM methodology to the car, general results at the group level will be discussed and sensitivity analysis to some of the critical input parameters used will be displayed. Examples at the subsystem level are also reported to show the benchmarking techniques used to calibrate the model.

Table 6–2: Assumptions Used in System Cost Model Estimations

	Item	Value
1.	Annual Production Volume	200,000
2.	Years of production	5
3.	Life of Equipment	10
4.	Interest Rate	12%
5.	Wage ($/hour including benefits)	$20
6.	Days per Year	240
7.	Number of Shifts	2
8.	Line Available Time	87.5%
9.	Free capacity utilization	100%
10.	Development Cost (% Sales)	4.0%
11.	Component Logistics Cost (% Sales)	4.0%
12.	Subassembly Supply Distance (Km)	2,000
13.	Subassembly Transportation Time (days)	2

The calculation of the manufacturing and logistics costs associated with the components and systems in the car rely on a set of baseline assumptions, described in Table 6–2. Production volume and number of years in production are instrumental in defining the type of vehicle and its useful life. These replicate what is typically found for high volume vehicles in Europe or the US. The equipment life of 10 years correspond to what equipment manufactures and parts suppliers usually report on average, although these can vary with process.

For the remaining set of variables that range from the interest rate to the average transportation time, values based on operating conditions found in the auto supply sector in a developed region, for example in a country like France or the Benelux area are used. These values reflect direct information gathered from interviews with firms, or values in published sources. Most of the base information was obtained from a recent project by Veloso et al. (2000) to assess the competitiveness of the Portuguese autoparts industry.

Interest rate, the fourth variable in Table 6–2 reflects the cost of capital that suppliers in the region have to pay. The value used in the calculations, which was given by firms interviewed, was 12%. Wages of US$20 per hour are average values practiced in the autoparts sector in the region and can be gathered from industrial statistics.

Line operating conditions are defined by variables 6 to 9. The number of days of operation per year is mostly established by labor or industry contracts. A value of 240 days is usually found in the European auto industry. It assumes no work on weekends and two weeks of line down for personnel holidays. Two shifts correspond to having 16 hours of operation per day. The number of days of operation in one year and the number of hours of work per day establish the baseline number of operating hours of the manufacturing processes for a year. Out of these, the line is not operating all of the time due to tasks such as maintenance and line problems. The value of 87.5% corresponds to having 2 hours of line downtime, both for planned activities and unplanned breakdowns, during the 16 hours of daily operation. Free capacity utilization indicates if capacity that is not required to manufacture the particular component considered is used or idle. The baseline assumption of is that all free capacity is used.

Line available time and free capacity utilization have an important impact on component cost. The first defines how efficiently the plant able to run its operation. Poor shop-floor organization often leads to rejects, rework or longer time for equipment adjustment. This reduces the available time for production, increasing the unit cost for individual parts. Free capacity utilization is a measure of the ability of firms to have multiple contracts that keep their equipment busy. Idle capacity means that either because of poor market conditions, or due to the specificity of the equipment, the firm is not able to put its equipment to alternative uses. These two variables are instrumental in characterizing some of the differences between a developed and an underdeveloped market.

Studies by the Economist Intelligence Unit (EIU, 1999) have reported the share of sales committed for research and development to be between 2% and 10% for large global companies in the European auto industry. Veloso et al. (2000) have shown that in smaller firms, further up in the value chain, this value is more likely to be between 1% and 4%. A base figure of 4% was considered in the model[48].

Logistics costs have two sections. For individual parts, 4% of their total manufacturing cost was used in the calculations. This value is consistent with the study mentioned in the previous paragraph, as well as other evaluations of logistics costs in the European components industry (see Inro, 1998). Concerning logistics of the delivery of subassemblies, these are considered to reach the assembler from locations throughout Europe, resulting in the average of two days and 2000 km of circulation before they reach their final destination[49]. The density factors (DF) considered were 10, 20 and 40, that correspond to have the real mass of the component taking respectively, 10%, 5%, and 2.5% of the total volume of the package.

The values reported directly in Table 6–2 are part of the baseline assumptions. There are other values used in the calculations that are not included in this discussion because they were less important for the overall understanding of the estimation. Two examples are the list of material costs, which were gathered from industry statistics, and the ranges of weights for the car components associated to each process used in the estimation. Nevertheless, all relevant inputs used in the calculations are presented in the Appendices.

Given this set of assumptions, the SCM methodology is used to estimate the automotive supply chain costs for each of the 3090 individual components and the 274 subassemblies. Table 6–3

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[48] This value was used across the board to all components It can be further refined to account for the various levels of the supply chain or for different components

[49] There may be an additional logistics cost of setting up the JIT supply that are not considered. It is assumed that, on an industry level, this does not influence the decision of which components to source. Moreover, since this is factory specific, it can be taken as being part of the OEM cost not calculated through SCM.

provides five examples of sub-assembly costs generated through SCM for which it was possible to find quotes provided by an OEM for equivalent components in similar cars (although not exactly the same car). Estimates fall within a 20% difference in cost from the OEM quotes. For the majority of the subassemblies for which it was possible to find an external quote, the difference between the estimate and the benchmark is within the 30% range, although there are outliers where the difference is larger.

Table 6–3: Examples of Sub-Assembly Cost - SCM Estimate and Data Provided by OEM

Group	SCM Estimate	OEM Quote*	Difference
Front Left Seat	$79	$85	8%
Steering Wheel	$10	$11	10%
Front Caliper Left	$28	$24	-14%
Starter	$30	$35	17%
Steering Column	$60	$48	-20%

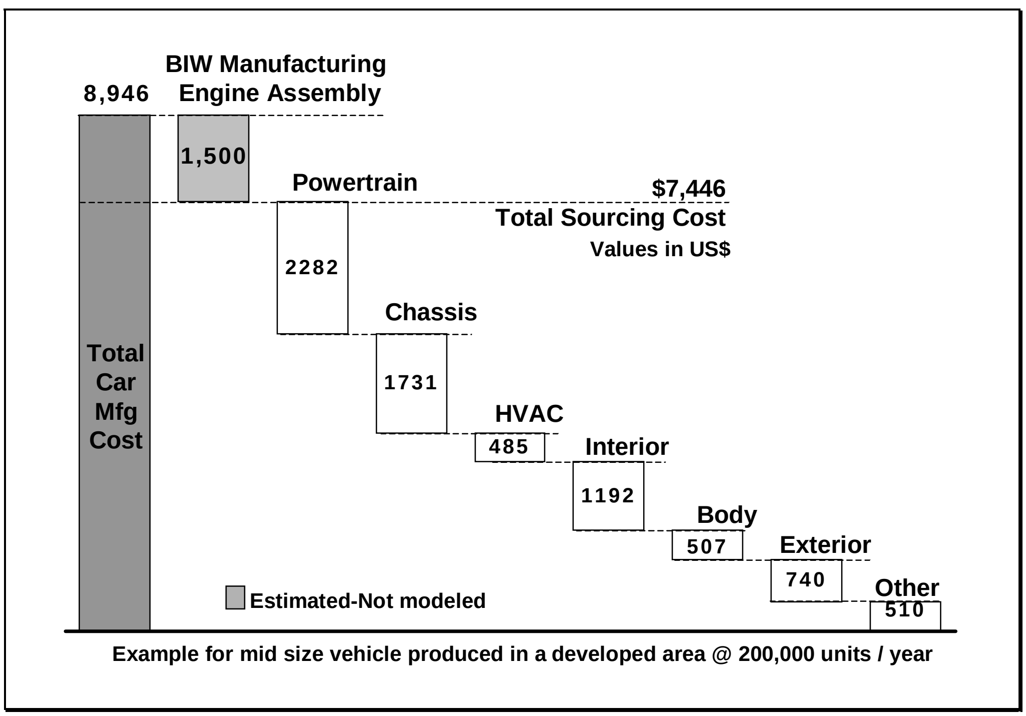
*quote is for similar component, but not exactly the same one

To ensure that cost comparisons are sensible and conclusions can be drawn from the analysis, the cost estimation process must be sufficiently accurate and no systematic errors in estimation must occur. The range of differences at the sub-assembly level between SCM estimates and external quotes provides a good indication of the validity of the modeling method. In fact, it is important to reaffirm that a close fit between individual sourcing prices and SCM estimates is not expected, or even an objective that should be pursued. The actual price that an OEM pays for a particular subassembly depends on a large number of aspects, that range from the particular location of the plant and the supplier of the component, the exact volume of production and whether there are wider purchasing agreements that go beyond the individual sub-assembly.

A potential problem, given the simplifications of the SCM estimation process, would be an understimation of cost. Although benchmark errors in estimation included both values where the external quote is above and below the value estimated though SCM, one does observe a slight tendency to have cost estimations below outside values. Nevertheless, this effect did not seem to be very discernible. Moreover, in case this systematic bias does exist, it would be included in all the contexts where costs are estimated and would not favor one of them in particular when comparisons are required.

The overall results by major area of the car are presented in Figure 6–4. The powertrain is the most expensive system of a vehicle, followed by the chassis and the interior. The exterior, HVAC system (Heating Ventilation and Air Conditioning) and body parts make up the second class of system sourcing cost. The figure also presents an estimate of the engine and body assembly work to show the relative importance of OEM manufacturing responsibility against purchased parts. If all the components of the car would be subcontracted, the share of manufacturing cost that is directly attributed to the OEM is less than 20%. These values also follow closely the cost estimates that automakers are able to gather from accounting information for similar vehicles, endorsing the validity of the overall cost estimation process (see Lane, 2000 for public data available on a slightly different aggregation of the major car cost areas).

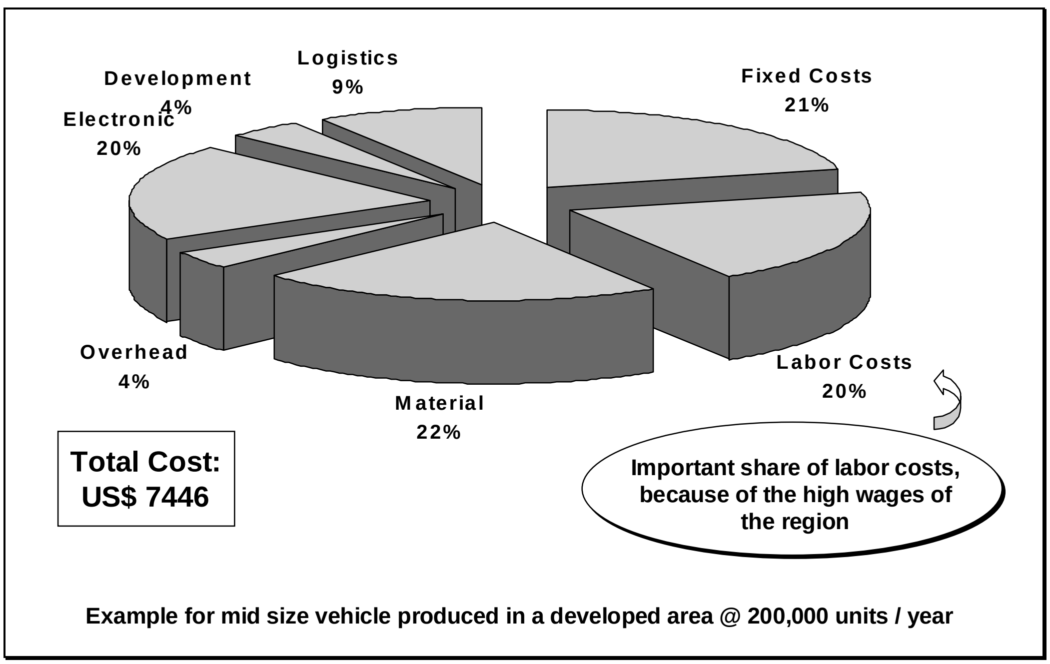
Figure 6–4: Car Manufacturing Cost



Given that SCM analyzes each cost driver and adds them up, it is important to consider how the overall cost is shared among these drivers. Figure 6–5 presents the sum of all costs across the automotive component supply chain for each of the included categories. Since SCM only takes electronics as a purchased component, this includes all the stages of production, from raw material up to the final subassembly that is delivered to the OEM.

Material cost is the major cost driver of today's vehicle, with 22% of total. Fixed costs and labor costs trail closely at 21% and 20% respectively. As important as these is the share of the cost that is associated with purchased electronics. This corresponds to more than $1400, a value close to the reported average value for today's vehicle (Wards, 1999). Logistics, which also include inventory, represent 9% of the total cost, while overhead labor stands at 4%. The value for development costs is part of the assumptions that were considered in the analysis.

Figure 6–5: Major Cost Drivers of the Car Supply Chain

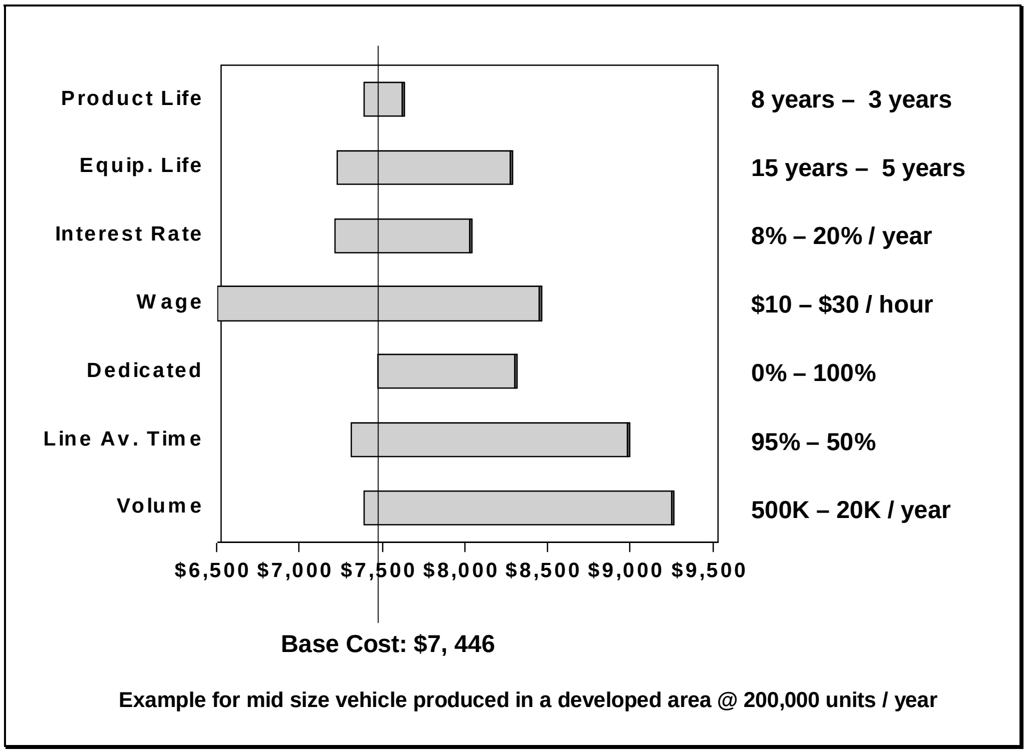


Among the results, it is important to note that labor costs have an importance that could be surprising in today's era of automation and high capital investment. There are two reasons for this result. The first is that the analysis considers the complete supply chain costs, which means that there are several layers of manufacturing and assembly on the overall cost structure. The second aspect is that the analysis presented here considers that all the manufacturers are all in a high wage area. This means that some components such as wiring harnesses, that are traditionally subcontracted to plants in lower wage areas, are penalized by this generic location assumption.

As it will be shown below, manufacturing in a low wage area may bring this share to values substantially below the reported 20%.

The results discussed so far are the product of a set of baseline assumptions. Therefore, it is important to understand how changes in this set of assumptions may alter the values discussed above. As it can bee seen in Figure 6–6, different items have diverse levels of impact on the overall cost estimation. Wages, as noted above, have a substantial impact on cost. A reduction of 50% in wage levels results in a decrease in cost of almost $1000, 13% of the total value. Conversely, an increase in wages from the base value of $20, results in a substantial cost penalty.

Figure 6–6: Sensitivity Analysis of Cost to Main Model Assumptions



The two other critical assumptions are production volume and line available time. The first is intuitive, as less production volume imply the same fixed costs divided by fewer units. While in what concerns equipment this may not be relevant, provided that the capacity made available can be used in the production of alternative products, dedicated tooling usually results in a significant cost penalty at lower production volumes. Line available time is a critical measure of efficiency in SCM, reflecting the ability of a company to achieve a good utilization of production equipment. Therefore, it has a significant impact on total cost. Finally, it can be seen from the influence of the variable ‘dedicated’, i.e. the firm inability to utilize this extra capacity for other purposes also results in a significant cost penalty. If this equipment is completely dedicated to manufacturing and assembly of the components under analysis (variable dedicated set to 100%), overall sourcing cost increases by 10%, roughly $800.

Changes in remaining assumptions have less impact on the overall cost. Interest rates need to vary significantly to have a meaningful impact on cost. Wide variations are not likely in the context of a developed region. Nevertheless, if the manufacturing context were to change to a developing region, often with much higher interest rates, the cost differences could then become significant. Increases in equipment life do not dramatically change the car sourcing cost, but a significant decrease in equipment life, due for example to obsolescence of some technologies, may have an impact.

6.2.3. The impact of Regional Condition on Manufacturing Cost

The sensitivity analysis described in the previous paragraph has shown that the cost structure of the automotive supply chain is affected by a number of variables, in particular factor costs and operating conditions. This is an important aspect because the critical idea explored in the thesis is that of understanding the sourcing decisions of the OEMs in the context of developing nations and their policies of domestic contents.

The reality in a developing world pushes some of the cost drivers towards higher cost, while others change in the opposite direction. For example, wages in a developing region are often much lower than those found in the developed world, contributing to a smaller cost in manufacturing. On the other hand, the interest rates are higher and the volumes are smaller, hurting the overall cost. In addition, each of these relevant variables affects individual components in different ways. A component that is heavily dependent on labor will probably benefit from the operating conditions of the developing world, while one that has a crucial dependence on volume may by face important penalties.

Understanding the complete set of conditions and how the affect overall cost is very relevant for the analysis of local content decisions. Therefore, a new scenario with conditions that are typically found in a developing region, for example Brazil or Argentina, is considered. The set of assumptions that will be used to generate the manufacturing scenario in a developing world is presented in Table 6–4. Like the case of the variables used for the scenario of the developed world, most of the values were gathered through extensive consultations with the local industry. The general industry conditions in this part of the world are discussed in Veloso (2000). There are meaningful differences in factor and operating conditions that are bound to have a significant impact on cost. These are discussed in the following paragraphs.

Table 6–4: Assumptions used in System Cost Model Estimations

	Item	Value
1.	Annual Production Volume	35,000
2.	Years of production	5
3.	Life of Equipment	10
4.	Interest Rate	20%
5.	Wage ($/hour including benefits)	$6
6.	Days per Year	260
7.	Number of Shifts	2
8.	Line Available Time	75%
9.	Free capacity utilization (weight>1Kg)	50%
10.	Development Cost (% Sales)	4.0%
11.	Component Logistics Cost (% Sales)	6.0%
12.	Subassembly Supply Distance (Km)	500
13.	Subassembly Transportation Time (days)	1

One of the crucial differences is the smaller scale. Operations in these regions are normally set up to serve the local market, which is often small. As a result, cars and their components are produced in scales that are significantly below those found in the developed world. The base value used in the estimation will be 35,000 vehicles per year. This penalizing situation in terms of cost is aggravated because some automotive components require dedicated investment in specific equipment that frequently does not have an alternative application in the local market. As a result, free capacity is sometimes left unused (this is reflected in variable 9 of the Table).

An example for this situation would be an injection molding machine required to manufacture a front or rear bumper. This is a very large and precise component that requires equipment with unique characteristics. Therefore, it is possible that no alternative application outside the auto industry can be found for such equipment in the context of the developing world. If only small volumes are required, the equipment may stay idle a substantial part of the time. Nevertheless, this is not true for all equipment, as simpler parts require equipment that can easily be given alternative uses. To implement these market characteristics in the SCM estimations, it is assumed that the equipment used to manufacture components with complexity level equal to 3, or weight above 1Kg, had 50% of the free capacity not taken by other products. As explained in the previous section this will imply an additional cost due to greater use time of the equipment.

Another relevant factor related to operating conditions is the efficiency in equipment utilization (implemented through variable 8 in the Table). Firms in developing regions are less able to control manufacturing processes, which leads to more unpredicted breakdowns and rework. To consider this situation, line utilization is reduced to 75% of all potential operating time, down from 87.5% considered in the developed region. This means that the line is down 2 hours in every shift of 8, instead of 1 hour considered for the context of the developed world. Because of the same inefficiency questions, inventory in these firms is also higher than what is found for the average firm in the western world. The average value gathered from the firms was 6% of sales.

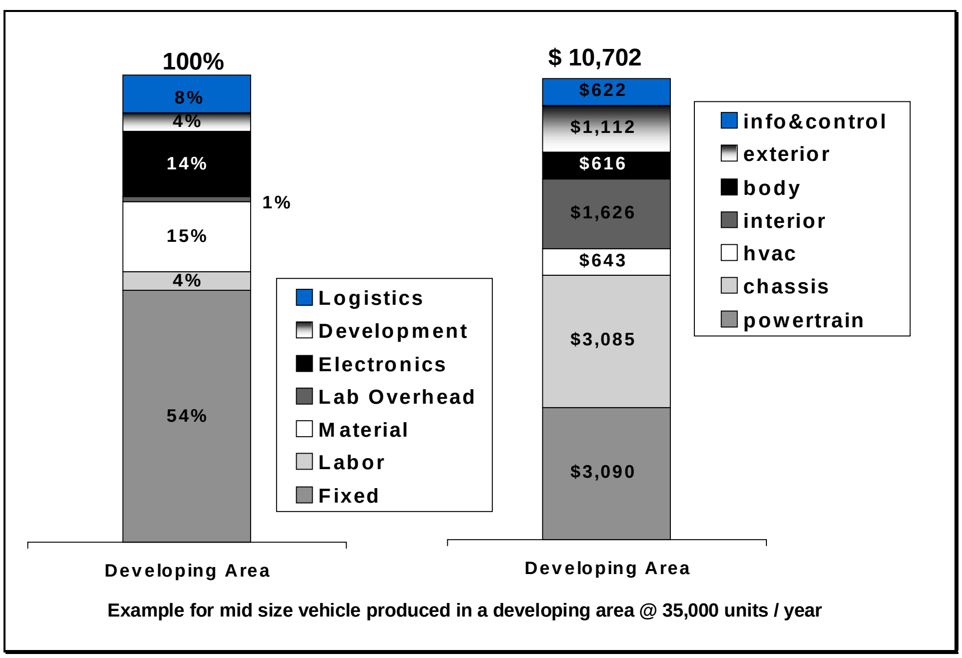
The other crucial difference is in factor conditions. Wages are much lower, and a value of US$6 per hour is considered, consistent with what is found in South America in the industry. With the contrary behavior of wages, interest rates that determine the opportunity cost of capital are much higher. The firms interviewed in the industry report this value to be at least 20%, a significant higher value than found in Europe. This value reflects the scarcity of capital in the region when compared with the developed worlds, but it also results from unstable macroeconomic conditions in the region, that often drives interest rates in these regions to high levels. There are more working days per year, 260 compared with 240 used previously for the developed region, are part of reported industrial practices.

The average supply distance and time are assumed to be smaller because companies producing for major OEM manufacturers in these regions are mostly concentrated in the industrial area where the auto plant is usually located. A good example is the city of S. Paulo which gathers a substantial share of industrial production of the country.

Although the assumptions used in the model cover a significant part of the issues associated with manufacturing conditions, they do not explicitly consider quality, an important aspect that often conditions sourcing decisions. Although quality problems are usually reflected in poor line utilization efficiency, something that SCM addresses, companies may never be able to reach certain levels of quality, even with major rework. When this is the case, the component is not considered for purchase from the OEM, even with lower price. Therefore, the modeling has an underlying assumption that local manufacturers are able to reach this minimum level of quality that is required by the assembler.

The results of the cost estimation for the new scenario are presented in Figure 6–7. When compared to the results presented in Figure 6–4, the overall manufacturing cost increases by $3,400, a substantial penalty. Like the overall sourcing cost, each of the areas considered in the analysis also has higher costs. The drivers for this substantial change are understood when analyzing the left hand side of Figure 6–7. Fixed costs are more than double the share of total costs when compared to the scenario of the developed nation. The reasons for this situation are the high interest rate and the poor line utilization conditions. As expected, the reverse happens with labor, which now makes only 4% of the total cost, compared with the 20% share that had been found for the developed region.

