The U.S. Automobile Industry:
Three Essays on Multinational Corporations

Thesis
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To my family for the strong support to this project.

To my Professor, M.P. Tucci, who has been an important guide to me and whose ethic has an important influence on my way of working.

Index

Introduction

A striking increase of the globalization process characterized the period 1980–2007. The increasing trend in world's trade levels is due to the decline in trade barriers and trade costs, which in turn affects the production process. The production chain is more and more vertically decomposed in its different stages, which are located worldwide to benefit comparative advantages of different countries. These international production linkages, in turn, impact the increase in the world's trade level. This increasing globalisation allows the activity of multinational corporations (MNCs) to rise, strengthening the links among different regions of the world.

Foreign Direct Investment (FDI) is the most important channel through which MNCs organise their activity and their production across countries because FDI is strictly related to control and management activities. Indeed, "Direct Investment is ownership that carries with it actual control over what is owned" (Graham and Krugman, 1995). The OECD Benchmark Definition of FDI qualifies foreign investment as reflecting "the objective of obtaining a lasting interest by a resident entity in one economy ('direct investor') in an entity resident in an economy other than that of the investor (direct investment enterprise)". The "lasting interest" is conceived as implying a "long-term relationship between the investor and the enterprise and a significant degree of influence in the management of the enterprise". The "significant degree of influence in the management of the enterprise" is recognised to a foreign investor who owns at least 10 percent of the ordinary shares or voting power.[1] The absolute control is not required by the foreign investor.[2]

In the Balance of Payments Manual Fifth Edition (IMF, 2004), direct investment includes equity capital (claims on affiliated enterprises plus liabilities to affiliated enterprises), reinvested earnings, other capital (including claims on affiliated enterprises plus liabilities to affiliated enterprises), and financial derivatives associated with various intercompany transactions between affiliated enterprises. As reported by IMF (2004)

[1] The 10 percent cut-off point is only a general suggestion by OECD. It is possible to find direct investors who own less than 10 percent of voting shares having an effective voice in the management, as well as cases in which the ownership of the 10 percent of shares does not lead to any significant influence.

[2] From the generality of this definition a problem of misclassification arises, that is, the possibility of overstatement or understatement of FDI. It is possible to find investment meeting the 10 percent criterion with no operational control as well as the opposite case. However, the problem is not so common due to the fact that in the aggregate foreign affiliates are majority owned, and so the foreign control is unambiguously applied.

"Direct Investment abroad is usually shown with a negative figure, reflecting an increase in net outward investment by residents, with a corresponding net payment outflow from the reporting economy."

FDI can be divided into two main groups according to its direction, that is Inward Foreign Direct Investment (IFDI) and Outward Foreign Direct Investment (OFDI). IFDI is the investment country A receives from an enterprise located in another country B (i.e. the source country), while OFDI is the investment a company located in country A undertakes in country B different from its home-country. In addition, FDI is classified in vertical and horizontal investment according to their scope. Vertical FDI is that investment undertaken to lower production costs. It implies a fragmentation of the production chain in its basic stages, which will be relocated according to countries' comparative advantages, in order to benefit from the most profitable conditions. Horizontal FDI is usually undertaken to enter new markets. It implies the replication of the whole production process in the foreign country. Another basic distinction is between resource-seeking and advantage-exploiting FDIs. The former is investment undertaken to access the host countries' advantages. On the other hand, exploiting FDI is undertaken to exploit firm-specific advantages in a foreign country, as suggested by Dunning (1980) in the "Eclectic Paradigm".

The world's stock of OFDI have increased six times in the last three decades, rising from 5.6 percent of the world's Gross Domestic Product (GDP) (US$548,675 million) in 1980 to 28.9 percent (US$15.6 billion) in 2007. This pattern has been characterised by a parallel increase in the OFDI of both developed and less developed countries (LDCs). On the other hand, the world stock of IFDI rose from 6.6 percent of the world's GDP (US$704,256 million) in 1980 to 27.9 percent (US$15.2 billion) in 2007.[3] The great majority of IFDI stock is held by the developed countries (DCs). Indeed IFDI stock of developed economies, being half of that of LDCs in 1980 had reached quite the same amount in 2007 (27.2 percent and 29.8 percent, respectively of world's GDP). Also, at the flow level DCs' IFDI accounted for 1.9 percent of Gross Fixed Capital Formation in 1970, which rose to reach 15.6 percent in 2007. This increase overtook that of LDCs, which had moved from 4.6 percent of Gross Fixed Capital Formation in 1970 to 12.6 percent in 2007. The outward flows are, instead, characterised by a noticeable positive trend of investment out of developing economies (UNCTAD, 2008).

The United States has historically been the most attractive destination for FDI until the late 1980s (U.S. Department of Commerce, 2008). The majority of foreign investment

[3] Source: www.unctad.org.

was from OECD countries until 2002. Starting the new millennium, however, emerging countries such as India, Russia, Chile, South Korea, and Brazil have a growing role in the U.S. IFDI. The U.S. share of IFDI at the world level decreased from 31 percent of the world total in 1980 to 13 percent in 2006. The decrease in U.S. IFDI was counterbalanced by the increase in investment inflows in China and the United Kingdom. In 2005 China captured a larger FDI inflow than U.S. However, by 2006 the U.S. regained its lead position in attracting foreign investments (U.S. Department of Commerce, 2008).