Figure 6–7: Supply Chain Cost breakdown for Developing Area



Electronics costs are reduced as a share of the total because they are purchased from outside sources and therefore assumed to be of constant cost regardless of the manufacturing region. The share of development cost is constant because it is considered a fixed share of total cost. Logistics costs go down slightly because of the shorter distances and reduced time in transit.

Despite the cost penalty on the overall sourcing cost, the impact of the manufacturing conditions on the cost of each individual component and subassembly is different. For those which have labor as the main cost driver, changing the manufacturing conditions to the developing world is bound to have a positive impact on cost. On the contrary, components that are very capital intensive will be the most penalized when manufactured under the new scenario. Table 6–5 illustrates precisely this situation. Components such as the wiring harness and the fuel injection system that have components of limited complexity and are heavy on assembly are less expensive to produce in the developing region. The opposite happens with more capital intensive components. The cost difference in the crankshaft assembly is a good example of this situation.

Table 6–5: Examples Subassembly Cost on Developed and Developing Region

Group	Developed	Developing	Difference
Wiring Harness Dashboard	\$196	\$158	-19%
Fuel Injection Assembly	\$67	\$60	-10%
Instrument Panel Assembly	\$23	\$23	0%
Starter	\$30	\$35	17%
Crankshaft Assembly	\$99	\$172	74%

Like the scenario described in section 6.2.2, the particular cost values for the developing region are sensitive to the assumptions on each of the factors presented in Table 6–4. If wages are to be higher than the value used, the cost of each component will rise, and so will the cost of the overall system. Changing any other parameter will also change the final cost calculations. The result is not presented here because the general conclusions are identical to those presented for the case of the developed world.

Given the circumstances described in the previous paragraphs, the best solution for the automaker is to mix component sourcing from the two regions. In fact, if one observes the sourcing locations for the assemblers located in Europe, it is normal for purchasing managers to buy components that require significant amounts of labor from the countries in the south or east of Europe, where wages are lower, and more recently from North African countries. On the contrary, engine plants and other capital intensive operations often remain in the developed markets of Germany, France and surrounding nations. How to make this match in the context of the developing world is the subject of Chapter 7.

6.3. Summary

This chapter explores the System Cost Model described in Chapter 5 in the context of the automotive industry. First, it assesses the global trends in the industry contrast and the purchasing policies in particular. Second it describes the car manufacturing costs in both a developed and developing region, exploring the tradeoffs and the potential sourcing decisions of the OEM.

Data from a particular car is then used build a sourcing cost structure. The cost estimation is based on a comprehensive list of components for a mid-size car of a major manufacturer, includes 3090 individual components, excluding screws, bolts, pins or other small parts that are used in assembly. Individual component costs are estimated and aggregated over 274 major subassemblies. These constitute the object of sourcing decision of the OEM. The overall results of the estimation process are presented; critical benchmarks at subsystem and group level and sensitivity to key parameters are also discussed.

A study comparing the impact of regional conditions is then presented. Calculations show that overall manufacturing conditions in the developing world have a significant negative impact on cost. Nevertheless, this effect is not general and depends on the characteristics of individual components and subsystems. As a result, the best solution for OEMs is to mix component sourcing from developing and developed regions.

Chapter 7.

Domestic Content Requirements and the Auto Supply Chain

This Chapter analyses the specific context of domestic content requirements, integrating the theoretical models presented in chapters 3 and 4 with the system cost model proposed in chapter 5 and the specific context of the auto industry supply chain presented in chapter 6.

First, it discusses why local content requirements are an important issue in the automotive industry. The analysis follows the sequence of the models and issues presented in chapters 3 and 4, integrating cost data calculated through the system cost model. In section 7.2, free market decisions are considered to establish the benchmark sourcing structure against which the various results will be compared. This calculation provides an understanding of how a domestic content policy might affect welfare. The implications of potential gaps between social and private costs of the key resources are investigated and the specific context of learning and spillover effects is considered. Section 7.3 addresses the situation of optimal contracts and asymmetric information. In all the analyses, sensitivity to key parameters is examined.

7.1. Domestic Content Policies in the Auto Industry

The automotive industry is a massive generator of economic wealth and employment. In Western Europe, Japan and the United States, it accounts for as much as 13% of GDP, and one in every seven people is employed through the industry, either directly or indirectly (i.e. insurance) (Maxton and Wormald, 1995). Moreover, sectors like rubber or steel are highly dependent on the 50 million cars produced each year. Furthermore, demand characteristics are another critical aspect of this industry. Buying a car is usually the second largest investment objective of a family, right after the house. This behavior, that is similar around the world, creates a predictable need for the availability of cars in every country.

Because of these characteristics, the auto industry has been extremely important to national economies and a source of concern for the governments, particularly since the 1950s, with a world 'boom' in the demand for consumer and industrial products (Shapiro, 1993). The late industrializing countries that started their catch-up process during this period have accrued sources of concern. As demand started to grow, imports of cars and parts from the world oligopolistic producers started to create trade balance disparities that affected the capacity to access capital goods much needed for their industrialization process.

In the process of targeting solutions to address this important issue, most governments realized that this predictable demand for cars could also be seen as a major industrial development opportunity. In fact, besides the employment and trade issues, this industry created a significant demand for intermediate inputs, creating pressure to develop other sectors of the economy. They figured that the automotive industry could provide a hub for an integrated industrial structure by triggering the domestic production and technological advance of industries such as steel, machine tools and components, among others (see for example Krueger, 1975; Amsden, 1989; Shapiro, 1993; Veloso, Soto et al., 1998). The problem was the creation of national industrial capability in a context of oligopolistic market structures. The solution was the adoption of strong trade protection mechanisms (quotas, tariffs), forcing assemblers to locate plants in their countries if they wanted to access local demand. Simultaneously, the enactment of policies to stimulate Foreign Direct Investment (FDI) and local content requirements would foster the desired linkages within the national economy. These policies evolved over time and the initial schemes were complemented later with measures for export promotion, quality, R&D, etc.

The utilization of performance standards to encourage investing firms to reach certain objectives important for the government and in particular the adoption of domestic content requirements has been pervasive in the industry. As noted in chapter 2, empirical research suggests that although with different degrees of success, performance standards played an important role in the development of the auto industry in countries as diverse as Mexico (Bennet and Sharpe, 1990) (Veloso, Soto et al., 1998), Taiwan (Veloso, Soto et al., 1998), Portugal (Veloso, Henry et al., 2000), Korea (Amsden, 1989), Brazil (Shapiro, 1993) and Spain (Lagendijk, 1993), among others. Among the wide array of policies used to foster the development of the automotive industry and reported in these and other studies, domestic content has been one of the most prevalent. Government has considered it a major instrument to promote backward linkages to local suppliers and encourage the investment of foreign players in the local market, deepening the supply chain.

Table 7–1: Domestic Content Requirements in Selected Regions

Country or Region	Components Local Purchase Policy
China	40% to 90% depending on year and product
Malaysia	60% up to 1850cc, 45% up to 2850cc and commercial
Thailand	0% (54% until 2000)
Philippines	40% to 50%
AFTA (Asean Free Trade Area)	Expected to be 60%
Mercosur	50% first year, 60% after (new rules under negotiation)
NAFTA	62.5% Rule of Origin; Mexican local requirements until 2004
EU	60% Rule of Origin
India	50% after 3 years, 70% after five years
Korea	Non-market barriers: national ownership

Sources: www.asean-auto.org (Asean); www.indiainfoline.com (India); www.cacauto.com/ (China); http://www.rediff.com/ (India); US DOC STAT-USA (rest)

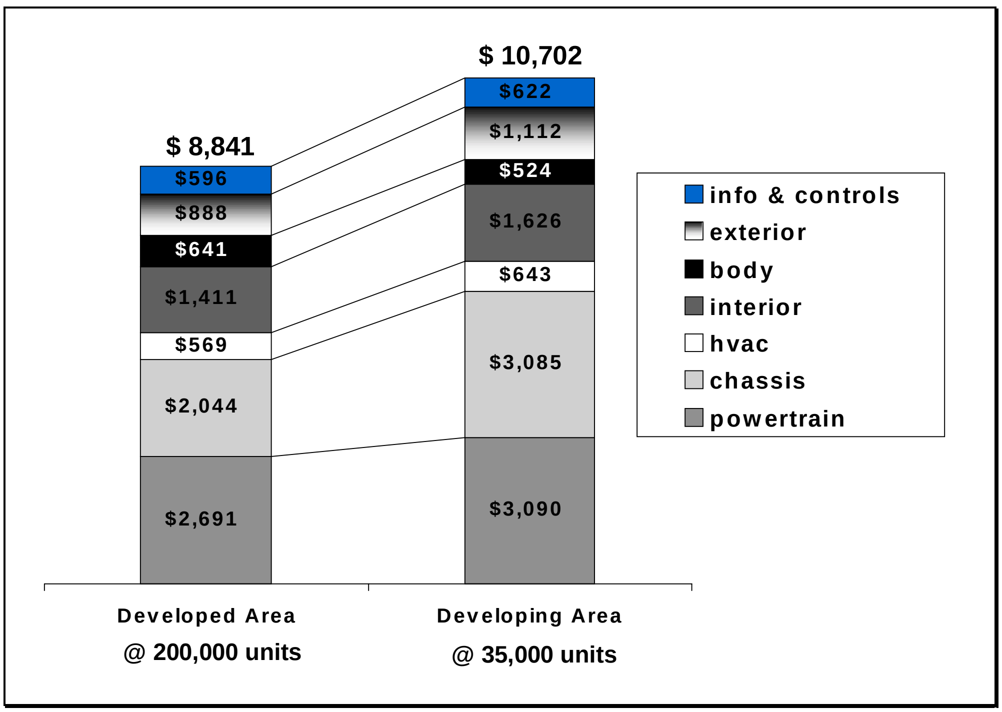
Industrial policies have been tamed by international agreements, in particular the rounds of trade liberalization that led to the creation of the World Trade Organization. Nevertheless, as detailed in chapter 2, domestic content requirements have been one of the more resilient government policies, especially in the auto industry. A number of individual countries still have active requirements of domestic purchases, aiming to contribute to the development of upstream industrial capabilities.

Table 7–1 presents the current state of these policies in a number of regions of the world. As it can be seem, either at the level of individual countries, or within the context of regions, these regulations continue to be present throughout the globe. Moreover, because of the flexible conditions of the WTO regarding transition periods, they are bound to continue in the near future. The persistence and importance of this policy in the context of the automotive industry is the motivation for choosing it as the case study for the models described in previous chapters that will be discussed in the next sections.

7.2. *Estimating Welfare Effects of Domestic Content Policies*

The implementation of the domestic content model discussed in chapter 3 uses the SCM methodology in the context of the auto industry to assess policy implications of domestic content requirements. The particular factor costs and operating characteristics used try to replicate the manufacturing environment in France or the Benelux vs. the one found in the Mercosur Region (see Veloso, Henry et al., 2000 for a description of the automotive industry conditions in the Mercosur). These results are the core data to evaluate the effect of the domestic content policies on the economic agents and the overall country welfare.

Figure 7–1: Car Supply Chain Costs (Unit Value)



The SCM results are presented in Figure 7–1. The figure describes the sourcing cost of an OEM in the developing region, considering two extreme situations. The right hand side assumes that all components of the vehicle are sourced from the domestic environment, where the scale of vehicle production (and corresponding components) will be 35,000. On the left hand side, all components are bought from the international market, produced at high production volumes[50] (200,000 are assumed) and imported into the country.

The costs for the scenario of manufacturing in the developed world are different from those presented in chapter 6. The reasons for this difference are the added logistics and duty as well as tariff costs to which imported components are subject. Logistics costs result from a commercial freight cost of $1500 associated with shipping a 40' container for 15 days across the ocean and an insurance cost of 2% of product value. Duty and tariff costs are 16%, a value established against what is typically found in South America.

The total sourcing cost in the developing area is higher than the foreign alternative. Nevertheless, the same does not hold true for all individual subsystems. The body group is less expensive in the developing world. These aggregate results provide an initial perception of how an automaker may want to pick and choose suppliers from different regions of the world depending on the component. If the choices were limited to those described above, an OEM investing in the developing country would buy the body from local firms and the rest from foreign suppliers. Using the models developed in chapter 3 and 6, this section analyzes in detail the sourcing decisions and costs of an automotive OEM, including how these are affected by government policies, and the overall impact on domestic welfare.

7.2.1. Market Conditions and Sourcing Decisions

To study the pattern of OEM sourcing decisions, the SCM model for the context of the automotive is used. As described in chapter 6, the decision involves 274 systems that are bought by the OEM. This almost continuum of components enables a very reasonable replication of the model described in Chapter 3 regarding OEM sourcing decisions. Figure 7–2 represents an application of the model to the component data set. The two graphs in the figure show the two equivalent representations of the problem. On the left hand side, costs are presented as a function

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[50] The idea is that a similar car is produced in the foreign region, thus taking all the remaining volume of components that is not exported

of the component index, and on the right hand side, a correspondence between sourcing cost and local content is presented.

The two extreme sourcing costs, when all the components are sourced either abroad or in the local market, correspond to the values presented in Figure 7–1. The intermediary costs follow patterns anticipated in the description of the model in chapter 3 and are determined by the relative sourcing of domestic and foreign components. With the possibility to switch components between the local and foreign markets, OEMs will choose the minimum sourcing cost. This corresponds to US$7,974, a reduction of US$867 from the cost of importing the whole set of components. The value of local content that leads to the minimum cost is 45% of the total price paid by the OEM for the components.

Figure 7–2: Component Sourcing Cost Tradeoffs

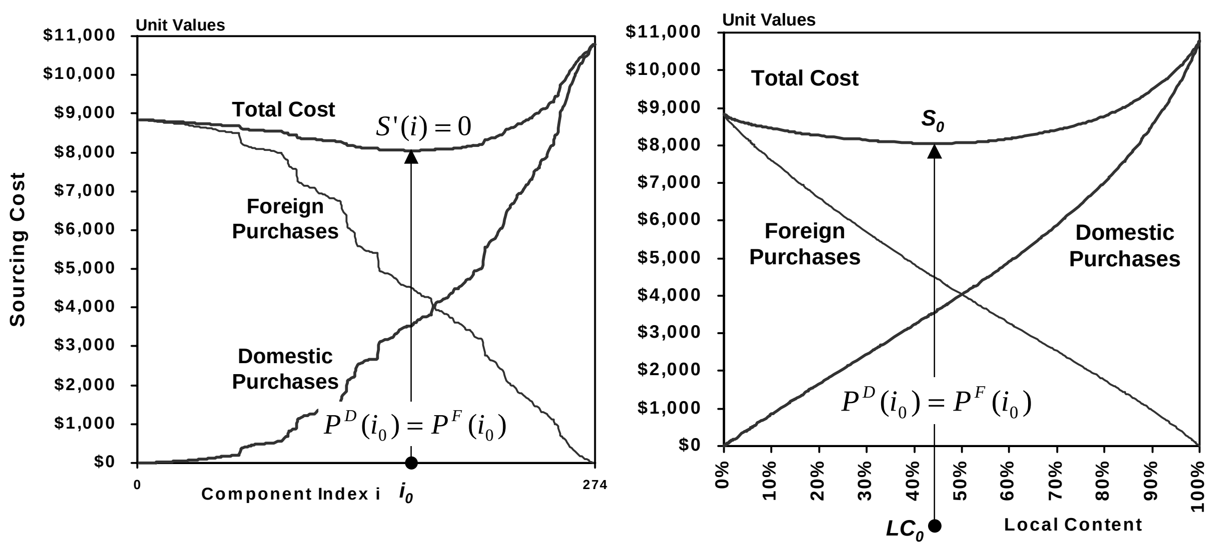
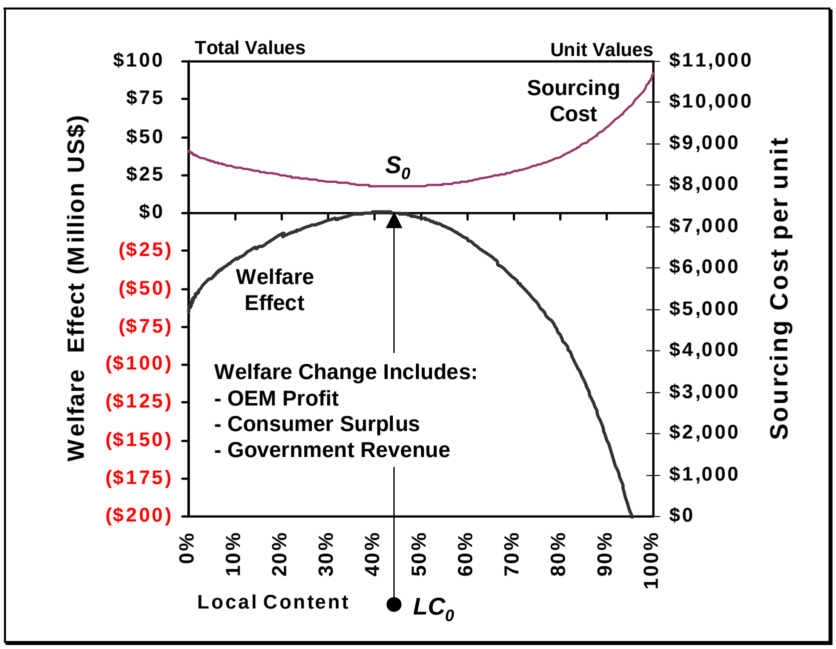


Figure 7–2 also provides information regarding the sourcing cost penalty associated with local content requirements. If the OEMs are forced to source 60% of the components in the local market, a typical requirement found in the industry, the cost penalty is US$124, which corresponds to roughly 1.5% of the total sourcing cost. Since the model application was benchmarked against the conditions found in the Mercosur market, these results suggest that complying with domestic content regulations is not a large burden for the OEMs, a circumstance that is confirmed by the opinion of local automakers (see Veloso, Henry et al., 2000). Nevertheless, if the policy would be more strict, the cost penalty would be much more severe.

For example, an 80% requirement would mean roughly US$715 of additional sourcing cost per each vehicle, a significant cost penalty.

The values presented in Figure 7–2 represent the sourcing penalty costs associated with each vehicle. Nevertheless, the base model described in section 3.3 also includes the possibility for demand effects. Since it assumes that the OEM is pricing with some degree of monopoly power, changes in sourcing cost will also affect the price of the car and quantity sold, which in turn will affect domestic welfare. Therefore, it is important to assess how these effects play out together. Figure 7–3 presents the result of the evaluation using equations described in section 3.3. As explained in that section, total welfare effects include changes in the OEM profit, consumer surplus and the revenue the government obtains through the tariff levied on foreign components.

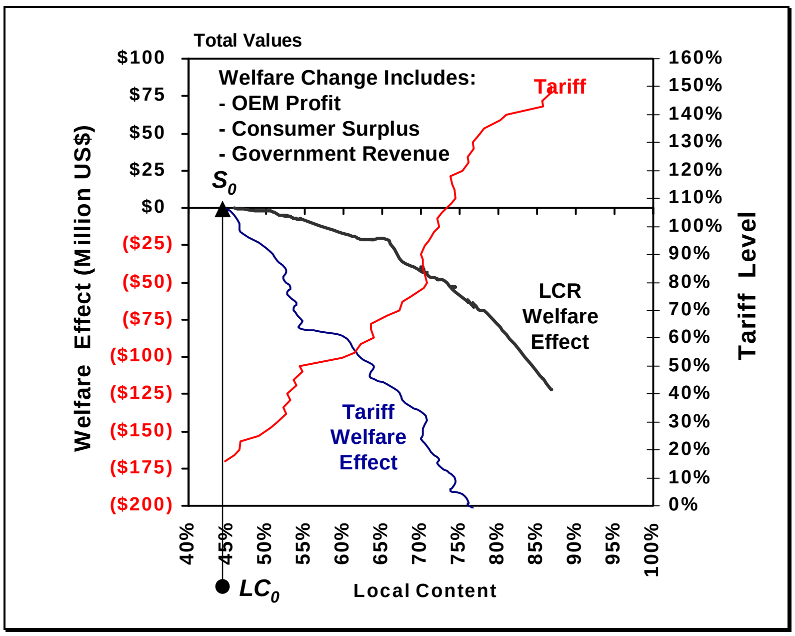
Figure 7–3: Welfare Effects of Content Requirements in Perfect Market



The calculation of welfare variation requires several pieces of information. Part of it has already been derived or assumed. This includes the sourcing cost defined by the OEM cost minimization subject to the policy constraints, as well as the base production volume, assumed above to be 35,000 vehicles per year. Two additional pieces of data are necessary as well. The first is the demand elasticity (E_d) for these types of cars. Based on results from previous research (see Berry, Levinson et al., 1995), a lower bound value of E_d= –2.5 was adopted. Other important information is the total costs associated with assembly and distribution of the car (The *c* value in equation (3–2) and subsequent ones of chapter 3). Based on industry information for these types of cars, a value of $7000 was used.

The calculations of the sourcing cost and the associated welfare are presented in Figure 7–3. Any degree of domestic content requirement has a negative impact on domestic welfare. Moreover, as the requirement becomes more severe, the impact is extremely negative. The scenario described in this figure represents the typical conclusion that previous authors analyzing the effect of domestic content policies have found: in a market with no discernable external effects associated with the investment or the purchasing practices, enacting domestic content requirement will always have a negative economic welfare effect.

Figure 7–4: Comparing Welfare effects of Local Content and Tariffs



In section 3.3.1, the model also showed that a content requirement could be replaced by a tariff on imported components. Figure 7–4 illustrates this conclusion in the context of the automotive industry case study. The figure presents the level of tariff required to achieve a particular level of domestic content (starting with the 16% value for the benchmark case). For example, to achieve 50% domestic content a 28% tariff is required, while to reach 80% of domestic purchases, the tariff has to rise to 138%.

The model also demonstrates the superiority of content requirements over tariffs as a policy mechanism because it generates fewer distortions in the economy. The welfare impact of both the content requirement and the tariff are presented on the left axis. The welfare effect for the tariff policy is always substantially inferior to the one for the content requirement policy. For small deviations away from the natural content level, the relative difference is particularly important. For example, to increase the level of domestic content from 45% to 55%, content requirements penalize the economy by 8.2 million dollars, 3% of the total base sourcing cost (unit cost times quantity), while a tariff diminishes domestic welfare by 76 million dollars, 27% of the total base sourcing cost.

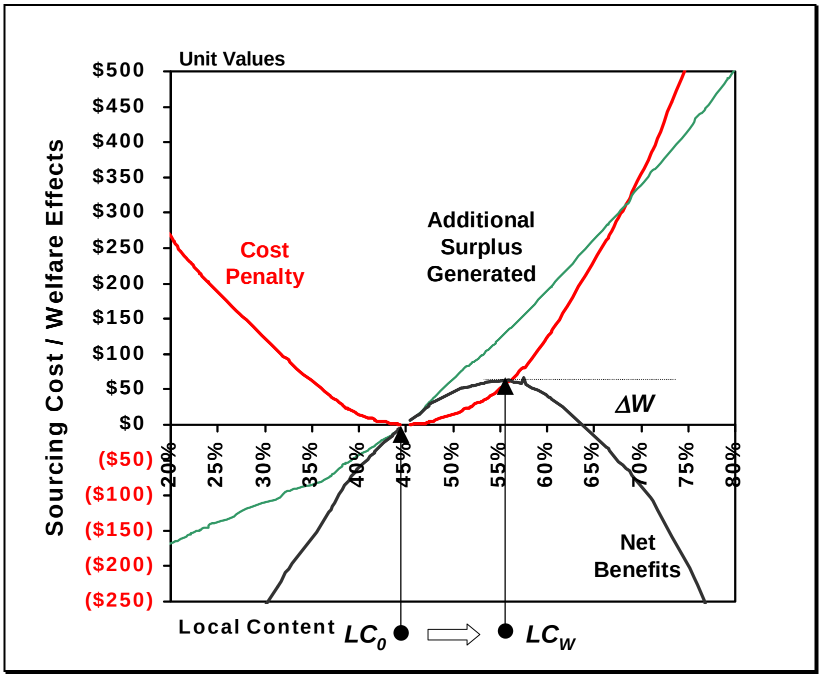
7.2.2. The Social Opportunity Cost and the Welfare Effect of a Content Policy

The critical question the model addresses is the issue of social opportunity cost and externalities-from-entry. The idea explained in section 3.4. is that there may be a gap between the social and private costs for the resources used in the supplier activities. If this is the case, the content policy may become valuable to the local economy.

Accurate estimates of the social opportunity costs of resources require a detailed investigation of the economic conditions of the region where the investment is taking place. Since this thesis discusses a generic evaluation of the local content policy rather than an analysis of a particular project, a base set of average levels are considered and a sensitivity analysis to the values of these parameters is done to make sure that the conclusions are not biased by the particular values that were chosen.

For the application of the theoretical models to the auto industry case, the social opportunity cost for the wages of the workers is considered to be half of the value paid by the firms, which results in a 0.5 value for the parameter λ. This means that an alternative use for the labor only results in half the result for the local economy. Following a similar logic for the cost of capital, each dollar of capital used by the suppliers is assumed to have a social opportunity cost of 80 cents. As a result, the value of ϕ is 0.2[51]. The social opportunity cost of the expenses related to development is assumed to be zero (π=0). Finally, any resources that the government may have to provide are also subject to a penalty. The conservative value of 120% (ψ=1.2) was used in the application (Grossman, 1990). All the values reported are used to establish a base case for evaluation.

Figure 7–5: Welfare Effects of a Domestic Content Policy



The cost penalty and economic welfare results under this set of assumptions are shown in Figure 7–5. The empirical results follow what the theoretical model has anticipated. There is a net benefit to an increase in domestic content beyond the natural level of sourcing. Moreover, this effect has an extreme point, for which the domestic welfare is a maximum. This value for the data generated is roughly 56%. This would mean that domestic requirements up to this level would be beneficial for the overall economy. While inducing a small purchasing cost penalty, on the order of $61 per car, it also attracts valuable resources for the economy that compensate for this penalty. Given that in the Mercosur area the OEMs are forced to source 60% of their components' value in the local market, the conclusion is that this policy is likely to have a

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[51] This is reflected in the results by repeating the SCM calculations for the developing region with an interest of 16% instead of the rate of 20% used in the base case (0.8*0.2). This new value is a 50% reduction in the gap to the private interest rate of 12% considered in the foreign region.

positive impact on the economy for the sets of assumptions considered, in particular the production volume, an issue further discussed below.

Shifting the domestic content to this optimal level has a meaningful impact on the economy. With 56% of domestic purchases, the total surplus value for the economy is US$16 Million annually, corresponding to sales of US$156 Million. These values contrast to those in a free market environment, where the annual domestic component sales would be US$125 Million with an associated value of US$14 Million, an increase of 20% in sales and 13% in value[52].

7.2.3. Sensitivity to Key Variables

Because some of the variables used in the calculations presented above were not derived from a specific evaluation of market conditions associated with a project and a region, it is important to understand how the results and their interpretations may be affected by the choice of these values. Among these, the social opportunity costs for each of the resources used by the local suppliers and the volume of production play a critical role. Therefore, sensitivities for these parameters are considered in this section.

Figure 7–6 includes an analysis of welfare variation as a function of the opportunity cost of the resources, with values presented on a unit (one car) basis. The two extremes values for the opportunity cost of capital that are studied correspond to the 40% and 100% of the private value. The former represents an interest rate of 12%, thus removing any local premium above the rate practiced in the foreign market. In what concerns wages and development costs, the variations are from 0% to 100%, corresponding either to no alternative use for the resources, for example high unemployment levels for the case of wages, that renders the opportunity costs equal to zero, or to no difference between private and social valuation. The ranges considered for the opportunity cost of government subsidies follow previous evaluations of these values by other authors (see Grossman, 1990).

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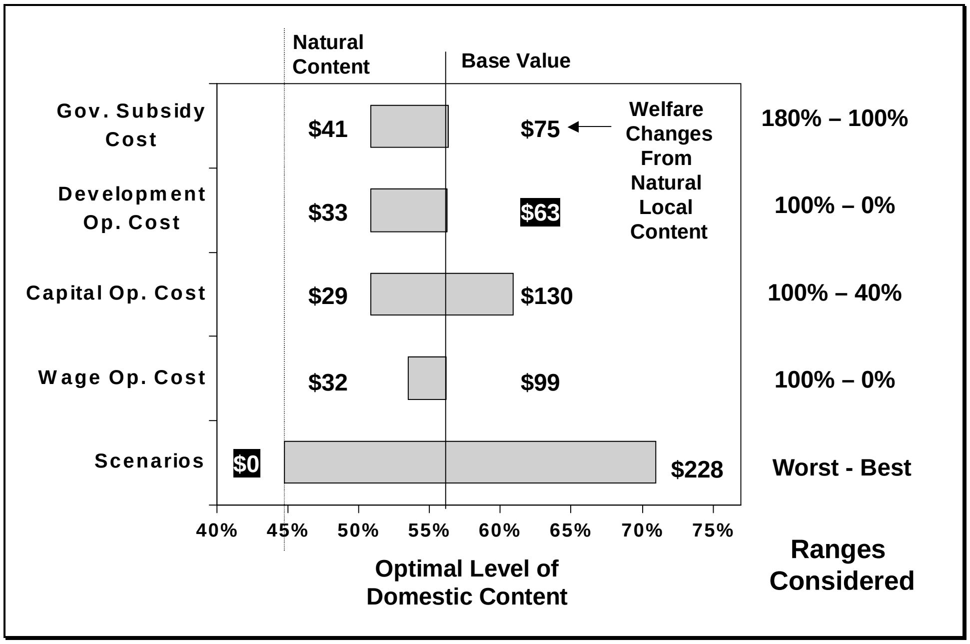
[52] It is important to remind that part of the policy scenario considered in the analysis involves compensating the OEM for the cost penalty that results from the content policy. Because of this assumption, the quantity effects on welfare included in section 7.2.1 can be ignored

Figure 7–6: Sensitivity Analysis for Key Factors

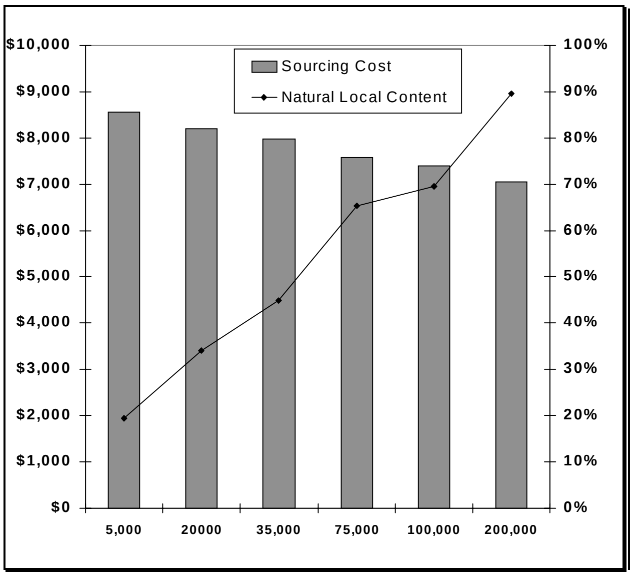


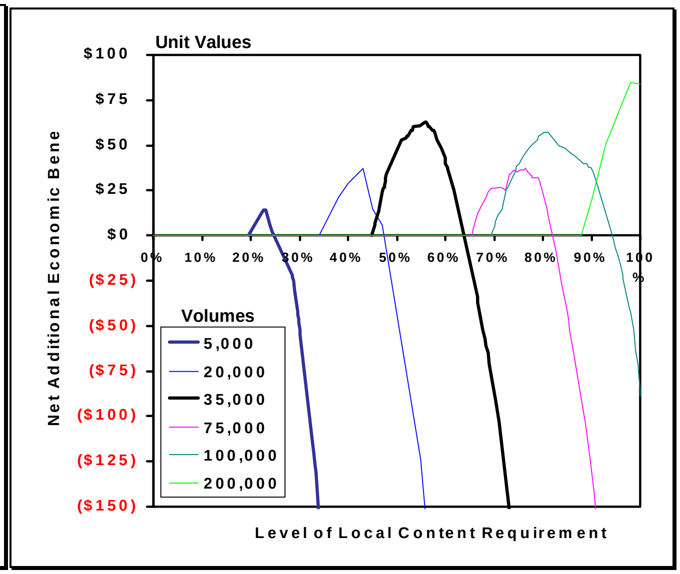
The figure shows that the factor with the largest effect on the optimal level of domestic content is the opportunity cost of capital in the local economy. This result is natural if one remembers that fixed costs are 54% of the total sourcing cost in the local economy. Another important factor is the cost of government subsidies. The fact that the government compensates the OEM for the penalties it has to withstand when forced to buy more domestic components than it would normally creates an important dependence on the efficiency of the tax system. If collecting subsidies is very expensive for the economy, the ability to generate a positive benefit through bundling requirements and subsidies is severely hampered. It is also relevant that wages have a small impact on optimal level of domestic content. Because labor costs are only a small portion of unit cost, changes in the opportunity cost of labor have a small effect on welfare.

The same figure also considers the two extreme scenarios, with either no differences between social and private opportunity costs, or all the variables with the lowest opportunity costs within the ranges discussed in the above paragraph. In the first case, the best choice is to have no requirement at all, which brings the sourcing decision back to the OEM natural content level. In the extreme scenario, with very low social opportunity costs, the optimal level of domestic content is raised to 71%, a very large difference from the natural level.

Scale is the other the key factor affecting manufacturing cost. Smaller production volumes affect the component manufacturing cost and, as a consequence the natural level of domestic purchases and the impact of any domestic content requirements. Figure 7–7 shows that very small production volumes imply important decreases in the level of domestic content. At volumes on the order of 5,000 cars per year, roughly 20% of the total purchases are done in the local economy, while for 200,000 cars per year, the domestic content reaches almost 90%.

Figure 7–7: The implications of Volume for Domestic Content





The production scale also affects the ability of the domestic content policy to have a positive effect on the economy. For very small scales, the rise in the cost penalty curve is so steep that it rapidly reaches the marginal benefit generated by forcing domestic purchases through regulation. Therefore, for a production volume of 5,000 vehicles, the maximum benefit that the local economy can reach through the content policy is negligible. On the contrary, as production increases, there are greater potential welfare improvements from establishing such a policy.

These results show the determinant role of the relative curvature of the domestic and foreign cost functions. If these are similar, the total cost curve will have a wide flat region around the minimum, which means that there is a large leeway in substituting between domestic and foreign components with minimum impact on the sourcing cost, but potentially important benefits for the welfare of the domestic economy. On the contrary, a sharp difference in curvatures, usually due to a technological gap between the regions will limit the ability to derive a positive result by forcing domestic contents. This effect follows the logic presented in figure 5 of chapter 3. The effects of production scale are a good example of how this relationship affects natural and optimal domestic content levels.

These results indicate that within reasonable ranges of social opportunity cost for the relevant variables, there is value to the enactment of modest levels of domestic content requirements. To have a positive impact, these ought to be aimed at pushing the natural decisions of the OEMs beyond what they would normally do. Nevertheless, there is a clear maximum benefit that can be achieved and strict policies can have very harmful effects to an economy. Moreover, it is crucial to recognize the role that scale plays. For very small scales, there is little potential welfare improvements that can be generated through content requirements. Scale also indicates how setting a blanket policy that is equal for all automakers and plants can have very different results. While for some the impact can be positive, there are also others where it will be either negligible or even negative.

7.2.4. Externalities and Learning Effects

The argument so far has relied on the notion of differences between social and private values for the resources used in the industry. Parameters representing the potential gaps were considered to in order to understand how their relative importance could justify the enactment of policies such as domestic content requirements. Following the description of section 3.4.2, this section models two situations that can drive this gap and result in sub-optimal decisions from private players: the potential for learning by doing and then the possibility of learning by spillovers.

Before presenting the implementation of the model it is important to note that discussion is only a first approximation to this complex problem. Give the approach used in chapter 5 to build up the supplier’s cost structure, a detailed assessment of the learning effects should be grounded in this model. This would require a careful modeling of how learning affects the use of resources and the efficiency parameters of the manufacturer. This analysis is beyond the scope of the thesis. Therefore, the choice to model learning as a direct effect on base cost is a first approximation to the problem that bundles all the effects together. A detailed specification of the learning mechanisms and their cost impact will be left for future work.

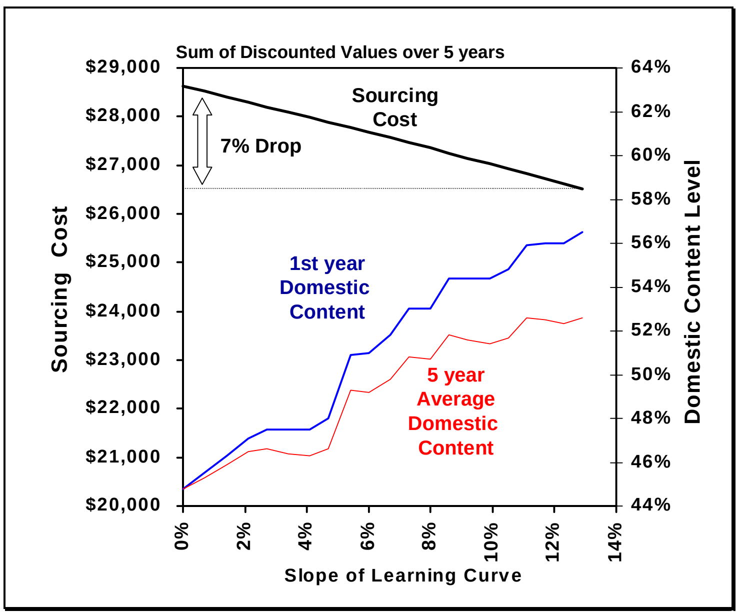
As explained in chapter 3, the existence of learning is associated with the cumulative output of individual firms and the industry as a whole. Therefore, assessing its effect requires the introduction of a time horizon for the project. In the context of the auto industry, the time horizon considered will be five years. This period corresponds to the time over which a particular car model retains similar characteristics and, as a result, the same supplier base (Veloso, Henry et al., 2000, chapter 3). After this period, the OEM is likely to introduce significant design and technical changes in the vehicle, or change the production to a completely different car. When this happens, a new open bid for suppliers is usually conducted, which may result in significant changes in the supplier base.

Following section 3.4.2., the effect of learning on the decisions is evaluated by minimizing equation (3-31) with respect to *i* for particular values for the learning indexes γ and β and comparing the results to the base situation with no learning (which corresponds to having exponents equal to zero). The base discount rate used in the 5 year discounted sourcing cost calculations will be the one considered in the evaluation of the cost of the domestic components. In this case it will be 20%.

The level of domestic content over the 5-year period can be calculated by dividing the discounted sum of the domestic purchases by the total discounted cost. While this value reflects the true level of domestic content, it makes it hard to compare with the previous discussions that were done on a year and unit basis and with a fixed cost. Therefore, learning effects are also discussed by analyzing the first year level of domestic content. This value is calculated by dividing the cost of domestic sourcing by the total cost in the first year of the five. Since, by construction, learning and discounting only affect sourcing cost calculation starting in the second year, the first year calculation of the local content value enables a good comparison of how much learning shifts the firm decision to incorporate local components from the market base choice presented in Figure 7–5.

Initially, only learning by doing is assumed to be taking place. This means that the exponent β will be zero. Figure 7–8 presents the results of the simulation. It considers values for the learning parameter γ between 0 and 0.2, a range consistent with recent finding by other authors (Sinclair, Klepper et al., 2000). Nevertheless, the horizontal axis is presented in terms of the learning slope instead of the elasticity to facilitate perception (this calculated as $2^{-\gamma}$). The left axis has the total five year discounted sourcing cost, while the right axis presents the five year average and the first year equivalent levels of domestic content. As seen in the Figure, the maximum value of γ corresponds to a cost reduction of 13% in total cost every time cumulative output doubles. This extreme value implies that, in the fifth year, the cost of each domestic component is 76% of the original cost. The drop in the cost of domestic components due to learning is reflected in the total discounted sourcing cost. At the maximum learning rate, the total cost is 7% below its original value.

Figure 7–8: Learning by Doing and Domestic Content

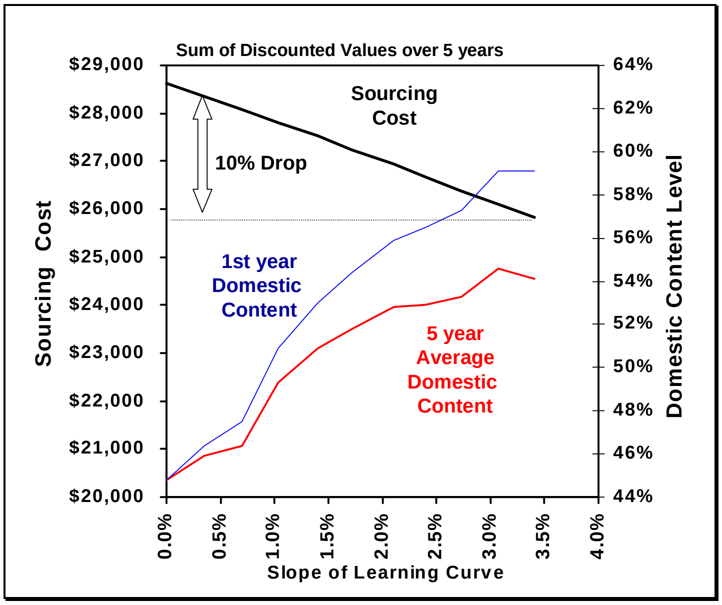


Because domestic cost is reduced over the project life, some components that are more expensive than foreign equivalents in initial years will have a total discounted cost over the project time below the imported counterparts total cost. These components, which would not be sourced locally in the static analysis discussed in the previous sections, will now be part of the domestic content. As a result, this is reflected in the share of sourcing that is done in the domestic market, which increases with the learning rate[53]. As it can be seen in Figure 7–8, a learning curve slope

[53] A careful analysis of the graph reveals that there are regions where the average domestic content curve is downward sloping. This happens because, unless a there is a change in the sourcing structure (change in the value if

of, for example, 7% corresponds to an increase in the level of domestic content from 45% to 50%. For the extreme case considered, with a learning slope equal to 13%, local content raises to 52%. The level of domestic content is larger when measured in terms of first year local content equivalent. At the maximum learning rate considered, the first year equivalent domestic content increases more than 10% from the OEM market decision.

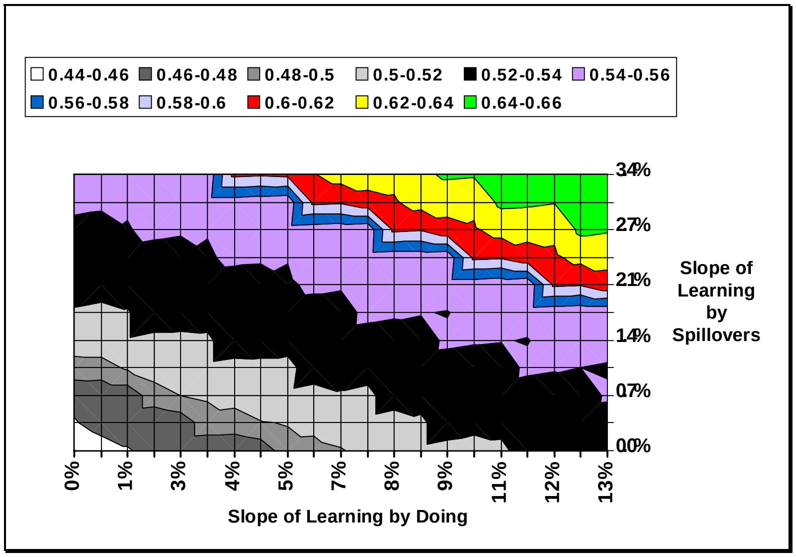
Figure 7–9: Learning by Spillovers and Domestic Content



The results from spillover learning are similar. The important difference in the analysis is in the values of the elasticity of learning that were considered. The range of elasticity considered was 0 to 0.05. The maximum value for the elasticity corresponds to a yearly reduction of 3.5% in cost every time the number of domestic sourced components doubles, a value that would translate into a reduction of 24% in cost if all the 274 components would be manufactured in the domestic market. Figure 7–9 illustrates the potential importance of the spillover effects. Within the scenarios considered, the sourcing cost can be reduced up to 10%, which would correspond to an equivalent increase in domestic content to roughly 55%. The importance of spillovers can be further assessed if the metric used is the first year content decision. As one can note, this value is 15% above the original level of domestic content with no learning, a significant change.

i), increasing learning results in smaller cost for the domestic components with fixed cost for the foreign ones. As a result, the ratio of domestic over total may be reduced.

Figure 7–10: Joint Learning and Domestic Content



The two effects can now be combined. Figure 7–10 presents the results of the joint learning effects on the level of domestic content. Because of the original formulation, the two learning mechanisms have an important reinforcing effect that increases domestic purchases beyond their individual results. If both learning effects reach their maximum value, domestic purchases increase to 66% of the total sourcing cost. The figure also strengthens the idea that spillover effects can have a significant effect on cost of individual firms. If firms do learn with others in the same industry, as empirical studies have indicated, then domestic content decisions may have a major impact on the future ability of a sector to be competitive in an industry.

A meaningful aspect of the decision is the level of discounting used to calculate the net present value of the sourcing cost. A direct sensitivity analysis to this factor indicates that the decisions are not significantly changed because of this variable alone. If the discount rate were lowered to 12%, matching the value used in the calculations for the developed region, the levels of domestic content at the maximum elasticity values would increase only by one percent if considered in isolation, and 2% if analyzed jointly. This would indicate that the estimations are robust to this variable. Nevertheless, one must note that a full sensitivity analysis ought to consider the fact that components costs calculated with the SCM would be changed if the discount rate were to be reduced (because a change in the government discount rate means that the private cost of capital is also likely to be altered), moving both the base and optimal domestic content levels. This analysis requires a more detailed framework that relates the micro variables used in the SCM with the learning dynamics, something that will not be addressed in the thesis.

As noted in the discussion of section 3.4.2., if the presence of learning effects is anticipated or known by OEM, it would naturally lead to higher levels of domestic purchases. The firm would incorporate the new price regime in the sourcing decision, finding the optimal solution to the problem from a private as well as social perspective. The natural level of domestic content would be the one presented in the figures above, conditional on the relative importance of learning.

The problem arises if learning is not recognized or accepted by the OEM, or impossible to measure ex-ante. If this were the case, the firm would make the base decision with no learning. Therefore, it becomes clear from the figures presented above that both the investing firm and domestic economy would benefit if government required a level of domestic content that accounted for the learning potential. This situation embodies the well known infant-industry protection argument, whereby because of myopic economic agents or coordination problems, the government establishes restrictive policies to allow learning from domestic producers, but with the understanding that the total welfare of the country will be improved (Dasgupta and Stiglitz, 1988; Grossman, 1990).

When enacting domestic requirements, the government should also be aware of their impact on the incentives of the economic agents. If suppliers see the market as guaranteed, they may slack and not learn as much as they would if pressed by a contract. On the other hand, they may effectively go down the learning curve, but do not reflect that in the cost of the components to extract rents from the contract. A potential solution to this problem is to enact contracts that require price reductions over time, meeting the expected effect of the learning curve. In fact, the establishment of contracts between OEMs and suppliers that have price reductions clauses are common practice in the industry, even in contexts without any type of domestic requirements (Clark and Veloso, 2000).

An important aspect to note is that within the reasonable levels of learning considered in the analysis, the optimal domestic sourcing decisions are similar to those justified through gaps in the valuations of the critical resources exposed in section 7.2.2. It we assume that learning effects are embedded in the use of capital and human resources in the suppliers, the two approaches converge. The idea is that each worker and each unit of capital embodies, not only its direct productive use that results in the component that is delivered to the OEM, but also a future learning potential that is not valued and paid by the market. This learning potential generates the gap between private and social opportunity costs. The underlying assumption is that the government must be able to see or value this learning better than the economic agents. Otherwise, it would be incorporated in the decisions of both the OEM and local suppliers. To the extent that learning is external and difficult to value ex-ante, this situation becomes more likely.

Another reason that could lead the OEM to underestimate the importance of learning could be management risk aversion. If learning happens only with a certain probability, then a risk averse purchasing manager might prefer a foreign supplier with a cost for sure to a domestic supplier with a lower expected cost but a non zero chance of a higher cost than the foreign alternative. This aspect will be detailed in the next section.