Given the role of the United States in attracting FDI, this thesis focuses on the analysis of the operations of multinational corporations (MNCs) in the U.S. The dissertation consists of three chapters, each of which analyzes separately different topics related to multinationals' activity. The chapters are based on empirical analysis. The first two chapters carry out a quantitative analysis of the U.S. operations of MNCs, while the third focuses on a qualitative perspective. The dissertation is based on the use of a unique dataset in order to make homogeneous and comparable results. The data used here are from the U.S. Bureau of Economic Analysis (BEA). This represents a novelty in the FDI literature, given that a work based solely on the BEA dataset does not exist in the literature. "The BEA is one of the world's leading statistical agencies" (http://www.bea.gov). It collects economic data on the U.S. economy at national, international, regional, and industry levels. As for MNCs, it provides useful information on companies' total assets, number of and compensation to employees, export and import of goods, net income, total sales, capital expenditures, and expenditures on research and development (R&D). MNCs are split by ownership in order to investigate differences between domestic MNCs, i.e. U.S. Parents, and foreign-owned companies, i.e. U.S. Affiliates. Depending on the availability of data, the period analyzed is 1983–2007.

The thesis analyzes MNCs' activity in the U.S. in the automotive sector. The U.S. auto industry has been chosen because it has been the object of important political debates regarding its competitiveness and social impact. Consequently several government policies have been formulated in order to improve its performance against foreign competition. That makes the U.S. auto industry an interesting sector by analyzing the activity of MNCs and pairing domestic versus foreign companies. Indeed U.S. automakers have been traditionally focused on the production of big size cars until the 1960s, when foreign producers successfully entered the U.S. market by importing small and compact vehicles. During late 1970s and early 1980s, the two oil shocks tilted consumers' preferences toward small and compact cars. U.S. car producers continuously lost their market shares in favour of importers of foreign vehicles so much as feeling as in a recession. In the early 1980s the Japanese government imposed voluntary export restraints (VERs) on Japanese automotive export toward U.S. At the end of 1981 the U.S. Government passed the Fair Practices for Automotive Product Act requiring foreign automakers to start U.S. based production in order to retain their current levels of U.S. sales. In 1982 foreign car producers started creating U.S. production transplants. As a consequence, the U.S. Big Three market shares continued to fall in favour of the foreign competitors until recent times.

First, this thesis intends to assess the differences and causality relationships between U.S. Parents and foreign-owned U.S. Affiliates. A great part of FDI literature is devoted to analyzing the inter-relationship among differently owned companies, but evidence is mixed. It is not possible to generalize the effects of foreign investments from existing empirical works (Lipsey, 2002). Two simultaneous equations systems will be constructed to investigate the economic behaviour of the two different types of MNCs. The system specifications will take into account all the variables available from BEA website in order to be as complete as possible. In addition, for each variable a Granger-causality test between activities of U.S. Parents and U.S. Affiliates will be run. The activity of the competitors will be taken into account in order to underline possible inter-relationship between the two types of MNCs. Finally, the role of rational expectations will be accounted for by using variables one-period forward. This chapter represents a novelty in the literature. Indeed it is likely to be the first attempt in estimating a simultaneous equations system in a multivariate framework concerning multinational corporations.

Chapter 2 of the dissertation addresses the productivity issue in the multinational framework. More precisely it investigates whether the results on productivity in the U.S. automotive industry discussed in the recent microeconomic literature hold when macroeconomic data are used. In particular, the impact of models' variety on productivity will be investigated, given that the supply of differentiated products is a key issue in the automotive market. To this aim, the recent model estimated by Van Biesebroeck (2007) has been taken as reference and it has been estimated again for both U.S. Parents and U.S. Affiliates using the macroeconomic dataset from BEA. In order to deal with endogeneity problems and un-observables bias, estimations are carried out through the construction of two simultaneous equations systems for productivity, one for each type of MNCs. Empirical results will show whether the same productivity equation can be estimated for both U.S. Parents and U.S. Affiliates and whether the two types of MNCs differ in their productivity behaviors. In addition, the presence of spillover effects and causality relationships between domestic and foreign-owned firms will be tested by adding specific variables in the systems.

Chapter 3 consists of a qualitative analysis of the R&D patterns of U.S. automotive multinationals. Indeed from the early 1990s stringent environmental regulations induced car manufacturers to develop alternative fuel vehicles. It is very important to develop a good strategy in technological innovation in order to retain market power and lead the automotive market. Technological innovations are the final output for patenting activity, while R&D expenditures can be taken as proxy for innovation input. Macroeconomic data relative to U.S. Parents and U.S. Affiliates do not allow distinguishing the portion of R&D devoted to each single technology. Here the microeconomic evidence on firms' patenting activity is exploited in order to decompose by technology the macroeconomic dataset from BEA. The analysis of firms' patenting activity of Oltra and Saint-Jean (2009) is taken as microeconomic reference on the firms' technological specialization. The R&D of U.S. MNCs will be split by technology. U.S. Parents' R&D expenditures will be split following the specialization of the American Big Three. U.S. Affiliates' R&D will be split in two extreme ways in order to account for the two main FDI strategies, that is, technology sourcing versus technology exploiting. By this procedure an interval including the real R&D strategy will result. The procedure will lead to an innovative and more integrated meso-economic analytical perspective. The novelty of exploiting microeconomic results to improve the macroeconomic perspective is likely to be very important for the macroeconomic research.

Chapter 1

The U.S. Automotive Industry:

The Impact of Foreign Entrance on U.S. Multinational Companies

Abstract

The goal of the analysis is to assess differences and causality relationships between U.S. multinational corporations (MNCs) and foreign-owned MNCs over the period 1983-2007. The result will be the estimation of two systems of simultaneous equations. Empirical results show very different economic patterns for the two types of MNCs. In addition both U.S. Parents and U.S. Affiliates are likely to strongly influence each other. A significant role in influencing U.S. Parents' activity is played also by the expectations on competitors' strategies, underlining the important role of research departments. At the best of our knowledge this is the first attempt in estimating a simultaneous equations system in a multivariate framework concerning multinational corporations.