7.2.5. Risk Averse Decisions

Understanding the effect of risk aversion from the OEM managers is very close to the situation described above where potential learning effects are not recognized. As described in section 3.5, the focus is on a situation where the prices of domestic components have a normal distribution around a mean value, rather than a certain value, together with the fact that the purchasing manager is risk averse. Under certain assumptions, this situation can be described by replacing the original price by $P_i^D \to P_i^D + r.\sigma_{\varepsilon_i}^2 / 2$, where r is the degree of risk aversion and σ_i^2 is the variance of the price of component *i*.

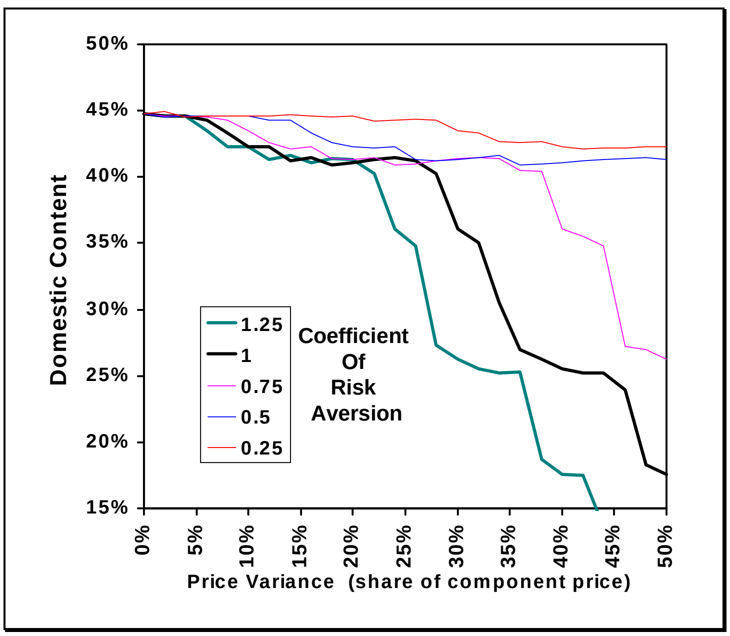
The importance of risk aversion depends on the potential variances associated with prices and with the degree of risk aversion. The variance is taken to be a share of the price of the component, varying between zero and half the expected price[54]. The coefficient of risk aversion

[54] A more general model could be considered, but that would mean that the component index generated through increasing cost ratio would no longer be valid. The solution could be achieved through a mixed integer programming analysis, that would yield similar results, although of less intuitive analysis.

will be assumed to go from zero to 1.25, to be able to evaluate a wide spectrum of risk aversion. The results of the estimates are presented in Figure 7–11.

As it can be seen from the figure, the impact of risk aversion on the degree of domestic content can be quite significant. Risk averse purchasing managers that face local component costs with variances below 35% of the expected cost will substantially reduce their level of domestic purchasing. These variances are rather small. For the average component that is bought by the OEM, which costs on the order of $35, this variance represents a standard deviation in cost on the order of $3.5, 10% of the price. As one would expect, as the degree of risk aversion is reduced, the impact on the level of domestic cost is much reduced.

Figure 7–11: The Impact of Risk Aversion in Domestic Sourcing



The reason small uncertainties on cost have an important impact on the level of domestic content is very similar to the reason that differences between private and social opportunity costs affect the level of domestic content, only with the reverse interpretation. As described in section 7.2.1, there are a large number of components whose cost difference between domestic and foreign sourcing is very small. Therefore, forcing some of these to be bought in the local economy beyond what would be natural generates a limited sourcing cost penalty, which may be overcompensated by the additional benefits that result from the differences in opportunity cost.

The risk-averse manager has precisely the opposite logic. Because there is a range of components with small differences in expected cost, even a small uncertainty will make him choose the foreign supplier with a price for sure, rather than a domestic one with uncertainty on cost. The idea is that, because the potential cost penalty of the imports is small, he prefers not to take any chances. The remedy discussed in section 3.5 may be the establishment of a preemptive domestic requirement that counters the aversion of the purchasing manager. If it enacts a regulation that is equal to the base level of domestic content, it forces the manager to choose the solution that an equivalent risk neutral manager would choose, with obvious benefits for the local economy.

7.3. Incentive Contracts, Asymmetric Information and Content Decisions

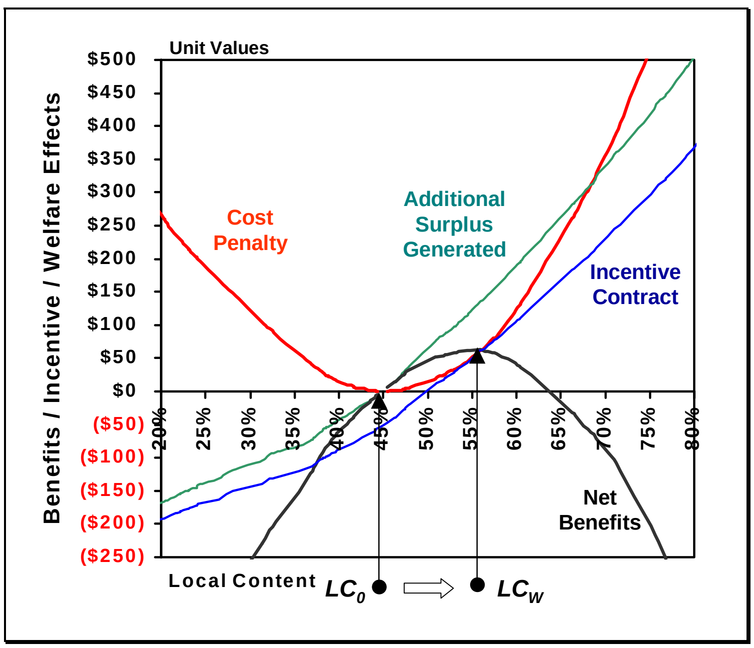
The previous section implemented the overall framework and the models discussed in chapter 3. It discussed the implications of domestic content policies for a range of market conditions, analyzing the circumstances under which the domestic market may benefit from this policy, as well as those where it is likely to hurt the economy. This section follows the approach and models presented in chapter 4. This chapter addressed contractual conditions and the mechanisms that local governments may use to maximize the benefit of the policy in the domestic market. In particular, it showed that, instead of demanding content levels, it was possible to establish incentive schemes that would lead the OEM to make the sourcing decisions according to the desires of the local government. This section presents the application of these models to the context of the automotive case study that has been the object of this chapter.

7.3.1. The Optimal Incentive Contract

Section 4.3.1 described the general case whereby the government receives increasing benefits from higher levels of domestic purchases, but the firm faces additional costs resulting from this increase in content. The equilibrium solution matches the findings of chapter 3. The general result is that components will be sourced in the domestic market until the marginal benefit to the government matches the marginal cost resulting from the subsidies awarded to compensate the OEM for the cost penalties it has to endure. The section also showed that, if both the government and the firm were aware of the cost structure of the components, it was possible to establish an optimal incentive scheme that would drive the OEM to choose the degree of domestic content that maximizes the result to the local economy.

This optimal incentive scheme was presented in equation (4-2). Its structure can be applied to the context of the automotive industry, according to the base model that has been described throughout this chapter. The results are presented in Figure 7–12, which adds to Figure 7–5 the incentive contract. This contract establishes the amount the government will offer the OEM as a function of the level of domestic content. This will be an additional source of revenue, which the firm will balance against the cost penalty of including more expensive domestic components. As expected, the results presented in the figure are consistent with the theory, showing that the benefits and costs for the firm are equalized at the optimal level of domestic content. The firm will be indifferent between this equilibrium and the original one, while the government maximizes surplus to the local economy.

Figure 7–12: Incentive Contract to Drive Domestic Content



A pertinent note in what concerns the analysis of domestic contents for the auto industry is the assessment of the structure of the incentive contract for this type of situation. For the situation illustrated in Figure 7–12, it can be shown that a polynomial of order 2 matches the incentive contact with a high degree of confidence (R^2=0.997). This suggests that a subsidy to be awarded to the investing OEM ought have an increase that is more aggressive than a linear dependence on the commitment of the firm to buy domestic components beyond its market level (Subsidy = -52.3 + 1751.3(LC-45%)^2 + 862.28(LC-45%)).

The shape of the incentive contract is determined by the benefit curve associated to the inclusion of domestic components. Sensitivity analysis to the various scenarios exposed in Figure 7–6 and a range of production volume indicates that, in general, an incentive contract for the auto industry with the aim of inducing higher levels of domestic content ought to be more aggressive than a linear one, but less than a full quadratic relationship.

7.3.2. Degree of Uncertainty, Government Menus and Firm Decisions

The results discussed in 4.3.1 and the application presented in the previous section relied on the assumption that the firm and the government had the same information regarding the cost structures of the components to be purchased. Nevertheless, there may be situations where this assumption is not true. In fact, it is reasonable to suppose that the OEM has more information than the government regarding the true costs of the components and that it tries to use it for its own advantage. Section 4.3.2 developed a simple model to study these effects, considering differences both in the cost penalty and in the benefits generated by increasing domestic purchases from the investing firm. The objective was to understand how this situation would affect the ability of the Government to enact efficient content policies, in particular its ability to establish incentive contracts. This section applies the asymmetric information model to the auto industry case study.

The application considers that the true cost of the domestic components is private information of the OEM. Domestic components will have either a base cost similar to the one presented in the section above (corresponding to the low cost $\underline{\beta}$ firm), or face a cost that includes an additional penalty (corresponding to high cost $\overline{\beta}$). The penalty is treated as a percentage increase over the base cost for every component that is bought in the domestic market. The OEM will be aware of which of the situations is true, but not the government, which will nevertheless know the probability that the cost of the domestic components cost is either the base cost or the high cost.

The benefit side is simplified, allowing each component to generate an identical surplus effect, regardless of its true cost[55]

The results of the theoretical model, detailed in Chapter 4, indicated that the incentive contract involves offering the investing OEM a menu that includes both a level of required domestic content and an associated subsidy targeted to the base cost $\underline{\beta} \rightarrow (\underline{t}, \underline{e})$, as well as one aimed towards the high cost scenario $\overline{\beta} \rightarrow (\bar{t}, \bar{e})$. The objective is to structure these offers to make sure that the OEM selects the option that fits its true cost structure, therefore revealing its type and maximizing the benefits to the local economy. The calculations show that the best incentive scheme that can be derived leads to an optimal choice of domestic content if the firm has the lower (base) cost, equivalent to the one that would be chosen in the case of full information, but a potential sub-optimal level of domestic content if the high domestic cost situation is verified. It also explains that the firm with the base cost will be able to extract subsidies from the government that go beyond what it would receive with full information.

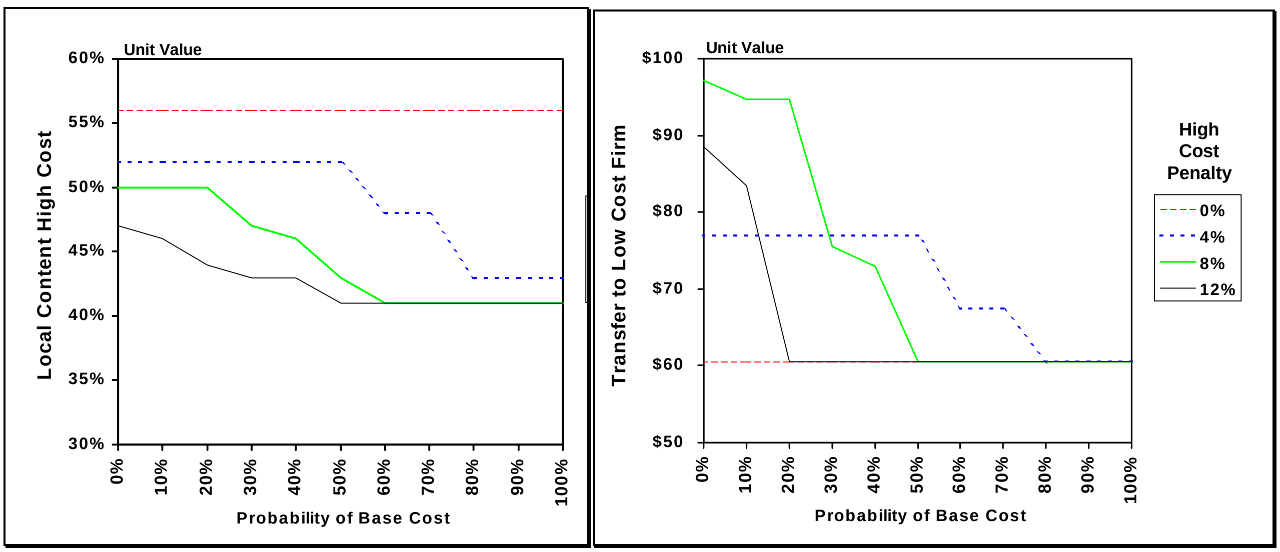
The reason for inefficient contracting is the ability of the low cost firm to mimic the behavior of the firm with high sourcing costs. To make sure that the OEM facing base costs chooses the optimal levels of domestic content and does not mimic the high cost behavior, the government uses two complementary mechanisms that drive the inefficiency of the contract: it may be less ambitious in the incentive contract towards the high cost and it may also award a subsidy targeting the base cost scenario that is greater than the value it would award with full information.

The auto application results for this second best contracting arrangement involve menus targeted both at the base cost and the high cost scenarios. For the menu targeted at the base case cost, a domestic content of 56% is always demanded (equal to the full information optimal content level) and the corresponding subsidy depends on the probability that the government is facing a

[55] A general discussion would consider the added costs to be generated by different underlying sourcing conditions (e.g. line efficiency) that would also affect the benefits generated to the domestic economy. Such an analysis was performed with similar results to those that are presented here. Nevertheless, because the interpretation of the full variation is less obvious, this simpler analysis is considered

higher domestic sourcing cost scenario and the particular cost penalty associated to it. The values for this subsidy transfer (represented as $\underline{t}(\rho,\xi)$) as a function of the probability of facing this higher domestic cost (ξ) and for several cost penalty scenarios (ρ) are shown on the right hand side of Figure 7–13. The left hand side shows the level of domestic content requirement targeted for the high cost scenario as a function of the same variables ($\bar{e}(\rho,\xi)$). The subsidy transfer for the high cost scenario, not shown in the graphs, is calculated as the value that exactly matches the cost penalty associated to reaching the required content level ($\bar{t}(\bar{e})$). The set of menus offered by the government can be represented as $\{(56\%,\underline{t}(\rho,\xi));(\bar{e}(\rho,\xi),\bar{t}(\bar{e}))\}$.

Figure 7–13: Menu of Contracts Offered as a Function of Uncertainty



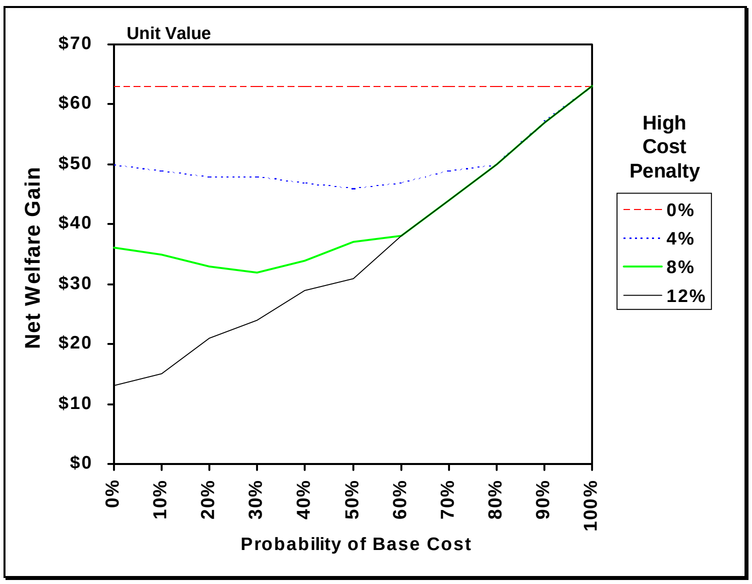
On the left hand side of Figure 7–13, it is possible to note that, if the government knows for sure that the OEM faces high costs (probability equal to zero), it will offer an optimal (first best) contract, similar to the one described in the beginning of the section, but adjusted to the higher cost conditions. Nevertheless, as the probability of facing base costs increases, the government will demand less content and award correspondingly lower subsidies for the high cost situation, eventually reaching the natural level of domestic content for the particular sourcing conditions (the domestic content when probability is one). When the domestic content reaches the natural level, the government stops considering it to be worthwhile to induce extra content from the high cost situation and will offer no subsidy at all. This is the extreme case of presenting the OEM with the choice of either no requirement and no subsidy, or a particular requirement and associated subsidy.

The ability of the lower cost OEM to extract extra rents from the government is clearly seen on the right hand side of the figure. To assure that the OEM does not mimic the higher cost situation, the government awards it with a subsidy that is greater than the value given out in the situation of full information (domestic content in the base cost scenario is always at the optimal level). As the probability of encountering a base cost situation increases, the need to award the extra subsidy is reduced, eventually reaching the base value of $61 dollars paid in the case of full information. Comparing the two graphs of Figure 7–13, it is also possible to see that a reduction in the probability of the base cost leads the government, initially to reduce the domestic content requirements in the part of the menu targeted for the higher cost situation, and only afterwards to start awarding extra subsidies to the base cost scenario.

An increasing gap between the base and the high cost scenarios has a different impact on in the two mechanisms discussed. The need to reduce content requirements for the high cost scenario is aggravated, since the ability to demand the optimal level of domestic content is reduced with the increasing cost penalty. The need to consider extra subsidies to the lower cost firm is less prevalent in the full range of probabilities as the cost penalty increases, but the values of these extra rents tend to be higher for greater cost penalties, up to a point. When the optimal level of domestic content for the high cost OEM reaches values close to the natural level of the base cost situation, the problems become separated and the need to award large rents is reduced. This is the reason why the transfer value with an 8% cost penalty is higher than the value for both the 4% and the 12% penalty levels. The separation is driven by the assumption that the OEM facing a base cost does not have an incentive to go below the natural level of domestic content. As a result, if the optimal domestic content for the high cost is below the natural content level for the base cost, the government offers a menu with two potential contracts that do not interact, the separation will be complete and the contract becomes efficient again.

Because asymmetric information limits the possibility of the government to establish efficient incentive contracts, its ability to maximize domestic welfare is reduced. This result is presented in Figure 7–14. To understand this reduction note that net welfare gains do not vary linearly with the probability. It was explained that a base cost probability of zero corresponds to an efficient contract to the high cost scenario, while a probability of 100% is also an efficient contract with the base cost situation. If the two situations were independent, the government would weigh the two scenarios according to their probabilities, leading to a straight line between the two extremes. Because of the inefficient contracting that arises from the incentive compatibility constraints, this is not possible and thus the net welfare gain is always below this optimal level. It also becomes clear from the graph the fact that reaching the natural level of domestic content in each of the cost penalty states limits the inefficiency. This is particular salient in the 12% cost penalty for the high cost scenario, where the contracting inefficiency is rather small.

Figure 7–14: Welfare Gain and Uncertainty in Sourcing Cost



These results and the ideas exposed in chapter 4 show how incentive contracts are key to the idea of using performance standards to promote for industrial development. As it was shown for this auto industry case, coupling content requirements with subsidies can be an optimal policy if there are underlying issues that prevent investing firms for making a natural choice that optimizes the welfare to the domestic economy. Nevertheless, it also becomes evident from the analysis that uncertainty hampers the ability of governments to enact contracts that drive OEM towards optimal decisions from the perspective of the domestic economy. Enabling knowledge in the government and minimizing uncertainty associated to a negotiation can critical for a successful contract and project.

7.4. Summary

This chapter analyzes the specific context of domestic content requirements, integrating the theoretical models presented in chapters 3 and 4 with the system cost model proposed in chapter 5 and the specific context of the auto industry supply chain presented in chapter 6.

The base scenario considers a market with no discernable external effects associated with the investment or the purchasing practices. The results confirm the typical conclusion that previous authors analyzing the effect of domestic content policies, whereby enacting domestic content requirement will always have a negative economic welfare effect. Similarly, it is also shown that the welfare effect of a tariff policy is always substantially inferior to the one resulting from a content requirement. For small deviations away from the natural content level, the magnitude of the relative difference is particularly important as tariffs may reduce welfare as much as nine times more than domestic content.

In the presence of external effects, the results confirm that there is a net benefit to an increase in domestic content beyond the natural level of sourcing. For the base case considered in the analysis, shifting the domestic content to this optimal level has a meaningful impact on the economy, with annual domestic sales of components increasing by 20% and the net external value growing by 13%. Nevertheless, the optimal level of domestic content and the related market effects depend on a number of variables, in particular the production volume of the vehicle and the opportunity cost of capital. Therefore, domestic content policies should be considered case-by-case. For very small scales, in particular, there seems to be little potential welfare improvements that can be generated through content requirements.

The model evaluation is then used to consider explicit learning mechanisms associated with cumulative output of the industry and the firm. As expected, these effects justify an increase in the level of domestic content An important aspect to note is that, within the reasonable levels of learning considered in the analysis, the optimal domestic sourcing decisions are similar to those justified through gaps in the valuations of the critical resources. If one considers that learning effects are embedded in the use of capital and human resources in the suppliers, then the two approaches converge and the comparable empirical results work as a confirmation of this idea.

The contracting analysis shows that, for the particular situation considered, a polynomial of order 2 matches the incentive contact with a high degree of confidence. In the presence of asymmetric information the incentive contract involves offering the investing OEM a menu that includes both a level of required domestic content and an associated subsidy targeted to the base cost as well as one aimed at the high cost scenario. The results show the expected contract inefficiency that results from the differences in information between the government and the firms, but only up to a point. Large cost gaps create a natural separation between potential players that enable the government to offer two contracts without the problem of having the low cost firm mimicking the high cost one.

Finally, the analysis associated with risk averse purchasing managers shows how this is pressing problem, as it may lead to substantial reductions in the level of domestic purchasing, even with modest uncertainty on domestic component costs.

Chapter 8.
Conclusions and Future Work

8.1. Conclusions

This thesis addresses the question of performance standards in developing nations, focusing on the role of local content requirements. Initial chapters proposed a theoretical framework to understand the impact of these policies on the decisions of the firms and the welfare of the domestic economy, while the later chapters offer a methodology to apply the analysis for the context of the automotive industry.

The first important conclusion deriving from the theoretical analysis presented in chapter 3 is that the policy of content requirements is superior to the use of tariffs and subsidies as a means to increase the share of domestic purchases from the OEM. The key intuition as to why this may be the case is the fact that the government is setting a standard, but relying on the OEM to make the decisions on how to comply, the government benefits from the firm’s ability to minimize potential negative impacts on its cost and, as a result, on the overall economy.

The second and central conclusion of the thesis relates to the existence of gaps between private and social opportunity costs of the resources employed in the OEM and its suppliers. In a developing country, a new foreign OEM investment generates a unique occasion for a set of local firms to enter into the manufacturing of complex products. Because of spillovers and learning effects, this possibility tends to propel the overall capability of the industry to levels that would not be attainable by alternative means. In some circumstances, these industry external effects may not be accounted in the valuations of private economic agents. If these effects depend on the breadth of the supplier structure, there will be an externality-from-entry associated with domestic suppliers that drives a gap between social and private valuation. This gap generates the opportunity for the enactment of domestic content requirements. The analysis shows that local content requirements can improve welfare as long as the opportunity cost gap of the components sourced beyond the OEM market decision is above the cost penalty associated with them.

Chapter 4 discusses implementation. Subsidies and requirements coupled through reciprocity principles act as incentive mechanisms that align the OEM decision with the optimal for the domestic economy. Nevertheless, the analysis also shows that uncertainty concerning the effects of content requirements on the cost structures of the firms reduces the ability of the government to have efficient incentive contracts and thus to improve domestic welfare.

A case study for the automotive industry, where content restriction policies are extremely active, is used to demonstrate the applicability of the model. This entailed the development of a new methodology, called Systems Cost Modeling (SCM), which proposes simple metrics and rules to build bottom-up cost structures where estimates for large number of components have to be considered. Detailed empirical data from a particular car is then used to build a sourcing cost structure. These costs are integrated with the content model to show that, for existing market and policy conditions there is value to the enactment of modest levels of domestic content requirement in the auto industry. It also shows that the impact of the policy is very sensitive to project characteristics and that this should be factored in the policy decisions of the nations.

There are also a number of insights that the model and application provide:

- <u>The social opportunity cost requirement</u>. Domestic content requirements are relevant for economies when differences between social and private opportunity costs exist. In an economy where social and private cost of the resources used in manufacturing components that result from the requirement policy are close, the requirement policy is bound to have a negative effect. This could be because the knowledge is already present or because there are alternative uses for the resources that are equally beneficial for the society. This is the case in advanced economies, where the same resources devoted to research and development are likely to generate greater benefits to the society.

- <u>Value at the margin</u>. Domestic content requirements are likely to be effective in regions where the overall technology gap of the components that are forced into local production is small. In this situation, the cost penalty is likely to be small and the region is able to realize the most from potential external-benefits from entry.

- Unique policies are not feasible. As illustrated, the optimal level of domestic content depends on a number of variables, in particular the production volume of the vehicle. Therefore, it is insufficient to establish only one measure of domestic content, but rather it should part of a case-by-case negotiation.

- Coupling requirements and subsidies is optimal. Coupling content requirements with subsidies can be an optimal policy to drive investing firms to make a choice that optimizes the welfare of the domestic economy without hurting their competitive ability. Nevertheless, uncertainty hampers the ability of governments to enact these contracts.

- Greedy government. Domestic requirements have a clear upper bound. Therefore, governments that are too greedy and demand too high a level of content are likely to severely hurt the economy. In adverse situations, often associated with small production volumes, it may be virtually impossible to have a positive effect from the regulation.

- Cooperative approaches. Governments and firms are likely to mutually gain by cooperating up-front in the decisions regarding local purchasing and subsidies. A careful balance between the two aspects is likely to propel the economy into a higher level of welfare, while leaving the investing firm indifferent.

- The importance of learning. As shown in the analysis, the presence of learning effects that are not internalized in the decisions of the firms can justify the enactment of content requirements. Moreover, they will benefit both the investing firm and the local economy.

- Risk averseness. Domestic content requirements can also be used to dampen potential risk averse behavior from the purchasing manager at the local plant.

These conclusions provide a good explanation regarding why it is possible to find situations where domestic content requirement have had a positive effect on the economy and others where the policy is disastrous. A government that forces high levels of domestic content in a context where cost penalties are high will never be able to recoup the costs to the economy through external effects. It also helps to explain why, in situations where the cost penalty is small (and often paid by subsidies) and local jobs are being generated, managers in the investing OEM may feel indifferent or even have a positive attitude towards local content requirements. A final aspect that the analysis presented in this thesis exposes the need for additional empirical research associated with the conditions under which linkages generate learning in the local firms.

8.2. Future Work

As expected, the research work raises a number of additional questions that are not directly addressed in the work presented here. Some of these that are of particular significance in terms of future work are discussed below.

The analysis of the thesis has shown that the results of the models are sensitive to the ability of local suppliers to improve their manufacturing cost through learning. Therefore, this is an area where it is important to develop further research. While learning has been considered an exogenous mechanism in this dissertation, it is important to change this aspect and incorporate endogenous supplier learning.

The intuitive idea is that if local suppliers are expected to learn as they work with foreign multinationals, government could be more aggressive in terms of local content requirements. Nevertheless, because these same local firms may feel that they are shielded by government regulation, they may have fewer incentives to invest in learning. Understanding the dynamics of this relationship is the objective of this section of the proposed research.

Another area where further work is appropriate is in the decision of the OEM to invest. The research presented in the dissertation assumes the decision to invest in the particular region under analysis to have already taken place. Nevertheless, competition for foreign investments has become increasingly important. Therefore, it is important to understand how competition for foreign investment may affect the results of the models presented in the dissertation. The avenue to pursue is to couple the models discussed in the thesis with a model of government competition for multinational investment.

One of the aspects of the thesis where significant future development can be made is in the System Cost Model described in chapter 5. The critical issue is refining the estimation process used for each of the technologies. This will entail gathering component and processing conditions data for each process to enable more accurate estimates of the functional relationships between component characteristics and fixed costs, labor utilization and cycle time. The first step is refining the factor relations that establish the relative importance of complexity and weight. A second step is to have enough information to enable direct regression estimates.

A different level of development is related to alternative applications of the systems cost model in the study of global supply chain dynamics, in the auto industry or elsewhere. The ability to have estimates for the complete supply chain cost structure of a product, as well as the capacity to evaluate cost sensitivity to key parameters, can be of relevance to examine issues ranging from distribution strategies to global capacity management or e-commerce cost savings. Any of them provide an avenue of research that can be pursued.

Chapter 9. Appendix

9.1. Appendix with Details of the Demonstrations of Chapter 4

9.1.1. Calculations for Asymmetric Information

First, the implications of the four constraints for the behavior of both the government and the firms are examined. First lets consider the ICCs. Adding them up one gets:

$$S(\overline{e},\underline{\beta})+S(\underline{e},\overline{\beta})-S(\underline{e},\underline{\beta})-S(\overline{e},\overline{\beta})\geq 0 \Leftrightarrow$$

$$\Leftrightarrow \int_{\underline{\beta}}^{\overline{\beta}} S'_{\beta}(\underline{e},\beta)-S'_{\beta}(\overline{e},\beta)d\beta \geq 0 \Leftrightarrow \int_{\underline{\beta}}^{\overline{\beta}}\int_{e(\underline{\beta})=\underline{e}}^{e(\overline{\beta})=\overline{e}} S''_{e\beta}(e,\beta)ded\beta \leq 0$$

For this to be verified, the profit function of the firms should verify the single crossing property (SC), which can be translated as:

$$\frac{\partial}{\partial\beta}\left[-\frac{\partial\Pi/\partial e}{\partial\Pi/\partial t}\right]>0 \Leftrightarrow \frac{\partial^2 S(e,\beta)}{\partial\beta\partial e}>0 \Leftrightarrow S''_{e\beta}(e,\beta)>0$$

This result is consistent with our assumptions, provided that $\overline{\beta}>\underline{\beta}$ and $\frac{\partial e}{\partial\beta}<0$ (which can be understood as more cost penalty inducing less content effort).

The solution of the constrained maximization problem involves some useful simplifications. First, it is not difficult to see that, if IC1, IC2 and PC2 are valid, then PC1 is automatically verified (since the low cost firm is better off than if it would choose to play the role of the high cost one). Second, following the literature, the analysis initially ignores IC2, and then later verifies that it holds with the solution found.

The Lagrangean is:

$$L = \xi\left[V(\underline{e},\underline{\beta}) - (1+\psi)\underline{t}\right] + (1-\xi)\left[V(\bar{e},\bar{\beta}) - (1+\psi)\bar{t}\right] - \lambda\left[\underline{t} - S(\underline{e},\underline{\beta})) - \bar{t} - S(\bar{e},\underline{\beta})\right] - \mu(\bar{t} - S(\bar{e},\bar{\beta}))$$

The first order conditions are:

$$\frac{\partial L}{\partial \underline{e}} = \xi V_e^{'}(\underline{e},\underline{\beta}) + \lambda S_e^{'}(\underline{e},\underline{\beta}) = 0 \Leftrightarrow \xi V_e^{'}(\underline{e},\underline{\beta}) = -\lambda S_e^{'}(\underline{e},\underline{\beta})$$

$$\frac{\partial L}{\partial \bar{e}} = (1-\xi) V_e^{'}(\bar{e},\bar{\beta}) - \lambda S_e^{'}(\bar{e},\underline{\beta}) + \mu S_e^{'}(\bar{e},\bar{\beta}) = 0$$

$$\frac{\partial L}{\partial \underline{t}} = -\xi(1+\psi) - \lambda = 0 \Leftrightarrow -\lambda = \xi(1+\psi)$$

$$\frac{\partial L}{\partial \bar{t}} = -(1-\xi)(1+\psi) + \lambda - \mu = 0 \Leftrightarrow \xi(1+\psi) - (1+\psi) - \xi(1+\psi) = \mu$$

$$(1-\xi) V_e^{'}(\bar{e},\bar{\beta}) + \xi(1+\psi) S_e^{'}(\bar{e},\underline{\beta}) - (1+\psi) S_e^{'}(\bar{e},\bar{\beta}) = 0 .$$

The equilibrium solution is:

For $\bar{\beta}$: $\dfrac{V_e^{'}(\bar{e}^{*},\bar{\beta})}{1+\psi} = S_e^{'}(\bar{e}^{*},\bar{\beta}) + \dfrac{\xi}{1-\xi}\left[S_e^{'}(\bar{e}^{*},\bar{\beta}) - S_e^{'}(\bar{e}^{*},\underline{\beta})\right].$

Noting that it is possible to write $\Phi^{'}(e) = S_e^{'}(e,\bar{\beta}) - S_e^{'}(e,\underline{\beta}) = \int_{\underline{\beta}}^{\beta} S_{e\beta}^{''}(e,\beta)d\beta$, then the result can be summarized as:

For $\bar{\beta}$: $\dfrac{V_e^{'}(\bar{e}^{*},\bar{\beta})}{1+\psi} = S_e^{'}(\bar{e}^{*},\bar{\beta}) + \dfrac{\xi}{1-\xi}\Phi^{'}(\overline{e^{*}})$

For $\underline{\beta}$: $\dfrac{V_e^{'}(\underline{e}^{*},\underline{\beta})}{1+\psi} = S_e^{'}(\underline{e}^{*},\underline{\beta})$

To see that the low cost firm derives an extra rent, consider IC1:

$$\underline{t} - S(\underline{e},\underline{\beta}) = \bar{t} - S(\bar{e},\underline{\beta}) \Leftrightarrow \underline{t} - S(\underline{e},\underline{\beta}) = \underbrace{\bar{t} - S(\bar{e},\overline{\beta})}_{=0, because of PC2} + S(\bar{e},\overline{\beta}) - S(\bar{e},\underline{\beta}) \Leftrightarrow$$

$$\Leftrightarrow \underline{t} - S(\underline{e},\underline{\beta}) = \int_{\underline{\beta}}^{\overline{\beta}} S_{\beta}(\bar{e},\beta)\,d\beta = \Phi(\bar{e})$$ <= This is the extra rent derived by the able firm.

9.1.2. Deviations from Optimality

When the government can only offer one contract, it maximizes the expected result, subject to the firms' participation constraints:

$$\underset{e,t}{Max}: \xi\left[V(e,\underline{\beta}) - (1+\psi)t\right] + (1-\xi)\left[V(e,\overline{\beta}) - (1+\psi)t\right]$$

s.t. the khun-tucker conditions

$$\underline{\Pi^0} + t - S(e,\underline{\beta}) \geq \underline{\Pi^0} \text{ or } S(e,\underline{\beta}) - t + S_{\lambda} \leq 0 \qquad \text{(a)}$$

$$\overline{\Pi^0} + t - S(e,\overline{\beta}) \geq \overline{\Pi^0} \text{ or } S(e,\overline{\beta}) - t + S_{\alpha} \leq 0 \qquad \text{(b)}$$

The first order conditions are:

$$\xi.V_e^{'}(e,\underline{\beta}) + (1-\xi)V_e^{'}(e,\overline{\beta}) - \lambda S_e^{'}(e,\underline{\beta}) - \alpha.S_e^{'}(e,\overline{\beta}) = 0$$

$$\xi(-(1+\psi)) + (1-\xi)(-(1+\psi)) + \lambda + \alpha = 0$$

$$2\lambda S_{\lambda} = 0;\ 2\alpha S_{\alpha} = 0$$

Given that, by assumption, $S_{e\beta}^{''} > 0 \Rightarrow S(e,\overline{\beta}) > S(e,\underline{\beta}) > 0 \Rightarrow S_{\alpha} = 0$, the result is:

$$\xi.V_e^{'}(e,\underline{\beta}).+(1-\xi)V_e^{'}(e,\overline{\beta}) = (1+\psi)S_e^{'}(e,\overline{\beta}) \text{ or}$$

$$V_e^{'}(e^*,\overline{\beta}) - \xi.\int_{\underline{\beta}}^{\overline{\beta}} V_{\beta e}^{''}(e^*,\beta)d\beta = (1+\psi)S_e^{'}(e^*,\overline{\beta})$$

A different outcome happens when the difference in marginal benefit from domestic content requirements between the low and high cost firm is very large. The government will choose to shut down the high cost firm if the expected benefits of having this type of firm doing the project are below the rents that the government is giving away in case it gets a low cost type (this means dropping the khun tucker condition (b) above). In this situation, the government will always require a high level of content requirement, offering the appropriate high incentives. This happens when:

$$\xi\left[V(\underline{e},\underline{\beta}) - (1+\psi)(S(\underline{e},\underline{\beta}) + \Phi(\bar{e}))\right] + (1-\xi)\left[V(\bar{e},\overline{\beta}) - (1+\psi)S(\bar{e},\overline{\beta})\right] <$$

$$< \xi\left[V(\underline{e},\underline{\beta}) - (1+\psi)S(\underline{e},\underline{\beta})\right] \Rightarrow (1-\xi)/(1+\psi)V(\bar{e},\overline{\beta}) < S(\bar{e},\overline{\beta}) + \xi\Phi(\bar{e})$$

This holds if Φ(e) is large enough, which is equivalent to have $S_{e\beta}^{''}(e,\beta) >> 0$.

9.2. *Information for SCM Calculations in Chapters 5 and 6*

Table 9–1: Material Prices Used in Calculations

MATERIAL	PRICE ($/Kg)		MATERIAL	PRICE ($/Kg)	
ABS	$	1.60	PHENOLIC RESIN	$	2.00
ABS/PC	$	3.50	PMMA	$	3.00
AL	$	1.60	POLYESTER	$	2.50
ASA	$	2.00	POM	$	3.00
BR	$	3.50	PP	$	0.95
BRASS	$	3.50	PP/EPDM	$	1.00
CAST IRON	$	0.10	PPE/PA	$	3.00
CHARCOAL	$	0.08	PPE+SB	$	3.00
CU	$	3.70	PPO	$	3.00
EPDM	$	2.00	PP-T20	$	0.95
FABRIC	$	1.00	PP-T40	$	0.95
FIBER	$	0.10	PS	$	1.50
FIBERBOARD	$	0.50	PUR	$	2.00
GLASS	$	0.70	PVC	$	1.20
HDPE	$	1.10	RUBBER	$	0.70
LEAD	$	1.00	SHODDY	$	0.20
MG	$	3.10	SMC	$	2.00
PA-6	$	3.50	S-RIM	$	2.00
PA-66	$	3.50	STAINLESS STEEL	$	1.00
PAPER	$	0.70	STEEL	$	0.77
PBT	$	2.00	TEO	$	1.70
PC	$	3.70	TPO	$	1.70
PC/PBT	$	3.50	TPU	$	4.00
PE	$	2.00	VINYL	$	3.50
PET	$	2.00	ZN	$	1.25

Table 9–2 Base Inputs for Foreign Component SCM Estimation

GENERAL INPUTS		LOGISTICS INPUTS	
Annual Line Volume	200,000	Steel Density (g/cm3)	7.8
Annual Product Volume	200,000	Plastics Density (g/cm3)	1.2
Years of production	5	Aluminum Density (g/cm3)	2.7
Life of Equipment	10	Packing Density Factor 1	10
Interest Rate	12%	Packing Density Factor 2	20
Building Cost % of Equipment	6%	Packing Density Factor 3	40
Maintenance Cost	10%	Packing Density Factor 4	2
Overhead Labor	50%	Container Size (m^3)	68
Overhead Fixed	25%	Container Max Load (Kg)	26,500
Auxiliary Equipment % Equipment	25%	Packing Container Factor	80%
Equipment Installation Cost	15%	Area of pack cardboard p/ truck	425
Energy / Other Cost % of Material	3%	Cost of Cardboard Packing (/m^2)	$0.50
Line Utilization	87.5%	Cost of Transatlantic container	$2,000
Days per Year	240	Transportation period (days)	20
Number of Shifts	2	Shipping Insurance (%FOB)	2%
Wage ($/hour inc benefits)	$20	Cost of Truck per Km	$1.25
Dedicated (0 to 1of free cap)	0%	Truck Procurement cost	$200
Dedicated Simple (% dedicated)	0%	Truck Distance (Km)	1,000
Mass cutoff for simple parts (g)	-	Inventory (% Sales)	4.0%
Development Margin (% Sales)	4.0%		

Table 9–3 Base Inputs for Domestic Component SCM Estimation

GENERAL INPUTS		LOGISTICS INPUTS	
Annual Line Volume	35,000	Steel Density (g/cm3)	7.8
Annual Product Volume	35,000	Plastics Density (g/cm3)	1.2
Years of production	5	Aluminum Density (g/cm3)	2.7
Life of Equipment	10	Packing Density Factor 1	10
Interest Rate	20%	Packing Density Factor 2	20
Building Cost % of Equipment	6%	Packing Density Factor 3	40
Maintenance Cost	10%	Packing Density Factor 4	2
Overhead Labor	50%	Container Size (m^3)	33.4
Overhead Fixed	25%	Container Max Load (Kg)	21,700
Auxiliary Equipment % Equipment	25%	Packing Container Factor	80%
Equipment Instalation Cost	15%	Area of pack cardboard p/ truck	225
Energy / Other Cost % of Material	3%	Cost of Cardboard Packing (/m^2)	$0.50
Line Utilization	75.0%	Cost of Transatlantic container	-
Days per Year	260	Transportation period (days)	1
Number of Shifts	2	Shipping Insurance (%FOB)	-
Wage ($/hour inc benefits)	$6	Cost of Truck per Km	$1.00
Dedicated (0 to 1of free cap)	50%	Truck Procurement cost	$125
Dedicated Simple (% dedicated)	0%	Truck Distance (Km)	500
Mass cutoff for simple parts (g)	1000	Inventory (% Sales)	6.0%
Development Margin (% Sales)	4.0%		

Table 9–4: Key Parameters for Technologies Considered in the SCM Estimation Process

CODE	PROCESS	MASS		MACHINE COSTS	(x US$ 1,000)			TOOL COSTS	(x US$ 1,000)			CYCLE TIME	(sec)			LABOR UTILIZ	(number of workers)		
		Min	**Max**	**Factor**	**A**	**b**	**c**	**Factor**	**A**	**b**	**c**	**Factor**	**A**	**b**	**c**	**Factor**	**A**	**b**	**c**
		kg	kg																
11	Sand Casting	0.1	30	80%	230.85	49%	19%	50%	56.33	45%	60%	34%	101	23%	29%	80%	1.00	0%	0%
16	Die Casting	0.1	12	80%	749.34	48%	18%	50%	143.13	28%	50%	34%	32	54%	36%	80%	0.52	20%	13%
18	Lost Foam Casting	0.1	5	80%	292.68	47%	17%	50%	118.22	20%	39%	34%	142	37%	30%	80%	0.71	15%	10%
21	Roll forming	0.1	5	80%	116.36	37%	16%	50%	33.64	83%	61%	67%	4	35%	84%	80%	0.32	20%	12%
22	Forging	0.1	15	80%	713.59	46%	18%	50%	194.43	29%	52%	34%	29	39%	33%	80%	0.51	19%	13%
23	Extrusion	0.1	5	80%	232.72	37%	16%	50%	107.15	15%	34%	67%	44	7%	35%	80%	0.58	25%	13%
24	Stamp Press (Tandem)	0.1	15	80%	864.86	64%	20%	50%	176.19	55%	60%	67%	11	15%	67%	80%	1.55	19%	13%
25	Stamp Press (Transfer)	0.1	15	80%	3,867.57	29%	16%	50%	556.29	27%	50%	67%	3	21%	77%	80%	1.75	24%	15%
28	Bending	0.1	10	80%	268.33	13%	10%	50%	60.83	48%	58%	67%	24	21%	74%	80%	1.00	0%	0%
29	Coiling	0.1	3	80%	170.54	23%	12%	50%	15.86	50%	54%	67%	10	35%	80%	80%	0.63	28%	13%
31	Turning	0.1	5	80%	65.24	81%	20%	50%	6.35	10%	26%	34%	81	31%	28%	80%	0.47	37%	16%
34	Milling	0.1	5	80%	65.24	81%	20%	50%	6.35	10%	26%	34%	94	59%	35%	80%	0.47	37%	16%
38	Machining Center	2	35	80%	268.66	90%	19%	50%	9.06	14%	26%	66%	24	35%	73%	80%	0.37	43%	15%
51	Injection Molding	0.1	10	80%	349.28	54%	19%	50%	108.17	56%	60%	34%	47	54%	35%	80%	0.53	21%	13%
52	Blow Molding	0.1	2	80%	301.33	48%	16%	50%	84.27	45%	50%	67%	21	117%	99%	80%	0.69	32%	13%
53	Transfer Molding	0.1	10	80%	286.36	46%	18%	50%	64.81	33%	53%	34%	113	91%	37%	80%	0.53	21%	13%
55	RIM/Foam Molding	0.1	10	80%	559.02	35%	17%	50%	93.54	27%	49%	67%	49	15%	64%	80%	0.53	21%	13%
56	Compression Molding	0.1	15	80%	197.24	42%	18%	50%	65.67	34%	54%	67%	45	21%	77%	80%	0.51	19%	13%
6	Extrusion (plastic)	0.1	2	80%	150.67	48%	16%	50%	37.42	10%	20%	67%	28	27%	69%	80%	0.69	32%	13%
100	Thermoforming	0.1	5	80%	55.76	27%	14%	50%	57.27	28%	46%	67%	52	18%	64%	80%	0.53	21%	13%
101	Hand Lay-up	0.5	5	80%	8.12	70%	17%	50%	32.71	12%	20%	34%	155	37%	23%	80%	1.00	0%	0%
102	SMC, Preform	0.5	5	80%	441.21	82%	18%	50%	236.70	24%	32%	67%	72	14%	41%	80%	1.19	26%	10%
104	Filament Winding	0.05	2	80%	552.21	57%	18%	50%	19.96	46%	54%	67%	29	22%	69%	80%	0.72	26%	13%
105	Vulcanization	0.1	10	80%	286.36	46%	18%	50%	34.64	24%	46%	67%	37	43%	92%	80%	0.53	21%	13%
1064	GMAW/FCAW-MIG	0.1	15	80%	719.20	56%	19%					67%	52	-6%	-134%	80%	0.88	24%	15%
111	Nonwoven Technology	0.1	5	80%	172.52	54%	18%	50%	38.18	28%	46%	67%	17	25%	144%	80%	1.03	31%	15%
99	Assembly	0.01	15	80%	100.18	77%	20%					34%	6	15%	178%	80%	1.53	6%	10%
666	Electro-Mechanical	0.01	3.5	50%	2,733.14	7%	26%	50%	87.05	35%	56%	67%	8	13%	132%	80%	1.57	11%	10%
777	Harness	0.01	6	50%	54.34	37%	59%												

Table 9–5: Component List and Characteristics (weight > 100g; * means same as before)