1.1 Introduction

The present analysis is aimed at investigating the economic activity of U.S. Multinational Corporations (MNCs) in the manufacturing sector motor vehicles and equipment manufacturing through a system of simultaneous equations.[4] The analysis of the American automotive industry is very interesting given the ongoing loss of U.S. firms' market shares and its involvement on multinational activity. In this respect MNCs will be investigated distinguishing between domestic(U.S.)-owned and foreign-owned companies.

U.S. automakers focused their production in big-size cars. In the 1960s small and compact cars imported from abroad gained popularity in the U.S. market. In the early 1980s consumers' preferences changed because of the two oil shocks. Foreign market shares were continuously increasing until 1981, when voluntary trade restrictions were implemented through international agreements. In the eighties foreign MNCs entered the U.S. through Foreign Direct Investment (FDI) in order to additionally increase their presence on the U.S. market. US automakers were greatly damaged by the foreign presence and its increasing competition on the American market (Section 1.2).

Here the dataset from the U.S. Bureau of Economic Analysis (BEA) is used in order to investigate differences and similarities between the two types of MNCs over the period 1983-2007. U.S. automakers (i.e. U.S. Parents) and foreign-owned U.S. firms (i.e. U.S. Affiliates) differ a lot in their economic activity and their structures (Section 1.3). The data used are in millions of U.S. dollars at current prices. The use of monetary variables at current prices is not likely to bias the results given that the analysis is aimed at comparing the two types of MNCs in the same year and not over different periods of time.

In the literature there has been little formal systematic modeling on FDI. In addition the analyses accounting for simultaneity miss to investigate the topic through a multivariate framework. In order to fill these gaps here the dataset will be analyzed through a simultaneous equations system (Section 1.4). The analysis of MNCs will be additionally deepened by distinguishing between U.S.-owned and foreign owned multinationals operating in the United States. At the best of our knowledge this is the first

[4] The manufacturing sector motor vehicles and equipment manufacturing is the SIC 371, and NAICS 3361, 3362, 3363. The sector Motor Vehicles and Equipment manufacturing is part of the broader sector Transportation Equipment Manufacturing SIC 37 and NAICS 336.

attempt in estimating such a general system taking into account the difference in firms' ownership. Possible interrelationships between the two differently owned firms will be considered empirically in order to account for spillover effects or causality relationships.

Estimation results will be introduced in Section 1.5 for both U.S. Parents (Section 1.5.1) and U.S. Affiliates (Section 1.5.2). Empirical results show that the two types of multinationals significantly influence each other. In addition strong influence on U.S. Parent companies is exerted by the rational expectations on foreign competitors' activity. Section 1.6 concludes.

1.2 Historical background

U.S. automakers traditionally focused on the production of big-size cars until the 1960s when foreign car manufacturers entered successfully the U.S. market by importing small and compact cars. The continuously decreasing market shares of American firms induced the U.S. Government to follow trade protection measures in order to protect U.S. firms and employment. Despite the policy issues, U.S. automakers did not succeeded in retaining their level of sales, and foreign competition reached very high levels in the recent past. The following are the main facts on the economic development of the American automotive industry.

U.S. automotive industry relied until the seventies on the water-cooled, carbureted V8 engine, automatic transmission, rear-wheel drive developed in the 1930s. In the 1960s U.S. consumers' tastes start changing toward different and smaller car models with respect to the American automotive tradition. Foreign producers (primarily European companies) entered the U.S. market through an increasing import of vehicles. From less than 1% of consumption through the mid 1950s, import raised to over 10% in 1959. General Motors (GM) and Ford reacted by importing small cars from their foreign affiliates located in Germany and England. In 1959 the two American giants started to produce small cars domestically, successfully reducing the market shares of foreign cars to 6.4% in 1960 and 4.9% in 1961. Despite the domestic production of small cars, in 1966 import started to rise again with a 10% market share and a steady rate of growth to a 24% in 1970 (Nelson, 1996). This time the import growth was not only from European firms. Japanese firms started their U.S. import penetration. The Big Three continued their strategy of captive imports and small cars production. The new American cars were lighter, smaller, and cheaper than traditional U.S. vehicles, but still larger than foreign vehicles and sold for a higher price (Eden et al., 1996).[5] In addition foreign competitors benefited of established marketing networks and good reputation in the small and compact cars segment. American firms started losing market shares in favor of foreign imported cars (Nelson, 1996). In this way foreign competitors captured the small and compact cars' segment, while the Big Three continued to concentrate in the family-size cars, where they could have much higher profitability.[6]

At the end of 1970s and early 1980s the great publicity about gasoline shortages after the oil shocks of the 1970s pushed consumers' cars preferences to change in favor of small and compact cars. GM, Ford, and Chrysler continued to downsize their products, but their market shares did not stop to decrease (Eden et al., 1996). The Big Three were strongly affected by the Iran crises of 1979 ("second oil price shock"). In 1980 the U.S. automotive industry felt as in a recession, declining its production and increasing the unemployment rate because of reduced market demand. At the same time fuel-efficient Japanese cars increased their import rate by 500% from 1973 to 1980 (Cooney, 2005). Japanese imports were also favored by the Yen-Dollar exchange rate, which made Japanese products relatively cheaper with respect to American cars until the early eighties (Co, 1997). The Big Three closed many production plants in order to reduce total capacity. Plants located in highly unionized areas of the Northern regions were replaced by new plants located in the Southern U.S. to take advantage of low wages, weak trade unions, and

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[5] In this period "Ford, Chrysler and GM all introduced compact cars, one meter shorter than their conventional full sized models in 1960" (Eden et al., 1996).

About the price differential between American and Japanese cars, Nelson (1996) cited Abernathy et al. (1981), and Abernathy et al. (1983) which found that Japanese automakers had a labor cost advantage in the \$1100-\$1400 range and a material costs advantage in the \$600-\$800 range. Abernathy et al. (1981) show additionally that the differentials do not result from a difference in capital intensity given that the Japanese producers apply less capital per unit of output with respect to U.S. automakers. Accounting for transportation and marketing cost, Abernathy et al. (1983) show that the Japanese cost advantage over U.S. firms is in the \$1200-\$1500 range. Flynn (1984) addressed the topic in more detail, finding a Japanese cost advantage of \$1432 for labor and of \$1498 for land.

[6] Abernathy et al. (1983) show that, while the production cost for small cars were slightly less than those for large cars, the price differential was considerable. At the same time, hypothesizing a sufficiently inelastic demand for auto transportation, most consumers with a preference for small cars would buy large cars if small cars were not available (Nelson, 1996). In this respect White (1971) suggests that concern with the stability of the oligopoly encouraged the Big Three to stay out of the small cars' market. Indeed the small cars segment might support one firm, while it would not be profitable for all the Big Three together.

liberal work rules. The United Auto Workers (UAW) unionized also the new plants and the Southern strategy revealed immediately its weakness.

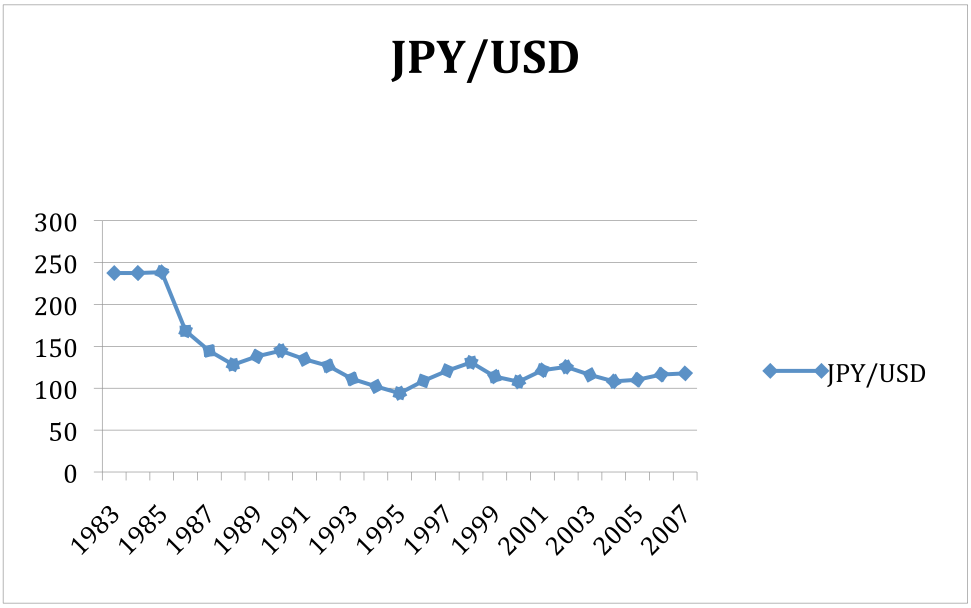
Given the importance of the automotive industry in the whole U.S. economy, the Big Three and the UAW were successful in lobbying for a political support. In 1979 through the Chrysler Loan Guarantee Act, Chrysler received a government-backed loan in order to avoid bankruptcy. Free Trade Sub-Zones and duty-free benefits were stipulated in order to stimulate U.S. firms' competitiveness.[7] In addition the Reagan Administration pressed Japan to act in its own by imposing "voluntary export restraints" (VERs) on Japanese automotive exports.[8] To avoid a possible conflict with U.S. antitrust rules, in 1981 the Japanese Government through the Ministry of International Trade and Industry (MITI) undertaken two important policies in May and December 1981 in order to reduce Japanese auto export and pushing Japanese FDI into the United States. First, in May 1981 the MITI placed VERs on Japanese auto export to the U.S. The VERs program started with a three years quantitative restriction on automobiles export, in order to roll back Japanese import level to the 1978 average. Japanese exports were restricted to 1.68 million units in the first year, with an unspecified growth in the last two years. The 70% of the U.S. VERs was allocated to Toyota, Nissan, and Honda. The rest was to Mitsubishi, Mazda, Fuji, Isuzu, and Suzuki. In this way Japanese cars import would be reduced by 7.7% with respect to the previous period. VERs program has been renewed for several years by the Japanese Government in order to avoid further American actions against Japanese auto imports (Bhagwati et al., 1992; Eden et al., 1996; Nelson, 1996; Carbaugh, 2002; Cooney, 2005). The import-regulation program was mainly aimed at providing the Big Three with the possibility to upgrading their production techniques in order to compete with superior Japanese products. On the other hand, Japanese automakers could increase their prices because of the disequilibrium between Japanese cars' demand and supply. Also the Big

[7] The Foreign-Trade Zones (FTZs) Program dates back to the FTZ Act authorized by the Congress in 1934. It was aimed at encouraging value-added activity at U.S. facilities in competition with foreign alternatives by reducing duty payments on foreign imports in the U.S.. In 1952 the law changed allowing a manufacturing plant to be a Free Trade Subzone (FTSZ). By the duty-free benefits many U.S. companies maintained their competitive advantages in the U.S., not moving to foreign facilities to reduce costs. In the late 1970s automotive companies started receiving the FTSZ designation. In the mid-1980s all the U.S. Big Three were given the duty-free status and all of them benefited from the FTSZ legislation. In addition in 1965 the Canada-U.S. Automotive Products Agreement (APTA) was signed. The Big Three greatly benefited from the APTA that removed tariffs on cars, trucks, buses, tires, and automotive parts between the two countries.