NUNMBER	ASSEMBLY	GROUP	ASSEMBLY DESCRIPTION	COMPONENT DESCRIPTION	MASS (g)	MATERIAL TYPE	MIXED WITH	SHARE 1st MATERIAL	QUANTITY	COMPLEXITY	PROCESS 1	PROCESS 2	PROCESS 3
1	1	1	AIR CLEANER	HOUSING UPPER	572.8	PA-66	-	100%	1	1	51	888	888
3	1	1	AIR CLEANER	HOUSING LOWER	754.4	PA-66	-	100%	1	1	51	888	888
6	1	1	AIR CLEANER	FILTER	228.6	PAPER	EPDM	100%	1	1	50	888	888
10	1	1	AIR CLEANER	BRACKET	255.8	STEEL	-	100%	1	1	24	888	888
12	1	1	AIR CLEANER	DUCT	149.6	PA-66	-	100%	1	1	51	888	888
13	1	1	AIR CLEANER	MUFFLER	862.2	PA-66	STEEL	60%	1	1	52	888	24
17	1	1	AIR CLEANER	DUCT	501.8	EPDM	-	100%	1	1	6	105	888
22	1	1	AIR CLEANER DUCT ASSY	DUCT	174.4	PA-66	-	100%	1	1	6	105	888
28	1	1	AIR CLEANER DUCT ASSY	MUFFLER	514.6	PP	-	100%	1	2	52	888	888
37	2	1	AIR CLEANER MASS AIR FLOW SENSOR	HOUSING	355	AL	-	100%	1	1	16	31	888
38	3	1	CAMSHAFT	CAMSHAFT	2169.6	STEEL	-	100%	2	3	22	38	888
42	3	1	CAMSHAFT	VALVE	339.6	STEEL	-	100%	1	3	22	31	888
43	3	1	CAMSHAFT	GEARS	1036.5	STEEL	-	100%	2	3	18	31	888
47	3	1	CAMSHAFT	SOLINOID	341.8	AL	CU	75%	1	1	16	31	104
49	4	2	CARRIER CASE	CATALYTIC CONVERTER	7720	STEEL	STEEL	60%	1	3	24	1064	24
52	4	2	CARRIER CASE	BRACKET	600.8	STEEL	-	100%	1	1	24	1064	888
59	6	1	COIL	BRACKET	460.6	STEEL	-	100%	1	1	24	888	888
61	6	1	COIL	COIL	983.4	STEEL	CU	75%	1	2	18	666	104
67	7	1	CRANKSHAFT	CRANSHAFT	14857.2	STEEL	-	100%	1	3	22	38	888
68	7	1	CRANKSHAFT	CAP	347.16	STEEL	-	100%	5	2	24	888	888
71	7	1	CRANKSHAFT	PULLEY	1441.2	STEEL	-	100%	1	1	22	31	888
74	7	1	CRANKSHAFT	GEARS	323.6	STEEL	-	100%	1	3	18	31	888
76	8	1	CYLINDER BLOCK LOWER	ENGINE BLOCK	5566.6	AL	-	100%	1	3	16	38	888
81	9	1	CYLINDER BLOCK SEAL REAR	COVER	208.6	AL	-	100%	1	1	16	31	888
83	10	1	CYLINDER BLOCK UPPER	ENGINE BLOCK	33800	CAST IRON	-	100%	1	3	11	38	888
94	11	1	CYLINDER BLOCK UPPERPCV VALVE	HOUSING	353.8	STEEL	-	100%	1	1	24	888	888
100	13	1	CYLINDER HEAD	CYL HEAD	12209.4	AL	-	100%	1	3	16	38	888
104	13	1	CYLINDER HEAD	GASKET	227.2	STEEL	-	100%	1	2	18	31	888
105	13	1	CYLINDER HEAD	BRACKET	326	STEEL	-	100%	1	1	24	888	888
126	14	1	ELEC ENG CNTRL	BRACKET	101	POM	STEEL	100%	1	1	51	888	888
129	14	1	ELEC ENG CNTRL	HOUSING	229	AL	-	100%	1	1	16	31	888
130	14	1	ELEC ENG CNTRL	CIRCUIT BOARD	458.4	AL	CU	100%	1	3	999	888	888
132	15	1	ENGINE ASSY	SERPENTINE BELT	222.4	EPDM	-	100%	1	2	56	105	888
133	15	1	ENGINE ASSY	CRADLE	20560	STEEL	STEEL	50%	1	2	24	1064	24
134	15	1	ENGINE ASSY	CRADLE	170.05	STEEL	-	100%	4	1	24	888	888
135	15	1	ENGINE ASSY	TENSIONER	311.6	STEEL	AL	50%	1	1	24	888	16
137	15	1	ENGINE ASSY	BRACKET	738.4	STEEL	-	100%	1	1	24	888	888

140	15	1	ENGINE ASSY	MOUNT	1388.4	AL	RUBBER	80%	1	2	16	31	56
153	15	1	ENGINE ASSY IDLER PULLY	PULLEY	206.8	STEEL	-	100%	1	1	22	31	888
156	15	1	*	BEARING	128.6	STEEL	-	100%	2	2	22	31	888
160	15	1	ENGINE ASSY OIL FILTER	FILTER	650.4	STEEL	-	100%	1	1	24	1064	888
165	15	1	ENGINE ASSY TENSIONER	TENSIONER	411	STEEL	AL	50%	1	1	24	888	16
171	16	1	ENGINE ASSY THERMOSTAT	HOUSING LOWER	397.4	PHENOL RESIN	AL	100%	1	2	51	888	888
175	17	1	EXHAUST ASSY	HEAT SHEILD	364.76	AL	-	100%	5	1	24	888	888
176	17	1	EXHAUST ASSY	HEAT SHEILD	510.6	STEEL	-	100%	1	1	24	888	888
179	17	1	EXHAUST MANIFOLD	MANIFOLD	4738.2	CAST IRON	-	100%	1	3	18	31	888
188	18	1	FRONT END ASSY HALF SHAFT LEFT	SHAFT	3935	STEEL	-	100%	1	3	22	38	888
190	18	1	*	COVER	1502.2	STEEL	-	100%	1	1	24	31	888
191	18	1	*	BOOT	154.2	PVC	-	100%	2	1	51	888	888
193	19	1	FRONT END ASSY HLF SHAFT RIGHT	SHAFT	2352.2	STEEL	-	100%	1	3	22	38	888
194	19	1	*	BRACKET	148	STEEL	-	100%	1	1	24	888	888
196	19	1	*	SHAFT	5967	STEEL	-	100%	1	3	22	38	888
198	19	1	*	BOOT	151.7	PVC	-	100%	2	1	51	888	888
201	19	1	*	BRACKET	380.8	AL	STEEL	100%	1	1	24	888	888
215	20	1	FUEL INJECTION-GAS FUEL ASSY	RAILS	263.2	AL	-	100%	1	1	24	31	888
220	21	1	MASTER CYLINDER	HOUSING	341.2	AL	-	100%	1	1	16	31	888
230	21	1	*	RESERVOIR	143.8	PP	-	100%	1	1	52	888	888
235	22	2	MUFFLER	MUFFLER/RESIN	14900	STEEL	STEEL	50%	1	3	24	1064	24
236	22	2	MUFFLER	BRACKET	182.4	STEEL	-	100%	1	1	24	888	888
239	23	1	OIL PAN	PAN	1265.8	STEEL	-	100%	1	1	24	31	888
242	24	1	OIL PUMP	COVER	364.8	STEEL	-	100%	1	2	24	31	888
245	24	1	OIL PUMP	HOUSING	759	AL	-	100%	1	1	16	31	888
247	24	1	OIL PUMP	ROTOR	188.6	STEEL	CU	75%	1	2	18	666	104
252	24	1	OIL PUMP PICKUP TUBE	TUBE	296	STEEL	-	100%	1	1	21	28	888
255	25	1	PISTON	PISTON	296.2	AL	-	100%	4	3	16	38	888
258	26	1	PISTON ROD ASSY	ROD	331.4	STEEL	-	100%	4	1	22	31	888
260	26	1	PISTON ROD ASSY	CAP	176	STEEL	-	100%	4	1	24	888	888
263	27	1	SPARK PLUG CBLE	CABLE	109.6	EPDM	CU	50%	4	1	6	105	104
265	27	1	*	COVER	138.8	PA-6	-	100%	1	1	51	888	888
267	28	1	THROTTLE BODY	HOUSING	456.4	AL	-	100%	1	1	16	31	888
269	28	1	THROTTLE BODY	SHAFT	130.8	STEEL	-	100%	1	1	21	31	888
288	29	1	TIMING CHN ASSY	BELT	158.6	EPDM	-	100%	1	2	6	105	888
289	29	1	TIMING COVER	COVER UPPER	254	PA-6	-	100%	1	1	51	888	888
291	29	1	TIMING COVER	COVER CENTER	915.8	AL	-	100%	1	1	16	31	888
297	30	1	TORQUE CONV	TORQUE CONVERTER	13816.4	STEEL	STEEL	75%	1	3	22	38	18
300	31	1	TRANSMIS ASSY	HOUSING LOWER	8860	AL	-	100%	1	2	16	38	888
302	31	1	TRANSMIS ASSY	HOUSING UPPER	7660	AL	-	100%	1	2	16	38	888
305	31	1	TRANSMIS ASSY	PLANETARY GEAR	8745.6	STEEL	-	100%	1	3	11	38	888
306	31	1	TRANSMIS ASSY	BAND	282.4	STEEL	FIBER	100%	1	1	24	888	888
307	31	1	TRANSMIS ASSY	GEARS	3130.6	STEEL	-	100%	2	3	18	38	888
309	31	1	TRANSMIS ASSY	CHAIN	1499.8	STEEL	STEEL	50%	1	2	24	99	24
311	31	1	TRANSMIS ASSY	BRACKET	1207	IRON	-	100%	3	1	11	31	888
314	31	1	TRANSMIS ASSY	MOUNT	1446.2	IRON	RUBBER	90%	2	1	11	31	56

317	31	1	TRANSMIS ASSY	MOUNT	1427	STEEL	AL	100%	1	1	24	888	888
319	31	1	TRANSMISSION ASSY CHAIN	SHIELD	567.2	STEEL	-	100%	1	1	24	888	888
320	32	1	TRANSMISSION ASSY CLUTCH	DRUM	2307.8	STEEL	-	100%	3	2	11	38	888
323	32	1	*	PISTON	183.1	AL	-	100%	4	2	16	38	888
324	32	1	*	PRESSURE PLATE	102	STEEL	-	100%	3	1	18	31	888
329	32	1	*	INSERT	443.4	STEEL	-	100%	2	1	24	888	888
331	33	1	TRANSMISSION ASSY DIP STICK	TUBE	115	STEEL	-	100%	1	1	21	888	888
336	33	1	TRANSMISSION ASSY GEAR ASSY	PLANETARY GEAR	5616.6	STEEL	-	100%	1	3	18	38	888
341	34	1	TRANSMISSION ASSY LINES ASSY	TUBE	129.8	STEEL	-	100%	4	1	21	888	888
342	35	1	TRANSMISSION ASSY OIL PAN	PAN	1336	STEEL	-	100%	1	1	24	31	888
345	35	1	*	FILTER	266.8	PA-66	-	100%	1	1	111	888	888
347	36	1	TRANSMISSION ASSY PUMP	HOUSING LOWER	2996.6	IRON	-	100%	1	2	11	38	888
349	36	1	*	PLATE	950.2	STEEL	STEEL	50%	1	2	24	31	24
351	36	1	*	GEARS	217.9	STEEL	-	100%	2	3	18	31	888
352	36	1	*	YOKE	613.2	STEEL	-	100%	1	1	24	31	888
357	36	1	*	HOUSING UPPER	1950.2	STEEL	-	100%	1	2	24	31	888
358	36	1	*	ROD	149.6	STEEL	-	100%	1	1	21	31	888
360	36	1	*	SHAFT	502.2	STEEL	-	100%	1	1	22	31	888
361	37	1	TRANSMIS ASSY SOLINOID	HOUSING LOWER	119	AL	-	100%	1	1	16	31	888
363	37	1	*	COIL	181.8	STEEL	CU	75%	1	2	18	666	104
366	37	1	*	SOLINOID	128.1	AL	CU	75%	2	1	16	31	104
382	39	1	TRANSMISSION ASSY VALVE BODY ASSY	HOUSING LOWER	1557.6	AL	-	100%	1	2	16	38	888
384	39	1	TRANSMIS ASSY VALVE ASSY	PLATE	232.1	STEEL	-	100%	2	1	22	31	888
386	39	1	*	HOUSING CENTER	744	STEEL	-	100%	1	1	24	888	888
393	39	1	*	HOUSING UPPER	1207.8	STEEL	-	100%	1	1	18	38	888
394	40	1	*	SHAFT	444.4	STEEL	-	100%	1	2	22	31	888
396	40	1	*	LEVER	146.8	STEEL	-	100%	2	1	21	888	888
401	41	1	TRANSMIS ASSY SERVO ASSY	PISTON	228	STEEL	EPDM	100%	1	2	18	38	112
402	41	1	*	SPRING	171.4	STEEL	-	100%	1	2	29	888	888
403	41	1	*	COVER	105.8	STEEL	EPDM	100%	1	1	24	888	888
404	42	1	VALVE COVER	GASKET	101.8	EPDM	-	100%	1	1	51	888	888
405	42	1	VALVE COVER	BAFFLE	174.8	STEEL	-	100%	1	1	24	888	888
409	42	1	VALVE COVER	COVER	1061.8	AL	-	100%	1	1	16	31	888
413	42	1	VALVE COVER PCV VALVE	HOSES	112.4	EPDM	-	100%	1	1	6	105	888
416	43	1	FLYWHEEL	FLEXPLATE	2069.4	STEEL	-	100%	1	2	11	31	888
420	44	2	CONTROL ARM LOW FRT LEFT	ARM	3871	STEEL	AL	75%	1	3	24	1064	24
427	44	2	CONTROL ARM LOW FRT RIGHT	ARM	3871	STEEL	AL	75%	1	3	24	1064	24
432	45	2	EMERG BRAKE CABLE ASSY	CABLE	223.2	STEEL	-	100%	1	2	104	888	888
433	45	2	*	HOUSING	912.4	STEEL	PP	80%	1	1	24	888	51
443	45	2	EMERG BRAKE HANDLE ASSY	HANDLE	1157.6	STEEL	-	100%	1	1	24	888	888
458	46	2	FRONT BRAKES LINES ASSY	TUBE	186.8	STEEL	-	100%	3	1	21	28	888
461	47	2	FRT BRAKE LEFT	ROTOR	5310.6	STEEL	-	100%	1	3	22	31	888

463	48	2	FRT BRAKE LEFT CALIPER ASSY	BRACKET	1074.2	STEEL	-	100%	1	1	24	31	888
471	48	2	*	PISTON	497.8	STEEL	-	100%	1	2	18	31	888
473	48	2	*	PAD	404.4	STEEL	-	100%	2	3	18	31	888
474	48	2	*	HOUSING	3018.2	IRON	-	100%	1	2	11	31	888
475	49	2	FRT BRAKE RIGHT	ROTOR	5310.6	STEEL	-	100%	1	3	22	31	888
477	50	2	FRT BRAKE RIGHT CALIPER ASSY	BRACKET	1074.2	STEEL	-	100%	1	1	24	31	888
485	50	2	*	PISTON	497.8	STEEL	-	100%	1	2	18	31	888
487	50	2	*	PAD	404.4	STEEL	-	100%	2	2	18	31	888
488	50	2	*	HOUSING	3018.2	IRON	-	100%	1	2	11	31	888
489	51	2	FRONT END ASSY SWAY BAR	SWAY BAR	3160	STEEL	-	100%	1	1	28	31	888
493	51	2	FRONT END ASSY SWAY BAR LINK	LINK	286.2	STEEL	-	100%	2	1	21	28	888
497	52	2	FRT END ASSY LFT	KNUCKLE	6258.2	IRON	-	100%	1	3	11	38	888
500	52	2	FRT END ASSY RGT	KNUCKLE	6258.2	IRON	-	100%	1	3	11	38	888
503	53	2	FUEL FILL DOOR	DOOR	175.4	PA-66	-	100%	1	1	51	888	888
504	53	2	FUEL FILL NECK	TUBE	1560	STEEL	STEEL	50%	1	1	28	1064	28
506	53	2	FUEL FIL NECK	HOSES	123.4	EPDM	-	100%	3	1	6	105	888
510	53	2	FUEL FILL NECK	INSERT	110.2	PA-66	EPDM	100%	1	1	51	888	888
521	54	2	FUEL PUMP	HOUSING	240.2	STEEL	-	100%	1	1	24	31	888
536	55	2	FUEL PUMP MOTOR ASSY	COVER	135.6	STEEL	-	100%	1	2	24	31	888
550	57	2	FUEL TANK	TANK	9298.6	HDPE	HDPE	50%	1	3	51	888	99
551	57	2	FUEL TANK	STRAP	305.3	STEEL	-	100%	2	1	24	888	888
557	57	2	FUEL TANK	SHIELD	1374	AL	-	100%	1	1	24	31	888
558	57	2	FUEL TANK LINES ASSY	TUBE	300	STEEL	-	100%	1	1	21	888	888
567	57	2	FUEL TANK LINES ASSY	FILTER	204.2	STEEL	-	100%	1	1	24	888	888
568	57	2	*	TUBE	344.4	STEEL	-	100%	1	1	21	888	888
581	59	2	HORN LEFT	HOUSING	121.8	STEEL	-	100%	1	1	24	888	888
591	60	2	HORN RIGHT	HOUSING	121.8	STEEL	-	100%	1	1	24	888	888
599	61	1	INTKE MANIFOLD	PLENUM	2314.6	PA-66	-	100%	1	3	51	888	888
604	62	1	INTKE MANIFOLD SOLINOID	CONNECTOR	108	STEEL	BRASS	100%	1	1	24	888	888
610	62	1	*	HOUSING	113	STEEL	-	100%	1	1	24	888	888
612	63	2	JACK ASSY	JACK ASSEMBLY	2207.2	STEEL	-	60%	1	2	24	31	24
616	63	2	JACK ASSY	TOOLS	546.4	STEEL	-	50%	1	2	24	31	24
617	64	2	PEDAL ASSY BRAKE PEDAL	BRACKET	457.7	STEEL	-	100%	2	1	24	31	888
624	64	2	*	PEDAL	915.6	STEEL	-	100%	1	1	24	1064	888
640	66	2	PEDAL ASSY GAS PEDAL	BRACKET	262	STEEL	-	100%	1	1	24	31	888
644	66	2	*	PEDAL	171.4	PA-6	-	100%	1	1	51	888	888
645	67	2	POWER BRAKE BOOSTER	HOUSING LOWER	963.2	STEEL	-	100%	1	2	11	38	888
647	67	2	POWER BRAKE BOOSTER	BRACKET	445	STEEL	-	100%	2	1	24	888	888
654	67	2	*	DIAPHRAGM	102.8	EPDM	-	100%	1	3	56	105	888
655	67	2	*	PISTON	108.2	PET	-	100%	1	2	51	888	888
657	67	2	*	PISTON	316.4	STEEL	-	100%	1	2	18	31	888
659	67	2	*	SHAFT	213.8	STEEL	-	100%	1	1	22	31	888
664	67	2	*	HOUSING UPPER	1052.8	STEEL	-	100%	1	2	11	31	888
672	68	2	POWR STEER PUMP	BRACKET	1043.8	AL	-	100%	1	1	24	31	888
675	68	2	*	HOUSING	1890.6	CAST IRON	-	100%	1	2	11	38	888

676	68	2	*	INSERT	141.2	STEEL	-	100%	1	1	24	888	888
679	68	2	*	PLUG	173.6	STEEL	-	100%	1	1	24	888	888
680	68	2	*	PULLEY	448.2	STEEL	-	100%	1	2	22	31	888
683	68	2	*	ROTOR	112.2	STEEL	CU	75%	1	2	18	666	104
684	68	2	*	SHAFT	116	STEEL	-	100%	1	2	21	31	888
687	68	2	*	VALVE	174.6	STEEL	-	100%	1	3	22	31	888
688	68	2	POWER STEERING PUMP LINES ASSY	TUBE	290.7	STEEL	-	100%	2	1	21	28	888
692	68	2	*	HOSES	234.9	EPDM	-	100%	2	1	6	105	888
696	68	2	POWER STRG ASY	RESERVOIR	234.2	PA-66	-	100%	1	1	52	888	888
701	68	2	POWER STRG ASSY COOLER	COOLER	390.2	AL	STEEL	75%	1	2	21	28	21
713	69	2	REAR BRAKE LEFT	DRUM	3997.2	STEEL	-	100%	1	3	22	31	888
714	69	2	REAR BRAKE LEFT	HUB/BEARING ASSY	1813.8	STEEL	-	100%	1	2	11	38	888
716	69	2	REAR BRAKE LEFT	BACKING PLATE	1196	STEEL	-	100%	1	1	24	31	888
719	69	2	REAR BRAKE LEFT	LINNING	368.5	STEEL	-	100%	2	2	24	888	888
723	69	2	REAR BRAKE LEFT	LEVER	203.8	STEEL	-	100%	1	1	21	888	888
730	69	2	REAR BRAKE LEFT WHEEL CYLINDER	HOUSING	258.4	IRON	-	100%	1	2	11	31	888
732	70	2	REAR BRAKE RGT	DRUM	3997.2	STEEL	-	100%	1	3	22	31	888
733	70	2	REAR BRAKE RGT	HUB/BEARING ASSY	1813.8	STEEL	-	100%	1	2	11	38	888
735	70	2	REAR BRAKE RGT	BACKING PLATE	1196	STEEL	-	100%	1	1	24	31	888
738	70	2	REAR BRAKE RGT	LINNING	368.5	STEEL	-	100%	2	2	24	888	888
742	70	2	REAR BRAKE RGT	LEVER	203.8	STEEL	-	100%	1	1	21	888	888
749	70	2	REAR BRAKE RGT WHEEL CYLINDER	HOUSING	258.4	IRON	-	100%	1	2	11	31	888
751	71	2	REAR SUSPEN ASY	BRACKET	10320	STEEL	STEEL	60%	1	3	24	1064	24
753	71	2	REAR SUSPENS ASSY SWAY BAR	SWAY BAR	1960	STEEL	-	100%	1	2	28	31	888
762	72	2	REAR SUSPENS ASSY LEFT	KNUCKLE	4759.6	STEEL	STEEL	60%	1	3	24	1064	24
763	72	2	*	KNUCKLE	106.9	STEEL	-	100%	4	1	22	31	888
764	72	2	*	UP CONTROL ARM	1213	STEEL	-	100%	1	1	24	31	888
767	72	2	*	LWR CONTROL ARM	1508.8	STEEL	-	100%	1	2	24	31	888
770	72	2	REAR SUSPEN ASY LEFT TRACK BAR	BRACKET	489.6	STEEL	-	100%	1	1	24	888	888
772	72	2	*	TRACK BAR	1447.2	STEEL	-	100%	1	1	28	31	888
775	73	2	REAR SUSPENS ASSY RIGHT	KNUCKLE	4759.6	STEEL	STEEL	60%	1	3	24	1064	24
776	73	2	*	KNUCKLE	106.9	STEEL	-	100%	4	1	22	31	888
777	73	2	*	UP CONTROL ARM	1213	STEEL	-	100%	1	1	24	31	888
780	73	2	*	LWR CONTROL ARM	1508.8	STEEL	-	100%	1	2	24	31	888
783	73	2	REAR SUSPEN ASY RIGHT TRACK BAR	BRACKET	489.6	STEEL	-	100%	1	1	24	888	888
785	73	2	*	TRACK BAR	1447.2	STEEL	-	100%	1	1	24	31	888
788	73	2	*	MOLDINGS	144.4	PVC	-	100%	2	1	51	888	888
789	74	2	SHIFTER ASSY	HOUSING	411.4	AL	-	100%	1	1	16	31	888
792	74	2	SHIFTER ASSY	LEVER	284.2	AL	-	100%	1	1	21	31	888
801	74	2	SHIFTER ASSY	GEARS	116.8	PA-66	-	100%	1	3	51	888	888
812	74	2	SHIFTER ASSY	SOLINOID	209.6	STEEL	CU	75%	1	1	18	31	104
816	75	2	SHIFTER ASSY CABLE ASSY	BRACKET	165.6	STEEL	-	100%	1	1	24	888	888
818	75	2	SHIFTER ASSY CABLE ASSY	HOUSING	240	STEEL	PA-66	75%	1	2	24	888	51
819	75	2	*	CABLE	110.2	STEEL	-	100%	1	2	104	888	888
823	76	2	SILL PLATE LEFT	SILL PLATE	508.2	PP	-	100%	1	1	51	888	888
827	77	2	SILL PLATE RIGHT	SILL PLATE	504.2	PP	-	100%	1	1	51	888	888