[8] The Government action was consequently to the lobby by the Big Three and the UAW for tariff protection against Japanese import (Eden et al., 1996). UAW requests were also to restrict imports unless Japanese auto producers invested in U.S. production (Nelson, 1996).

Three rose their prices registering record level profits in 1984, but they did not use the increased profits on technological upgrading, paying their executives large salary bonus. Given the Big Three's behavior and because of these bonuses, the Reagan Administration did not pressure to renewal the VER program (Eden et al., 1996). On the other hand the scenario was profitable for Japanese firms, and the Japanese Government decided to continue the restriction program, that lasted until 1994.

Figure 1.1: Exchange rate of Japanese Yen to US Dollar, 1983–2007



UAW was still encouraging U.S. production by Japanese firms to hire American workers, face the same competitive manufacturing conditions as the domestic Big Three, and lose the export advantage of the Yen/Dollar exchange rate. The appreciation of the U.S. dollar reached a maximum in 1985 and then dropped sharply (Figure 1.1). In the early 1980s the high Yen/Dollar exchange rate created serious problems for import-competing firms. Indeed the fluctuating exchange rate was influencing not only the purchasing power of U.S. consumers, but also the relative costs of Japanese producers and consequently their productivity advantage (Eichengreen et al., 1988).[9] Consequently, in December 1981 the

[9] In their study on the international competition of U.S. firms, Eichengreen et al. (1988) show the "power of exchange rate movements to bring about dramatic shifts in relative labor costs". In particular they argue that "the greater impact of exchange rate changes on autos and steel than on textiles and apparel makes sense when one observes that the dollar has fluctuated most dramatically (especially since the beginning of 1985) not against the currencies of developing countries, which are the principal suppliers of textile exports to the

U.S. Government passed the Fair Practices for Automotive Product Act (H.R. 5133). This legislation required that Toyota, Nissan, Honda, Toyo Kogyo, Mitsubishi, Isuzu, and Volkswagen engaged in local production in order to retain their current levels of sales (Nelson, 1996; Cooney and Yacobucci, 2005). More precisely, as stated by the Director of the Congressional Budget Office in 1982, "H.R. 5133 would attempt to restore U.S. auto industry jobs by instituting minimum domestic content requirements for passenger vehicles and light trucks sold in the United States…the domestic content requirements – defined as U.S. value added as a percentage of the wholesale price – would have to be met by each foreign or domestic auto manufacturer producing more than 100,000 units for sale in the U.S. market" (Rivlin, 1982).

In order to retain their market share and to circumvent trade frictions, in 1982 Japanese firms started the creation of U.S. production facilities (Singleton, 1992; Park, 2003; Chung et al., 2003), developing additional products specifically designed for the new American market (Cooney and Yacobucci, 2005). Japanese automakers were also encouraged to shift output to their U.S. transplants by the ongoing depreciation of the dollar that reached a minimum level in 1995, making it less expensive to start new production lines in the U.S. and making the U.S. an attractive manufacturing site for foreign automakers (Fine et al., 1996). As reported in Co (1997), "VERs on Japanese cars' export to the U.S. caused Japanese direct investment into the U.S. automobile industry". In addition, "a dollar depreciation (or a Yen appreciation) is expected to increase the likelihood of Japanese FDI into the U.S." The consequence of Japanese transplant in the U.S. was that the share of U.S. foreign sales held by imports fell from 30.9 per cent in 1983 to 15.7 percent in the late 1990s. At the same time the share of the U.S. Affiliates' production rose from 3 per cent in 1983 to 23 percent in 1998 and the Big Three's market shares continued to fall. Japanese products were better than American ones. Foreign firms had a much greater productivity level, and they were based on different and more efficient production techniques (Chung et al., 2003).[10] Japanese transplants established good and

U.S. market, but against the currencies of industrial countries such as Germany and Japan, which are the main suppliers of autos and steel."

[10] An example of the competitiveness of Japanese firms with respect to the Big Three can be found in the words of Carbaugh (2002): "One factor that influences the number of workers hired is a company's job classification, which stipulates the scope of work each employee performs. As the number of job classifications increases, the scope of work decreases, along with the flexibility of using available employees; this can lead to falling worker productivity and raising production costs. Japanese-affiliated auto companies have traditionally used significantly fewer job classifications than traditional US auto companies. Japanese transplants use work teams, and each team member is trained to do all the operations performed by the team.

cooperative relations with intermediate suppliers, motivating them to support the Japanese business (Zhang et al., 2009).

1.3 Motor Vehicle MNCs: General Trends

Accounting for Japanese transplants in the U.S. is very helpful in analyzing the patterns of the American motor vehicles industry. In doing that, it is also important to account for the foreign activity of the Big Three. GM, Ford, and Chrysler maintained the production of big cars in the U.S. leaving the production of small and compact cars to foreign, mostly European, affiliates. It has been well documented that the production of big size cars was held in the U.S. because it allows having higher markups than the production of small and compact vehicles (Abernathy et al., 1983). Furthermore, when foreign plants first started manufacturing in the U.S., most of their revenue was from sales of foreign produced cars, and the U.S. Affiliates were, therefore, classified as wholesale traders rather than manufacturers. Foreign-owned affiliates got moved into the manufacturing sector only when the majority of sales came from cars made in the U.S. as pointed out by Prof. R.E. Lipsey.[11] Indeed FDIs in the U.S. were mainly driven by trade restrictions and the investing firms entered the U.S. market as importers before being local producers. Accordingly the U.S. market shares of foreign MNCs were computed as including the total sales of the wholesale trade of foreign-owned enterprises. The U.S. Parents' market shares were computed as including the import shipped to U.S. Parents by their own foreign affiliates to account for the small-size cars produced in their foreign facilities and sold in the U.S. with American brand (Figure 1.2).[12]

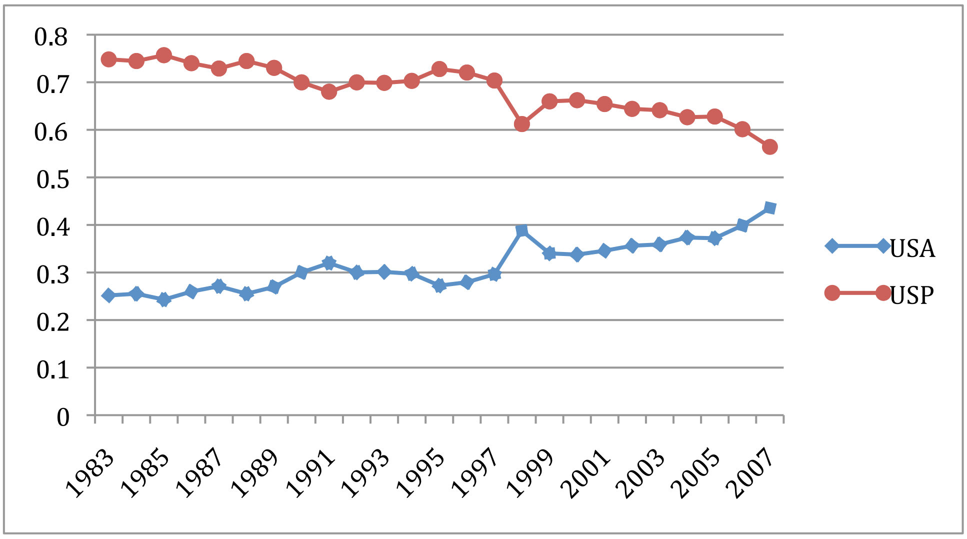
A typical Japanese-affiliated assembly plant has three to four job classifications… In contrast, traditional US auto plants have enacted more than 90 different job classifications, and employees generally perform only those operations specifically permitted for their classifications."

[11] "Indeed BEA collects data at the enterprise level and affiliates are classified into one industry code based on their sales. Therefore a company generally considered to be a manufacturer may be classified in wholesale trade", as pointed out by the Direct Investment Division, Bureau of Economic Analysis.

[12] Data from BEA on MNCs are in the "International Account", Section "Operations of Multinational Corporations". The "International Account" does not provide data on US total sales, but only on the MNCs' total sales in the U.S. Data on the U.S. Industry as a whole are on the "Industry Account". The "Industry Account" provides data on U.S. Industry's total sales. Since the two sections collect data based on different

Figure 1.2 shows that U.S. Parents' market shares follow a declining pattern in favor of their foreign competitors over the period analyzed. U.S. Parents held around 75 percent of the U.S. market in 1983 and only around 57 percent in 2007. In 1997, the Standard Industrial Classification (SIC), used to classify industries, was changed to the Noth America Industrial Classification System (NAICS). Here the SIC-to-NAICS shift has been dealt with by using the bridge tables provided by the U.S. Census Bureau.[13] Despite the use of bridge tables the year 1997 presents an abnormal change in the market shares. By dividing the time span into two sub-periods, U.S. Parents' market shares moved from around 75 percent to something more than 70 percent in 1996. A much more pronounced decrease (around 10 percent) has been registered by U.S. Parents' market shares during 1999–2007.

Figure 1.2: MNCs' market shares: U.S. Parents versus U.S. Affiliates



As suggested by Prof. R.E. Lipsey and by the BEA Direct Investment Division, a company generally considered to be a manufacturer may have been classified in wholesale trade. This bias arises because data are classified at the enterprise level and affiliates are classified into one industry code based on their sales. Only when the majority of sales was

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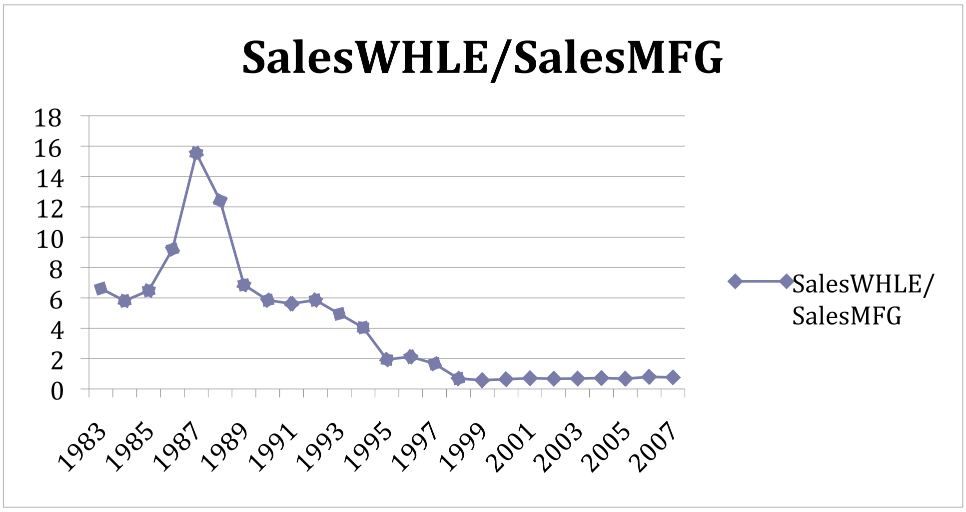
methodologies, "data on MNCs are not directly compatible with data on the U.S. Industry" (BEA: Balance of Payments Division). Accordingly U.S. Parents' and U.S. Affiliates' market shares are computed here over the MNCs total sales.