831	78	2	SPARE TIRE	TIRE	5068.8	RUBBER	STEEL	80%	1	3	56	105	104
832	78	2	SPARE TIRE	WHEEL	8049	STEEL	STEEL	50%	1	2	24	1064	24
835	79	2	SPARE TIRE COVER ASSY	CARPET	772	PET	-	100%	1	1	111	888	888
836	79	2	*	SUBSTRATE	2396.6	FIBER	-	100%	1	1	56	888	888
840	81	2	STEER COLUMN	HOUSING LOWER	668.6	MG	-	100%	1	1	16	31	888
842	81	2	STEER COLUMN	SHAFT	736.9	STEEL	-	100%	2	2	22	31	888
843	81	2	STEER COLUMN	PIVOT	357.6	MG	-	100%	1	1	16	31	888
846	81	2	STEER COLUMN	STUD	107	STEEL	-	100%	1	1	24	888	888
847	81	2	STEER COLUMN	HOUSING CENTER	102.4	STEEL	-	100%	1	1	24	888	888
850	81	2	STEER COLUMN	INSERT	772.2	ZN	-	100%	1	2	16	31	888
869	81	2	STEER COLUMN	HOUSING UPPER	577.8	MG	-	100%	1	1	16	31	888
870	81	2	STEER COLUMN	TUMBLER	125.4	ZN	CU	100%	1	2	24	888	888
871	81	2	STEER COLUMN	COVER LOWER	264.4	ABS	-	100%	1	1	51	888	888
873	81	2	STEER COLUMN	COVER UPPER	139.2	ABS	-	100%	1	1	56	888	888
875	81	2	STEER COLUMN SHAFT LOWER	SHAFT	732.6	STEEL	-	100%	1	2	22	31	888
911	83	2	STEERING GEAR	HOUSING	1783.8	AL	-	100%	1	2	16	31	888
912	83	2	STEERING GEAR	HOUSING	106.8	STEEL	-	100%	2	1	24	888	888
913	83	2	STEERING GEAR	BRACKET	800	STEEL	-	100%	1	1	24	888	888
915	83	2	STEERING GEAR	RACK	2204.8	STEEL	-	100%	1	3	22	38	888
916	83	2	STEERING GEAR	PINION	346.8	STEEL	-	100%	1	3	22	31	888
917	83	2	STEERING GEAR	SPOOL	145.8	STEEL	-	100%	1	1	21	31	888
918	83	2	STEERING GEAR	VALVE	177	STEEL	-	100%	1	3	24	31	888
922	83	2	STEERING GEAR	LINK	464.6	STEEL	-	100%	1	1	21	31	888
925	83	2	STEERING GEAR LINES ASSY	TUBE	255.2	STEEL	-	100%	2	1	21	888	888
929	83	2	*	HOSES	127.8	EPDM	-	100%	1	1	6	105	888
931	84	2	STRUT LEFT FRNT	SPRING	2984	STEEL	-	100%	1	2	29	888	888
932	84	2	STRUT LEFT FRNT	PLATE	466.4	STEEL	-	100%	1	1	18	31	888
937	84	2	STRUT LEFT FRNT	ISOLATOR	597.4	STEEL	EPDM	75%	1	1	24	888	51
943	84	2	STRUT LEFT FRNT	STRUT	3870	STEEL	STEEL	75%	1	2	24	1064	24
946	84	2	STRUT LEFT FRNT	STRUT	112.6	STEEL	-	100%	1	1	24	888	888
947	85	2	STRUT LEFT REAR	STRUT	4504.4	STEEL	STEEL	75%	1	3	24	1064	24
951	85	2	STRUT LEFT REAR	SPRING	2351	STEEL	-	100%	1	2	29	888	888
952	85	2	STRUT LEFT REAR	BUSHING	800.8	STEEL	-	100%	1	1	24	31	888
953	85	2	STRUT LEFT REAR	RETAINER	467.6	STEEL	-	100%	1	1	24	888	888
956	85	2	STRUT LEFT REAR	BOOT	112.8	EPDM	-	100%	1	1	51	105	888
959	86	2	STRUT RIGHT FRT	SPRING	2984	STEEL	-	100%	1	2	29	888	888
960	86	2	STRUT RIGHT FRT	PLATE	466.4	STEEL	-	100%	1	1	18	31	888
965	86	2	STRUT RIGHT FRT	ISOLATOR	597.4	STEEL	EPDM	75%	1	1	24	888	51
971	86	2	STRUT RIGHT FRT	STRUT	3870	STEEL	STEEL	75%	1	2	24	1064	24
974	86	2	STRUT RIGHT FRT	STRUT	112.6	STEEL	-	100%	1	1	24	888	888
975	87	2	STRUT RGHT REAR	STRUT	4504.4	STEEL	-	75%	1	3	24	1064	24
979	87	2	STRUT RGHT REAR	SPRING	2351	STEEL	-	100%	1	2	29	888	888
980	87	2	STRUT RGHT REAR	BUSHING	800.8	STEEL	-	100%	1	1	24	31	888
981	87	2	STRUT RGHT REAR	RETAINER	467.6	STEEL	-	100%	1	1	24	888	888
984	87	2	STRUT RGHT REAR	BOOT	112.8	EPDM	-	100%	1	1	51	105	888
987	88	2	TIE ROD LEFT	LINK	732.8	STEEL	-	100%	1	1	24	31	888
989	88	2	TIE ROD LEFT	TIE ROD	305.2	STEEL	-	100%	1	1	28	31	888
995	89	2	TIE ROD RIGHT	LINK	732.8	STEEL	-	100%	1	1	24	31	888
997	89	2	TIE ROD RIGHT	TIE ROD	305.2	STEEL	-	100%	1	1	28	31	888
1003	90	2	WASHER BOTTLE	RESERVOIR	365	PE	-	100%	1	1	52	888	888
1020	92	3	AC COMPRESSOR	BEARING	102.6	STEEL	-	100%	2	2	22	31	888

1021	92	3	AC COMPRESSOR	BRACKET		689	STEEL	-	100%	1	1	24	888	888
1024	92	3	AC COMPRESSOR	CLUTCH		484.2	STEEL	FIBER	100%	1	2	22	31	112
1026	92	3	AC COMPRESSOR	COIL		780.4	STEEL	CU	75%	1	1	18	666	104
1029	92	3	AC COMPRESSOR	HOUSING	1	938.4	AL	-	100%	1	1	16	31	888
1030	92	3	AC COMPRESSOR	HOUSING	LOWER	896.4	AL	-	100%	1	1	16	31	888
1031	92	3	AC COMPRESSOR	INSERT		367.1	AL	-	100%	2	1	16	31	888
1034	92	3	AC COMPRESSOR	PULLEY		724.4	STEEL	-	100%	1	2	22	31	888
1036	92	3	AC COMPRESSOR	RETAINER		163.6	AL	-	100%	1	1	16	31	888
1038	92	3	AC COMPRESSOR	SHAFT		232.2	STEEL	-	100%	1	2	21	31	888
1039	92	3	AC COMPRESSOR	VALVE		113.1	STEEL	-	100%	3	2	22	31	888
1041	92	3	AC COMPRESSOR LINES ASSY	TUBE		125.6	AL	-	100%	3	1	21	888	888
1050	93	3	AC CONDENSER	CORE		2566.8	AL	-	50%	1	1	23	28	23
1074	94	3	AC EVAPORATOR LINES ASSY	TUBE		122.5	AL	-	100%	2	1	21	28	888
1080	94	3	*	DRYER		1068.6	STEEL	-	50%	1	3	24	1064	24
1081	94	3	*	BRACKET		231.8	STEEL	-	100%	1	1	24	888	888
1089	95	3	HEATER HOSEA	TUBE		296.8	STEEL	-	100%	2	1	21	888	888
1092	95	3	HEATER HOUSING	PLENUM		3520	PP-T20	-	100%	1	2	51	888	888
1097	95	3	HEATER HOUSING	DOOR		247.15	STEEL	PUR	100%	4	1	24	888	888
1099	95	3	HEATER HOUSING	HEATER CORE		906.8	AL	-	100%	1	3	21	29	888
1100	95	3	HEATER HOUSING	VACUUM RESERV		211	PP	-	100%	1	1	52	888	888
1102	95	3	HEATER HOUSING	DUCT	LOWER	740	PP	-	100%	1	2	51	888	888
1104	96	3	HEATER HOUSING AC EVAPORATOR	CORE		1708.4	AL	-	100%	1	2	21	29	888
1106	97	3	HEATER HOUSING BLOWER MOTOR	HOUSING		140.6	PP-T20	-	100%	1	1	51	888	888
1107	97	3	*	COVER		617.8	STEEL	-	100%	1	2	24	31	888
1108	97	3	*	ARMATURE		477.2	STEEL	CU	75%	1	1	18	666	104
1115	97	3	*	FAN		134.4	PP	-	100%	1	1	51	888	888
1117	98	3	HEATER HOUSING HEATER CORE	ISOLATOR		116	PUR	-	100%	2	1	56	105	888
1174	103	3	INST/ DASH PANEL ASS DUCT ASSY	DUCT		655	PE	-	100%	1	2	52	888	888
1175	103	3	*	HOUSING		133	ABS	-	100%	1	1	51	888	888
1185	104	3	RADIATOR	RADIATOR		2667.6	AL	AL	50%	1	3	24	1064	24
1186	104	3	RADIATOR	TANK		332.2	PA-66	-	100%	2	1	52	888	888
1188	104	3	RADIATOR	COOLER		495	AL	-	100%	1	1	21	29	888
1190	104	3	RADIATOR	BRACKET		114.3	STEEL	-	100%	2	1	24	888	888
1193	104	3	RADIATOR	HOSES	UPPER	219.8	EPDM	-	100%	1	1	6	105	888
1199	104	3	RADIATOR DEFLECT LOWER	DEFLECTOR		850.2	PP/EPDM	-	100%	1	1	51	888	888
1207	104	3	RADIATOR HOSES LOWER	HOSES		297	EPDM	-	100%	1	1	6	105	888
1209	104	3	*	CONNECTOR		148.7	EPDM	PA-66	100%	2	1	51	105	888
1210	105	3	RADIATOR COOLING FAN	BRACKET		965.8	PA-66	-	100%	1	2	51	888	888
1212	105	3	*	FAN		236.1	PA-66	-	100%	2	2	51	888	888
1214	105	3	RADIAT COOL FAN MOTOR ASY LFT	COVER		678.8	STEEL	-	100%	1	2	24	31	888
1216	105	3	*	ARMATURE		675.4	STEEL	CU	75%	1	1	18	666	104
1222	105	3	*	PLATE		123.4	STEEL	-	100%	1	2	24	31	888
1228	105	3	RADIAT COOL FAN MOTOR ASY RGHT	COVER		678.8	STEEL	-	100%	1	2	24	31	888
1230	105	3	*	ARMATURE		675.4	STEEL	CU	75%	1	1	18	666	104
1236	105	3	*	PLATE		123.4	STEEL	-	100%	1	2	24	31	888
1242	106	3	RADIATOR OVERFLOW	RESERVOIR		767.8	PP	BRASS	80%	1	2	52	888	24

1244	106	3 *	HOSES	118.4	EPDM	-	100%	1	1	6	105	888
1252	107	3 WATER PUMP	PUMP	550.6	AL	STEEL	50%	1	3	18	666	24
1256	107	3 WATER PUMP	PULLEY	347.2	STEEL	-	100%	1	3	22	31	888
1259	107	3 WATER PUMP	HOUSING	985.4	AL	-	100%	1	1	16	31	888
1262	108	4 AIR BAG CNTROL MODULE	CIRCUIT BOARD	110	FIBERB	CU	100%	1	3	999	888	888
1263	108	4 AIR BAG CNTROL SENSOR ASSY	SENSOR	227.8	STEEL	PBT	100%	3	1	24	888	888
1265	108	4 *	BRACKET	252.8	STEEL	-	100%	2	1	24	888	888
1272	109	4 CARPET	FLOOR MAT FRONT	487	EPDM	FABRIC	75%	2	1	56	105	888
1273	109	4 CARPET	FLOOR MATS REAR	212.2	EPDM	FABRIC	100%	2	1	111	888	888
1274	109	4 CARPET	CARPET	2460	POLYES	-	100%	1	1	111	888	888
1275	109	4 CARPET	SHODDY	4300	SHODDY	-	100%	1	1	111	888	888
1276	110	4 CHARCOAL CANISTER	BRACKET	1039.8	STEEL	-	100%	1	1	24	888	888
1280	110	4 *	HOUSING	628.2	PA-66	-	100%	1	1	51	888	888
1281	110	4 *	CHARCOAL	737.4	CCOAL	-	100%	1	1	50	888	888
1282	110	4 *	TUBE	712.2	STEEL	-	100%	1	1	21	888	888
1325	111	4 CONSOLE FRONT LOWER	CONSOLE	842.2	ABS	-	100%	1	1	51	888	888
1336	112	4 CONSOLE REAR LOWER	CONSOLE	1179.6	ABS	-	100%	1	2	51	888	888
1340	113	4 COWL INSULATION	INSULATION	3214.6	PVC	SHODDY	90%	1	2	51	888	111
1347	113	4 *	STIFFNER	203.2	STEEL	-	100%	1	1	24	888	888
1348	113	4 *	SHODDY	1092	SHODDY	-	100%	1	1	111	888	888
1351	113	4 *	SHODDY	599.8	SHODDY	-	100%	1	1	111	888	888
1355	114	4 COWL VENT	BRACKET	153.2	PP	-	100%	1	1	51	888	888
1356	114	4 COWL VENT	FILTER	134.6	PAPER	-	100%	1	2	111	888	888
1359	114	4 COWL VENT	VENT	292.2	PP	-	100%	1	1	51	888	888
1363	115	4 COWL VENT PANEL LEFT	COWL VENT PANEL LEFT	679.8	PC	ASA	50%	1	2	51	888	51
1367	115	4 COWL VENT PANEL RIGHT	COWL VENT PANEL	684.6	PC	ASA	50%	1	2	51	888	51
1375	116	4 FRT DOOR ASSY LEFT SPEAKR ASY	MAGNET	388.8	STEEL	-	100%	1	1	11	31	888
1376	116	4 *	HOUSING	139.8	PP-T40	-	100%	1	1	51	888	888
1382	117	4 FRT DOOR ASSY RGHT SPEAKR ASY	MAGNET	388.8	STEEL	-	100%	1	1	11	31	888
1383	117	4 *	HOUSING	139.8	PP-T40	-	100%	1	1	51	888	888
1385	118	6 FRT DOOR ASSY LEFT WINDOW	WINDOW	2887	GLASS	-	100%	1	2	56	888	888
1391	118	6 *	CHANNEL	658.8	AL	PP/EPDM	80%	1	1	24	888	6
1392	118	6 *	WEATHERSEALS	179.6	AL	PP/EPDM	80%	2	1	24	888	6
1398	120	6 FRT DOOR ASSY RIGHT WINDOW	WINDOW	2887	GLASS	-	100%	1	2	56	888	888
1404	120	6 *	CHANNEL	658.8	AL	PP/EPDM	80%	1	1	24	888	6
1405	120	6 *	WEATHERSEALS	179.6	AL	PP/EPDM	80%	2	1	24	888	6
1412	122	4 FRT SEAT LEFT	COVER LOWER	346.6	FABRIC	PUR	25%	1	2	99	888	56
1414	122	4 FRT SEAT LEFT	COVER UPPER	645.8	FABRIC	PUR	25%	1	2	99	888	56
1416	122	4 FRT SEAT LEFT	CUSHION LOWER	1060.2	PUR	-	100%	1	1	56	888	888
1417	122	4 FRT SEAT LEFT	FRAME LOWER	5240	STEEL	STEEL	50%	1	3	24	1064	24
1418	122	4 FRT SEAT LEFT	FRAME UPPER	3720	STEEL	STEEL	50%	1	3	24	1064	24
1420	123	4 FRT SEAT LEFT ARMREST ASSY	FRAME	469.8	PP	STEEL	40%	1	2	56	888	28
1423	123	4 *	COVER	134.2	FABRIC	PUR	25%	1	2	99	888	56
1436	125	4 FRT SEAT LEFT CUSHION ASY	CUSHION UPPER	931.6	PUR	-	100%	1	1	56	888	888

1440	126	4	FRONT SEAT LEFT HEADREST	CUSHION	248.2	PUR	-	100%	1	1	56	888	888
1441	126	4	*	COVER	114.6	FABRIC	PUR	25%	1	2	99	888	56
1443	126	4	*	FRAME	314.8	STEEL	-	100%	1	1	24	888	888
1444	126	4	*	SUBSTRATE	129.4	PP	-	100%	1	1	51	888	888
1447	127	4	FRT SEAT RIGHT	COVER LOWER	346.6	FABRIC	PUR	25%	1	2	99	888	56
1449	127	4	FRT SEAT RIGHT	COVER UPPER	645.8	FABRIC	PUR	25%	1	2	99	888	56
1451	127	4	FRT SEAT RIGHT	CUSHION LOWER	1060.2	PUR	-	100%	1	1	56	888	888
1452	127	4	FRT SEAT RIGHT	FRAME LOWER	5240	STEEL	STEEL	50%	1	3	24	1064	24
1453	127	4	FRT SEAT RIGHT	FRAME UPPER	3720	STEEL	STEEL	50%	1	3	24	1064	24
1467	129	4	FRT SEAT RIGHT CUSHION ASSY	CUSHION UPPER	931.6	PUR	-	100%	1	1	56	888	888
1471	130	4	FRT SEAT RIGHT HEADREST	CUSHION	248.2	PUR	-	100%	1	1	56	888	888
1472	130	4	*	COVER	114.6	FABRIC	PUR	25%	1	2	99	888	56
1474	130	4	*	FRAME	314.8	STEEL	-	100%	1	1	24	888	888
1475	130	4	*	SUBSTRATE	129.4	PP	-	100%	1	1	51	888	888
1477	131	4	FRONT SEAT TRACK LEFT	TRACK	1401.8	STEEL	-	100%	1	2	24	31	888
1479	131	4	*	PIVOT	494.8	STEEL	-	100%	2	1	24	31	888
1483	131	4	*	ROD	161.4	STEEL	-	100%	1	1	21	31	888
1494	131	4	*	COVER	156.3	PP	-	100%	2	1	51	888	888
1502	132	4	FRONT SEAT TRACK RIGHT	TRACK	1401.8	STEEL	-	100%	1	2	24	31	888
1504	132	4	*	PIVOT	494.8	STEEL	-	100%	2	1	24	31	888
1508	132	4	*	ROD	161.4	STEEL	-	100%	1	1	21	31	888
1519	132	4	*	COVER	156.3	PP	-	100%	2	1	51	888	888
1527	133	4	HEADLINER	HEADLINER	970.4	FIBER	PUR	25%	1	2	56	888	56
1529	133	4	HEADLINER	COVER	172	FABRIC	-	100%	1	1	111	888	888
1545	135	4	INST/ DASH PANEL AIRBAG ASBLY	HOUSING	1315	STEEL	-	100%	1	2	24	31	888
1547	135	4	*	INFLATOR	1520.8	STEEL	-	100%	1	1	24	888	888
1551	135	4	*	BAG	663.2	PA-66	-	100%	1	1	111	99	888
1552	135	4	*	RETAINER	334.8	STEEL	-	100%	1	1	24	888	888
1554	135	4	*	SUBSTRATE	1079.8	PUR	AL	25%	1	2	51	888	24
1555	135	4	*	COVER	167.4	PVC	-	100%	1	1	51	888	888
1558	136	4	INST/DASH PAN AS	BRACKET	138.4	STEEL	-	100%	1	1	24	888	888
1560	136	4	INST/ DASH PANEL ASS CARRIER	CARRIER	3540	PPE+SB	PUR	75%	1	3	51	99	56
1564	136	4	*	COVER	900	PVC	PUR	75%	1	2	51	99	56
1565	136	4	*	COWL VENT PANEL	600	PPE+SB	-	50%	1	2	51	888	888
1566	136	4	*	INSERT	836	PPO	-	100%	1	1	51	888	888
1568	137	4	INST/ DASH PANEL ASS FRAME ASSY	FRAME	7720	STEEL	STEEL	60%	1	2	24	1064	24
1573	137	4	*	BRACKET	930	STEEL	-	100%	4	1	24	31	888
1576	138	4	INST/ DASH PANEL ASS GLOVE BOX ASSY DOOR	TRAY	745.2	PP	-	100%	1	2	51	888	888
1578	138	4	*	HINGE	176.8	STEEL	-	100%	1	1	24	31	888
1580	138	4	*	SUBSTRATE	728	AL	-	100%	1	1	24	888	888
1581	138	4	*	DOOR	361	TPO	-	100%	1	1	51	888	888
1595	140	4	INST/ DASH PANEL AS LOWER I/P LFT	SUBSTRATE	261.8	AL	-	100%	1	1	24	31	888
1597	140	4	*	COVER	413	TPO	-	100%	1	2	51	888	888
1599	140	4	*	SHODDY	102.8	SHODDY	-	100%	1	1	111	888	888
1601	141	4	INST CLSTR BEZEL	BEZEL	746.2	ABS/PC	-	100%	1	1	51	888	888
1612	143	4	INTERIOR COMP	MIRROR FACE	134.8	GLASS	-	100%	1	2	56	888	888

			REAR MIRROR										
1622	144	4	PARCEL SHELF	CARPET	295.8	FABRIC	-	100%	1	1	111	888	888
1626	144	4	PARCEL SHELF	SUBSTRATE	1041.6	SHODDY	-	100%	1	1	111	888	888
1627	145	4	PILLAR A LEFT	PILLAR A	183.2	PP	-	100%	1	1	51	888	888
1629	146	4	PILLAR A RIGHT	PILLAR A	183.2	PP	-	100%	1	1	51	888	888
1631	147	4	PILLAR B LFT LOW	PILLAR B	226.4	PP	-	100%	1	1	51	888	888
1633	148	4	PILLAR B LFT UP	PILLAR B	182	PP	-	100%	1	1	51	888	888
1638	149	4	PILLR B RGHT LOW	PILLAR B	226.4	PP	-	100%	1	1	51	888	888
1640	150	4	PILLR B RGHT UP	PILLAR B	182	PP	-	100%	1	1	51	888	888
1645	151	4	PILLAR C LFT LOW	PILLAR C	520.2	PP	-	100%	1	1	51	888	888
1649	152	4	PILLAR C LFT UP	PILLAR C	275.6	PP	-	100%	1	1	51	888	888
1652	153	4	PILLR C RGHT LOW	PILLAR C	541.4	PP	-	100%	1	1	51	888	888
1656	154	4	PILLR C RGHT UP	PILLAR C	275.6	PP	-	100%	1	1	51	888	888
1663	155	4	REAR DOOR ASSY LFT SPEAKR ASSY	MAGNET	383.2	STEEL	-	100%	1	1	11	31	888
1664	155	4	*	HOUSING	144	PP-T40	-	100%	1	1	51	888	888
1670	156	4	REAR DOOR ASSY RGHT SPEAKR ASY	MAGNET	383.2	STEEL	-	100%	1	1	11	31	888
1671	156	4	*	HOUSING	144	PP-T40	-	100%	1	1	51	888	888
1673	157	4	REAR SEAT	COVER LOWER	845.6	FABRIC	PUR	25%	1	2	99	888	51
1675	157	4	REAR SEAT	COVER UPPER	851.6	FABRIC	PUR	25%	1	2	99	888	51
1677	157	4	REAR SEAT	CUSHION LOWER	3720	PUR	-	100%	1	1	56	888	888
1679	157	4	REAR SEAT	FRAME	5200	STEEL	STEEL	60%	1	3	24	1064	24
1682	157	4	REAR SEAT CUSHION UPPER	BRACKET	595.2	STEEL	-	100%	1	1	24	888	888
1684	158	4	SEAT BELT CENTER REAR BELT RETRACTOR	BRACKET	396.4	STEEL	-	100%	1	1	24	31	888
1686	158	4	*	SPOOL	140	STEEL	-	100%	1	1	21	31	888
1688	158	4	*	WEBBING	131.2	POLYES	-	100%	1	1	111	888	888
1710	159	4	SEAT BELT LEFT FRONT BELT RETRACTOR	BRACKET	311	STEEL	-	100%	1	1	24	888	888
1712	159	4	*	SPOOL	170.8	STEEL	-	100%	1	1	21	31	888
1714	159	4	*	WEBBING	201.4	POLYES	-	100%	1	1	111	888	888
1733	160	4	SEAT BELT LEFT FRONT BRACKET	BRACKET	250.4	STEEL	-	100%	1	1	24	888	888
1743	161	4	SEAT BELT LEFT REAR BELT RETRACTOR	HOUSING	260.2	STEEL	-	100%	1	1	24	888	888
1745	161	4	*	SPOOL	141	STEEL	-	100%	1	1	21	31	888
1748	161	4	*	WEBBING	158.8	POLYES	-	100%	1	1	111	888	888
1768	162	4	SEAT BELT LEFT REAR BUCKLE	BRACKET	136	STEEL	-	100%	1	1	24	888	888
1781	163	4	SEAT BELT RIGHT FRONT BELT RETRACTOR	BRACKET	311	STEEL	-	100%	1	1	24	888	888
1783	163	4	*	SPOOL	170.8	STEEL	-	100%	1	1	21	31	888
1785	163	4	*	WEBBING	201.4	POLYES	-	100%	1	1	111	888	888
1804	164	4	SEAT BELT RIGHT FRONT BRACKET UPPER	BRACKET	250.4	STEEL	-	100%	1	1	24	31	888
1814	165	4	SEAT BELT RIGHT REAR BELT RETRACTOR	HOUSING	260.2	STEEL	-	100%	1	1	24	31	888
1816	165	4	*	SPOOL	141	STEEL	-	100%	1	1	21	31	888
1819	165	4	*	WEBBING	158.8	POLYES	-	100%	1	1	111	888	888
1851	167	4	STEERING WHEEL	WHEEL	677.6	MG	-	100%	1	1	16	31	888
1854	167	4	STEERING WHEEL	PAD	623.6	PUR	-	100%	1	2	56	105	888