[13] The SIC code lasted from 1930 to 1997, when the new NAICS code was introduced. The main difference between the two industry codes was that the SIC groups classified establishments by their primary types of activities, while the NAICS classified establishments according to production processes. Here the time series have been created by using the "bridge tables between SIC and NAICS" provided by the US Census Bureau (http://www.census.gov/epcd/ec97brdg/). In the "bridge tables" the US Census Bureau provides a correspondence between the two coding systems for the year 1997, providing a double classification in SIC and NAICS codes.

from U.S. production, U.S. affiliates were classified as manufacturers. The great share of U.S. Affiliates' wholesale trade total sales (WHLE) over their total manufacturing (MFG) sales (Figure 1.3) is likely to bias estimation results for the period 1983–1998. In order to account for this bias, a dummy variable will be interacted with the level of U.S. Affiliates' wholesale total sales in estimation. The dummy (dummyWHLE) will take the value of 1 for the period in question (1983–1998), 0 otherwise.

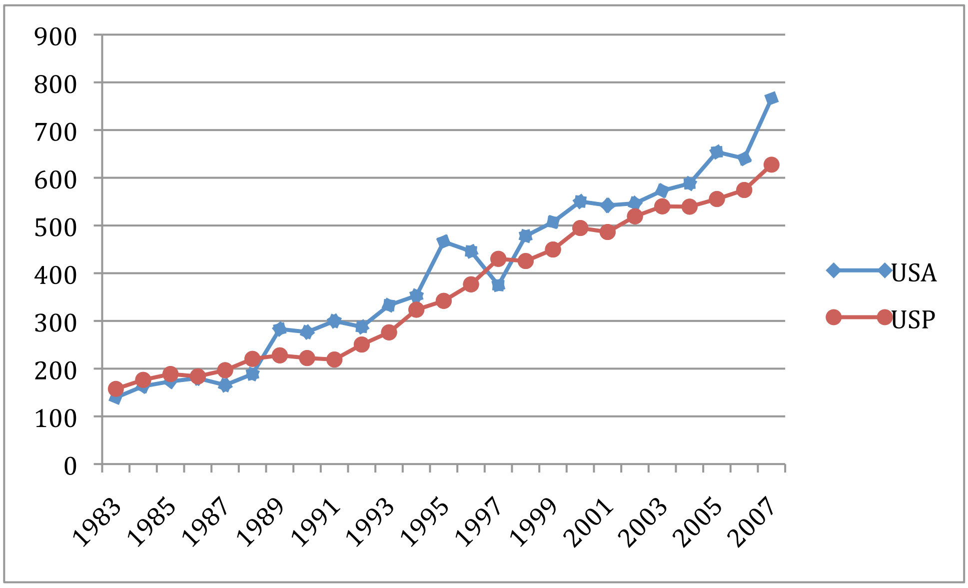
Figure 1.3: U.S. Affiliates motor vehicles: Percentage of wholesale total sales over the manufacturing total sales



From Figure 1.3, it appears also that the percentage of wholesale total sales over the manufacturing total sales decreased until 1984. This suggests that the VERs influence is still decresing U.S. imports. As stated earlier, the Fair Practices for Automotive Product Act required foreign firms to undertake local production in order to retain their current levels of sales. After the high level of the U.S. Dollar appreciation in 1985, Japanese automakers intensified their FDI into the U.S., and started transplant production that allowed them raising imports again. That scenario lasted until 1987 when a great depreciation of the U.S. Dollar continued to encourage foreign investment and discourage U.S. imports. The abnormal peack in U.S. import of Japanese cars in 1987 is possibly due to the end of the second run of restraints in Japanese exports. As Figure 3 shows, from 1987 onwards the imports as percentage of manufacturing total sales declined sharply until 1997. From 1998 onwards the WHLE total sales stabilized their percentage over the manufacturing total sales, representing about 0.7 percent of U.S. Affiliates' total sales in the U.S. motor vehicles industry until the end of the period analyzed.

Figure 1.4 shows the level of sales per employee for both types of manufacturing multinationals. U.S. Affiliates registered the highest level of sales per employee from 1989 onwards. The abnormally low level in 1997 is still attributable to the SIC/NAICS shift. On the other hand, the low level of U.S. Affiliates' sales per employee in the early years of the analysis is possibly due to the fact that in this period the majority of foreigners' sales were from the wholesale motor vehicle sector.[14] U.S. Affiliates are likely to have a great level of sales per employee because they are productive plants, leaving all the "non-productive" activities located in the foreign headquarters. Data are in millions of U.S. Dollar at current prices in order to compare the two types of multinationals.

Figure 1.4: Sales per employee: U.S. Parents versus U.S. Affiliates (million US dollars)



U.S. Parents are the multinationals involved in R&D activities the most (Figure 1.5). As previously hinted, U.S. Parents' headquarters and research centers are based in the U.S. On the contrary, the foreign-owned firms are productive plants, established mainly to avoid trade restrictions and to maintain market shares. In this line foreign multinationals are likely to leave the research and development centers close to the foreign headquarters. In addition, foreigners' market shares were based on the small and compact cars segment, while U.S. firms were focused on the production of big and family-size cars.[15] Thus FDI in the U.S. were mainly undertaken to maintain the U.S. market shares and not due to

[14] Adding the wholesale motor vehicle sector to the U.S. Affiliates, the sales per employee change the figure in the years before 1998 according to the wholesale over manufacturing sales ratio of U.S. Affiliates in Figure 3. Values at current prices are used here to compare U.S. Parents and U.S. Affiliates.