1855	168	4	STEERING WHEEL AIR BAG ASBLY	HOUSING LOWER	263	STEEL	-	100%	1	2	24	31	888
1858	168	4	*	BRACKET	118.8	STEEL	-	100%	1	1	24	888	888
1859	168	4	*	INFLATOR	521.8	STEEL	-	100%	1	1	888	888	888
1860	168	4	*	BAG	220.4	PA-66	-	100%	1	1	111	99	888
1861	168	4	*	COVER	231	PVC	-	100%	1	1	51	888	888
1864	169	4	SUN VISOR LEFT	SUBSTRATE	170.6	PAPER	-	100%	1	1	111	888	888
1879	170	4	SUN VISOR RIGHT	SUBSTRATE	170.6	PAPER	-	100%	1	1	111	888	888
1896	171	4	TRIM PAD LFT FRT	GRILLE	164.4	POM	-	100%	1	1	51	888	888
1906	171	4	TRIM PAD LFT FRT	WATERSHIELD	158.8	PUR	-	100%	1	1	6	105	888
1910	171	4	TRIM PAD LEFT FRT BOLSTER AS	SUBSTRATE	424.2	ABS	PUR	50%	1	2	51	888	51
1917	171	4	TRIM PAD LEFT FRONT LOWER	SUBSTRATE	1186.8	PP	-	100%	1	2	51	888	888
1918	171	4	TRIM PAD LEFT FRONT UPPER	SUBSTRATE	445.2	ABS	-	100%	1	1	51	888	888
1922	172	4	TRIM PAD RGT FRT	GRILLE	164.4	POM	-	100%	1	1	51	888	888
1932	172	4	TRIM PAD RGT FRT	WATERSHIELD	158.8	PUR	-	100%	1	1	6	105	888
1936	172	4	TRIM PAD RIGHT FRT BOLSTER AS	SUBSTRATE	424.2	ABS	PUR	50%	1	2	51	888	51
1943	172	4	TRIM PAD RIGHT FRONT LOWER	SUBSTRATE	1186.8	PP	-	100%	1	2	51	888	888
1945	172	4	TRIM PAD RIGHT FRONT UPPER	SUBSTRATE	445.2	ABS	-	100%	1	1	51	888	888
1947	173	4	TRIM PAD LFT RER	SUBSTRATE UPPER	1090.6	ABS	-	100%	1	2	51	888	888
1949	173	4	TRIM PAD LFT RER	COVER	131.2	FABRIC	PUR	50%	1	2	111	888	51
1956	173	4	TRIM PAD LFT RER	SUBSTRATE LOWER	394.4	PP	-	100%	1	1	51	888	888
1962	173	4	TRIM PAD LFT RER	WATERSHIELD	121.8	PUR	-	100%	1	1	6	105	888
1963	174	4	TRIM PAD LFT RER	SUBSTRATE UPPER	1090.6	ABS	-	100%	1	2	51	888	888
1964	174	4	TRIM PAD LFT RER	COVER	131.2	FABRIC	PUR	50%	1	2	111	888	51
1971	174	4	TRIM PAD LFT RER	SUBSTRATE LOWER	394.4	PP	-	100%	1	1	51	888	888
1977	174	4	TRIM PAD LFT RER	WATERSHIELD	121.8	PUR	-	100%	1	1	6	105	888
1978	175	4	TRUNK COMPART	TRIM	709.2	PP	-	100%	1	2	51	888	888
1981	175	4	TRUNK CARPET	CARPET	981.4	PET	-	100%	1	1	111	888	888
1985	175	4	TRUNK COMPART COVER ASSY	COVER	879.4	FIBER	-	100%	1	1	101	888	888
1999	177	6	BACK WINDOW	BACK WINDOW	10133	GLASS	CU	100%	1	2	56	888	888
2000	177	6	BACK WINDOW	SEAL	386	EPDM	-	100%	1	1	56	105	888
2006	178	5	BODY ASSY	TOW HOOKS	479.3	STEEL	-	100%	2	1	21	888	888
2010	178	5	BODY ASSY	SPLASH SHIELD RIGHT REAR	254.2	PP	-	100%	1	1	51	888	888
2012	178	5	BODY ASSY	BODY IN WHITE	269688	STEEL	-	100%	1	3	888	888	888
2013	179	6	FENDER LINER LEFT FRONT	LINER	813.2	PP	-	100%	1	2	51	888	888
2018	180	6	FENDER LINER LEFT REAR	LINER	722.8	PP	-	100%	1	2	51	888	888
2025	181	6	FENDER LINER RIGHT FRONT	LINER	818.4	PP	-	100%	1	2	51	888	888
2030	181	6	*	SPLASH SHIELD	220.6	PP	-	100%	1	1	51	888	888
2032	182	6	FENDER LINER RIGHT REAR	LINER	710	PP	-	100%	1	2	51	888	888
2039	183	6	FENDER FRT LFT	FENDER,FRT	2702.2	STEEL	-	100%	1	2	24	1064	888
2043	184	6	FENDER FRT RGHT	FENDER,FRT	2702.2	STEEL	-	100%	1	2	24	1064	888
2047	185	5	FRONT DOOR ASSY LEFT	DOOR	15600	STEEL	-	100%	1	3	888	888	888
2049	185	5	*	WEATHERSEALS	1000.4	EPDM	STEEL	40%	1	1	6	105	24
2050	185	5	*	WEATHERSEALS	464	EPDM	-	100%	1	1	6	105	888
2056	185	5	*	MOLDINGS	112.6	PVC	-	100%	1	1	51	888	888

2066	187	5	FRT DOOR ASSY LEFT DOOR CHECK	DOOR CHECK	214	STEEL	-	100%	1	1	24	888	888
2087	189	4	FRT DOOR ASSY LEFT LATCH ASSY	FRAME	247.6	STEEL	-	100%	1	3	24	1064	888
2120	192	4	FRT DOOR ASSY LEFT REGULATOR	CHANNEL	467	STEEL	-	100%	1	1	24	888	888
2137	193	5	FRONT DOOR ASSY RIGHT	DOOR	15600	STEEL	-	100%	1	3	888	888	888
2139	193	5	*	WEATHERSEALS	1000.4	EPDM	STEEL	40%	1	1	6	105	24
2140	193	5	*	WEATHERSEALS	464	EPDM	-	100%	1	1	6	105	888
2146	193	5	*	MOLDINGS	112.6	PVC	-	100%	1	1	51	888	888
2156	195	5	FRONT DOOR ASSY RIGHT DOOR CHECK	DOOR CHECK	214	STEEL	-	100%	1	1	24	888	888
2178	197	4	FRONT DOOR ASSY RIGHT LATCH ASSY	FRAME	247.6	STEEL	-	100%	1	3	24	1064	888
2211	200	4	FRT DOOR ASSY RGHT REGULATOR	CHANNEL	467	STEEL	-	100%	1	1	24	888	888
2228	201	5	FRONT DOOR HINGE LEFT	HINGE	345.3	STEEL	-	100%	2	1	24	31	888
2230	201	5	*	HINGE	345.2	STEEL	-	100%	2	1	24	31	888
2232	201	5	*	HINGE	354.6	STEEL	-	100%	2	1	24	31	888
2234	201	5	*	HINGE	354.6	STEEL	-	100%	2	1	24	31	888
2236	202	6	HOOD	HOOD	14800	STEEL	-	100%	1	3	24	888	888
2238	202	6	HOOD	HINGE	349.2	STEEL	-	100%	2	1	24	31	888
2240	202	6	HOOD	ROD	330	STEEL	-	100%	1	1	21	31	888
2241	202	6	HOOD	WEATHERSEALS FRONT	156.8	EPDM	-	100%	1	1	6	105	888
2243	202	6	HOOD	WEATHERSEALS REAR	357.2	EPDM	-	100%	1	1	6	105	888
2258	204	6	HOOD LATCH ASY	LATCH	454.8	STEEL	-	100%	1	3	24	1064	888
2268	207	5	REAR DOOR ASSY LEFT	DOOR	12840	STEEL	-	100%	1	3	888	888	888
2270	207	5	*	DOOR CHECK	213	STEEL	-	100%	1	1	24	888	888
2273	207	5	REAR DOOR ASSY LEFT	WEATHERSEALS	859.6	EPDM	-	100%	1	1	6	105	888
2304	210	4	REAR DOOR ASSY LEFT LATCH ASSY	FRAME	274.8	STEEL	-	100%	1	3	24	1064	888
2333	212	4	REAR DOOR ASSY LFT REGULATOR	CHANNEL	298.6	STEEL	-	100%	1	1	24	31	888
2351	212	4	REAR DOOR ASSY LFT REGULATOR ASSY CABLE	HOUSING	120.6	STEEL	PVC	100%	1	2	24	888	888
2352	213	6	REAR DOOR ASSY LEFT WINDOW	WINDOW	2497.4	GLASS	-	100%	1	2	56	888	888
2355	213	6	*	CHANNEL	466.4	AL	PP/EPDM	80%	1	1	24	888	50
2356	213	6	*	SEAL	149.3	AL	PP/EPDM	100%	2	1	16	31	888
2364	215	5	REAR DOOR ASSY RIGHT	DOOR	12840	STEEL	-	100%	1	3	888	888	888
2366	215	5	*	DOOR CHECK	213	STEEL	-	100%	1	1	24	888	888
2369	215	5	*	WEATHERSEALS	859.6	EPDM	-	100%	1	1	6	105	888
2400	218	4	REAR DOOR ASSY RGHT LATCH ASSY	FRAME	274.8	STEEL	-	100%	1	3	24	1064	888
2429	220	4	REAR DOOR ASSY RGHT REGULATOR	CHANNEL	298.6	STEEL	-	100%	1	2	24	31	888
2447	220	4	REAR DOOR ASSY RGHT REGULATOR ASSY CABLE	HOUSING	120.6	STEEL	PVC	100%	1	2	24	888	888
2448	221	6	REAR DOOR ASSY RIGHT WINDOW	WINDOW	2497.4	GLASS	-	100%	1	2	56	888	888
2451	221	6	*	CHANNEL	466.4	AL	PP/EPDM	80%	1	1	24	888	50

2452	221	6	*	SEAL	149.3	AL	PP/EPDM	100%	2	1	16	31	888
2460	223	6	TRUNK LID HINGE	HINGE	1166	STEEL	-	100%	2	1	24	31	888
2462	223	6	TRUNK LID HINGE	STRUT	194.2	STEEL	PA-66	75%	2	1	24	888	51
2463	224	6	TRUNK LIK	TRUNK LIK OR DECK	9899.4	STEEL	-	100%	1	3	24	888	888
2465	224	6	TRUNK LIK	WEATHERSEALS	1076.8	EPDM	-	100%	1	1	6	105	888
2470	225	6	TRUNK LIK OR DECK HANDLE	BRACKET	168.6	STEEL	-	100%	1	1	24	888	888
2481	226	4	TRUNK LIK OR DECK LATCH ASSY	FRAME	181.6	STEEL	-	100%	1	3	24	1064	888
2504	228	4	TRUNK LIK OR DECK LOCK CYLD	LOCK CYLINDER	149.8	ZN	STEEL	100%	1	3	24	31	888
2514	229	2	WHEEL	TIRE	7748.8	RUBBER	STEEL	75%	4	3	56	105	104
2515	229	2	WHEEL	WHEEL	8241	STEEL	STEEL	50%	4	2	24	1064	24
2520	231	2	WHEEL COVER	COVER	394.6	ABS/PC	-	100%	4	1	51	888	888
2522	232	6	WINDSHIELD	WINDSHIELD	14320	GLASS	-	100%	1	3	56	888	888
2523	232	6	WINDSHIELD	WEATHERSEALS	141.8	EPDM	-	100%	1	1	6	105	888
2525	232	6	WINDSHIELD	TRIM	238.3	AL	PVC	75%	2	1	24	888	6
2528	233	6	ANTENNA ASSY	BASE	100.4	ZN	-	100%	1	1	16	888	888
2534	233	6	ANTENNA ASSY	HARNESS	205.8	CU	PVC	100%	1	1	104	888	888
2540	233	6	ANTENNA ASSY	BRACKET	118.4	STEEL	-	100%	1	1	24	888	888
2543	234	6	CNTER TAIL LAMP	COVER	509.2	PP	-	100%	1	1	51	888	888
2545	234	6	CNTER TAIL LAMP	HOUSING	1120.2	PC	ASA	50%	1	2	51	888	888
2549	234	6	CNTER TAIL LAMP	LENS	203.3	PMMA	-	100%	3	2	51	888	888
2555	234	6	CNTER TAIL LAMP	TRIM	150.4	ABS	-	100%	1	1	6	105	888
2567	235	6	CHMSL HI-STOP LAMP	HOUSING	169.8	PC	-	100%	1	1	51	888	888
2569	236	6	FRONT BUMPER ASSEMBL FASCIA	FASCIA	4000	PP	-	100%	1	3	51	888	888
2578	236	6	*	DEFLECTOR	217	PP/EPDM	-	100%	1	1	51	888	888
2580	236	6	*	FRAME	206.8	TEO	-	100%	1	1	51	888	888
2582	236	6	*	REINFORCEMENT	5688.4	STEEL	PC/PBT	80%	1	3	24	888	51
2589	237	6	FRONT DOOR ASSY LEFT VIEW MIRROR	BRACKET	646	ZN	-	100%	1	1	24	888	888
2597	237	6	*	HOUSING	185.2	ABS	-	100%	1	1	51	888	888
2608	239	6	FRONT DOOR ASSY RIGHT VIEW MIRROR	BRACKET	646	ZN	-	100%	1	1	24	888	888
2616	239	6	*	HOUSING	185.2	ABS	-	100%	1	1	51	888	888
2624	241	6	GRILLE FRONT	GRILLE	384	ABS	-	100%	1	1	51	888	888
2626	241	6	GRILLE FRONT	FINISHER	232.2	ABS	-	100%	1	1	51	888	888
2628	242	6	HEADER – NOSE PANEL	HEADER - NOSE PANEL	4044.6	SMC	-	100%	1	3	102	888	888
2631	242	6	*	BRACKET	115	STEEL	-	100%	2	1	24	888	888
2634	243	6	HEADLAMP AS LFT	LENS	439	PC	-	100%	1	3	51	888	888
2644	243	6	HEADLAMP AS LFT	REFLECTOR	421.4	SMC	-	100%	1	2	102	888	888
2647	243	6	HEADLAMP AS LFT	BEZEL	277.2	PA-66	-	100%	1	1	51	888	888
2669	243	6	HEADLAMP AS LFT	HOUSING	556.4	PC	-	100%	1	2	51	888	888
2672	244	6	HEADLMP AS RGT	LENS	439	PC	-	100%	1	3	51	888	888
2681	244	6	HEADLMP AS RGT	REFLECTOR	421.4	SMC	-	100%	1	2	102	888	888
2684	244	6	HEADLMP AS RGT	BEZEL	277.2	PA-66	-	100%	1	1	51	888	888
2706	244	6	HEADLMP AS RGT	HOUSING	556.4	PC	-	100%	1	2	51	888	888
2713	246	6	REAR BUMPR ASY	FASCIA	9323.4	PC/PBT	-	100%	1	3	51	888	888
2716	246	6	REAR BUMPR ASY	ENERGY ABSORBER	955.4	PP/EPDM	-	100%	1	2	51	888	888
2731	249	6	TAIL LAMP AS LFT	LENS	143	PMMA	-	100%	1	3	51	888	888
2738	249	6	TAIL LAMP AS LFT	HOUSING	261.8	ABS/PC	-	100%	1	2	51	888	888

2740	250	6	TAIL LAMP AS RGT	LENS		143	PMMA	-	100%	1	3	51	888	888
2747	250	6	TAIL LAMP AS RGT	HOUSING		261.8	ABS/PC	-	100%	1	2	51	888	888
2749	251	6	WINDSHIELD WIPER ARM LEFT	ARM		299.8	STEEL	-	100%	1	3	24	888	888
2757	251	6	*	BLADE		126	STEEL	-	100%	1	3	24	888	888
2761	251	6	WINDSHIELD WIPER ARM RGHT	ARM		321	STEEL	-	100%	1	3	24	888	888
2769	251	6	*	BLADE		126	STEEL	-	100%	1	3	24	888	888
2773	252	6	WIPER MOTOR	HOUSING		250.8	AL	-	100%	1	1	16	31	888
2775	252	6	WIPER MOTOR	ARMATURE		403.2	STEEL	CU	75%	1	2	18	666	104
2789	252	6	WIPER MOTOR	COVER		562	STEEL	-	100%	1	1	24	888	888
2791	253	6	WIPER TRANSM	BRACKET		591.5	STEEL	-	100%	1	2	24	888	888
2793	253	6	WIPER TRANSM	PIVOT		157.9	ZN	-	100%	2	3	16	888	888
2794	253	6	WIPER TRANSM	ROD		161	STEEL	-	100%	2	1	21	31	888
2795	253	6	WIPER TRANSM	ARM		196.8	STEEL	-	100%	3	1	24	888	888
2803	254	7	CRUISE SPEED CONTROL	BRACKET		138	STEEL	-	100%	1	1	24	888	888
2805	254	7	*	HOUSING	LOWER	221.2	AL	-	100%	1	1	24	31	888
2806	254	7	*	COIL		331.2	STEEL	CU	80%	1	1	21	31	104
2807	254	7	*	ARMATURE		118.8	STEEL	-	100%	1	1	18	666	888
2808	254	7	*	GEARS		133.2	STEEL	-	100%	1	3	18	31	888
2828	254	7	CRUISE SPEED BRACKET ASSY	BRACKET		181.6	STEEL	-	100%	1	1	24	888	888
2830	254	7	CRUISE SPEED CABLE ASSY	HOUSING		148	STEEL	PA-66	100%	1	1	24	888	888
2857	257	7	INST/ DASH PANEL ASS SWITCH ASSY	HOUSING		107.2	ABS	-	100%	1	1	51	888	888
2874	258	7	INSTRUMENT CLUSTER	HOUSING	LOWER	437.8	PP-T20	-	100%	1	1	51	888	888
2905	260	7	INSTRUMENT CLUSTER SPEEDOM ASSY	BEZEL		168.4	ABS	-	100%	1	1	51	888	888
2906	260	7	*	LENS		122	PMMA	-	100%	1	2	51	888	888
2910	261	7	RADIO	BRACKET		403	ABS	-	100%	1	1	51	888	888
2912	261	7	RADIO	HOUSING		385.2	STEEL	-	100%	1	1	24	888	888
2914	261	7	RADIO	BRACKET		107.4	MG	-	100%	1	1	24	888	888
2916	261	7	RADIO	CIRCUIT BOARD		114.2	FIBER	CU	100%	2	3	999	888	888
2918	261	7	RADIO	HEAT SINK		102.6	ZN	-	100%	1	1	24	888	888
2920	261	7	RADIO	TAPE DECK		532.6	STEEL	CU	100%	1	1	24	888	888
2980	268	8	ALTERNATOR	HOUSING	LOWER	700.4	AL	-	100%	1	1	16	31	888
2982	268	8	ALTERNATOR	STATOR		1368.6	STEEL	CU	75%	1	3	24	888	104
2983	268	8	ALTERNATOR	ROTOR		3275.6	STEEL	CU	80%	1	3	11	666	104
2984	268	8	ALTERNATOR	BEARING		106.4	STEEL	-	100%	1	2	22	31	888
2985	268	8	ALTERNATOR	CONTACT		331.8	AL	CU	90%	1	3	24	888	888
2993	268	8	ALTERNATOR	HOUSING	UPPER	342.8	STEEL	-	100%	1	1	24	888	888
2994	268	8	ALTERNATOR	PULLEY		166.2	STEEL	-	100%	1	1	22	31	888
2996	268	8	ALTERNATOR	BRACKET		1787.4	AL	-	100%	1	1	16	31	888
2998	269	8	BATTERY COVER ASSY	BATTERY		14753.2	LEAD	PP	90%	1	1	16	99	51
3003	269	8	BATTERY TRAY	RETAINER		161	STEEL	-	100%	1	1	24	888	888
3005	269	8	BATTERY TRAY	TRAY		1477.2	STEEL	-	100%	1	1	24	888	888
3007	270	8	STARTER	HOUSING	LOWER	502.8	AL	-	100%	1	1	16	31	888
3009	270	8	STARTER	HOUSING	CENTER	743.4	STEEL	-	100%	1	1	24	31	888
3012	270	8	STARTER	SHAFT		173.2	STEEL	-	100%	1	1	21	31	888
3014	270	8	STARTER	ARMATURE		856.8	STEEL	CU	75%	1	1	18	666	104
3016	270	8	STARTER	CLUTCH		231.2	STEEL	-	100%	1	2	18	31	888
3022	270	8	STARTER	HOLDER		183	PA-66	CU	100%	1	1	51	888	888

3023	270	8	STARTER	SOLINOID	657	STEEL	CU	75%	1	1	18	31	104
3025	270	8	STARTER	PLATE	300.2	STEEL	STEEL	50%	1	2	24	31	24
3028	271	2	WIRE HARNESS – BODY	HARNESS	3449.6	PVC	CU	25%	1	3	888	888	104
3029	271	2	*	HARNESS	204.2	PVC	-	100%	1	1	51	888	888
3030	271	2	*	HARNESS	165.4	STEEL	-	100%	1	1	24	888	888
3031	271	2	*	HARNESS	102	BRASS	-	100%	1	3	24	888	888
3034	271	2	*	HARNESS	335	PP	-	100%	1	1	51	888	888
3035	271	2	*	HARNESS	345	PA-6	-	100%	1	1	51	888	888
3036	271	2	*	HARNESS	138	PA-6	-	100%	1	1	51	888	888
3037	271	2	*	HARNESS	421.6	PP	-	100%	1	1	51	888	888
3038	271	2	*	HARNESS	222.4	PA-66	-	100%	1	1	51	888	888
3039	271	2	*	HARNESS	379.4	EPDM	-	100%	1	1	56	105	888
3040	271	2	*	HARNESS	340.2	PBT	-	100%	1	1	51	888	888
3041	271	2	*	HARNESS	193.6	PA-6	-	100%	1	1	51	888	888
3045	271	2	*	HARNESS	219	PA-66	CU	25%	1	1	888	888	104
3047	272	2	WIRE HARNESS – DASH	HARNESS	2554.2	PVC	CU	25%	1	3	888	888	104
3056	272	2	*	HARNESS	257.6	PA-66	-	100%	1	1	51	888	888
3057	272	2	*	HARNESS	155.8	PBT	-	100%	1	1	51	888	888
3062	273	1	WIRE HARNESS - ENGIN	HARNESS	5538.8	PVC	CU	25%	1	3	888	888	104
3063	273	1	*	HARNESS	442.4	STEEL	-	100%	1	1	24	888	888
3064	273	1	*	HARNESS	376.2	CU	-	100%	1	3	21	888	888
3065	273	1	*	HARNESS	314.6	BRASS	-	100%	1	3	21	888	888
3066	273	1	*	HARNESS	478.6	PA-66	-	100%	1	1	51	888	888
3068	273	1	*	HARNESS	517.8	PVC	-	100%	1	1	51	888	888
3069	273	1	*	HARNESS	201.4	EPDM	-	100%	1	1	51	105	888
3071	273	1	*	HARNESS	600.6	PBT	-	100%	1	1	51	888	888
3078	273	1	*	HARNESS	265.4	PA-66	CU	50%	1	1	888	888	104
3080	273	1	*	HARNESS	143.2	PA-66	-	100%	1	1	51	888	888
3082	273	1	*	HARNESS	365.2	PP-T40	-	100%	1	1	51	888	888
3086	273	1	*	HARNESS	116.4	PBT	-	100%	1	1	51	888	888

The Assembly column number corresponds to the OEM sourcing level component. Process Codes correspond to the numbers presented in the first column of Table 9–4. Groups are as follows: 1 – Powertrain; 2 – Chassis; 3 – HVAC; 4 – Interior; 5 – Body; 6 – Exterior; 7 – Information and Control; 8 – Electrical Power.

The total number of parts is 3090. There are additional 2432 parts with mass less than 100g that are not listed. Their total mass amounts to 42kg. These include both electronics and very simple parts. The cost of electronics was obtained from suppliers and the simple parts were estimated on a material plus rule. The total cost of the simple parts is US$106. Electronics cost a total of US$1,344.

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