[15] In the early 1960s the Big Three imported small cars from their foreign affiliates and sold them in the US under the American brand (Nelson, 1996). US firms did not implement specific production line focused on the small and compact cars sector. They just tried a production of resized traditional vehicles.

technology-seeking and research motives.[16] Accordingly, the low level of U.S. Affiliates' R&D per employee is in line with the theory of market-seeking FDI. Figure 1.5 shows that also in the case of the R&D variable the SIC/NAICS bridge implies some bias in the time series. Data are in millions of current U.S. dollars. The use of money variables at current prices does not bias the comparison between foreign-owned and American MNCs.

Figure 1.5: R&D expenditures per employee: U.S. Parents versus U.S. Affiliates

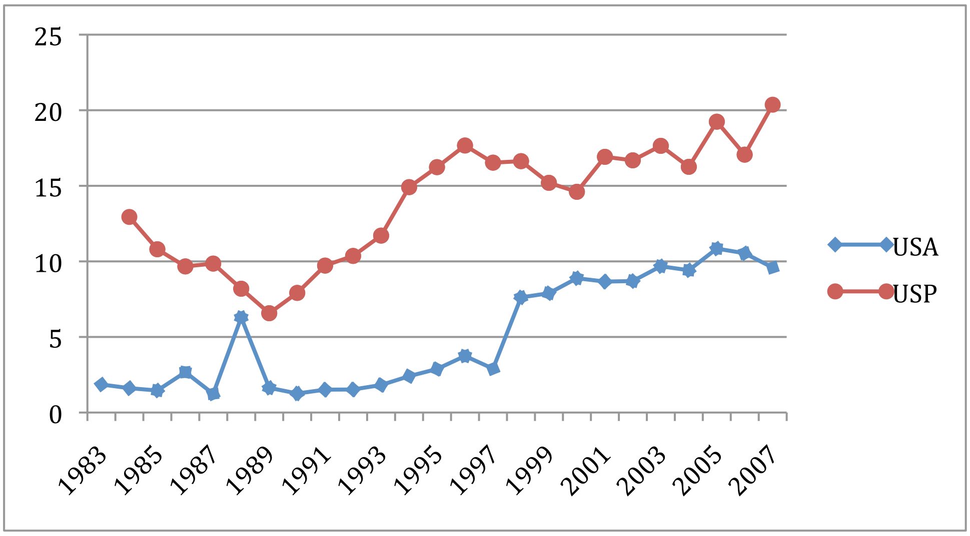
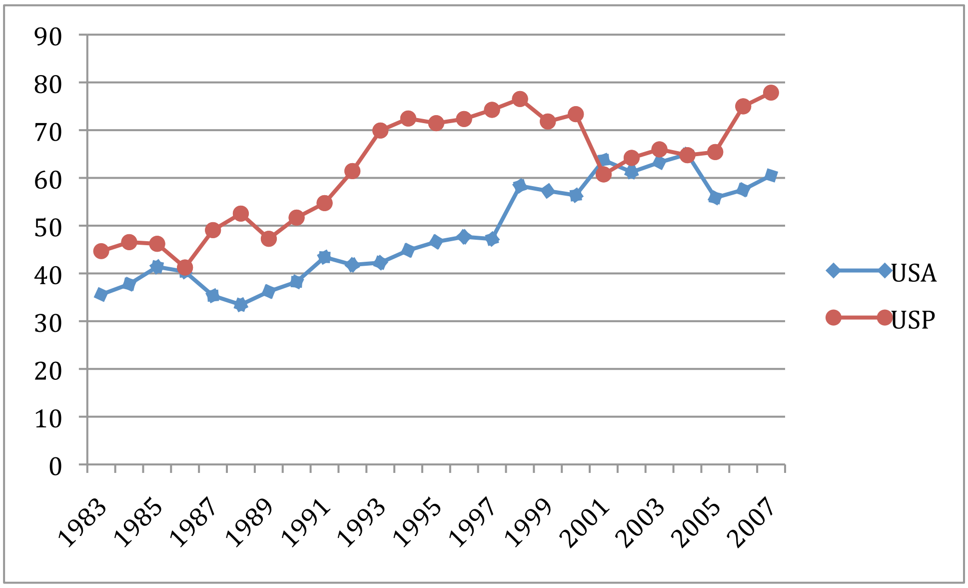


Figure 1.6 shows that domestic MNCs' compensation per employee is higher on average than the U.S. Affiliates' levels. On the contrary, many studies in the literature found that on average, foreign-owned firms pay higher wages than domestically owned companies. The wage gap is usually explained by the differential in productivity between foreign-owned and domestic owned firms. Even if once controlled for difference in wage determinants, the foreigners' wage premium falls substantially at least in developed countries (Lipsey and Feliciano, 1999).[17] Here the U.S. Parents' highest wage level is likely due to the fact that U.S. Parents' employment include headquarters high-wage employment, while U.S. Affiliates are mostly based on production-blue-collar workers. Also in this case values at current U.S. dollars are taken just for the sake of comparison.

[16] For the distinction between market-seeking and technology- or resource-seeking FDI, see Barba Navaretti and Venables (2004)

[17] Lipsey (2002) reports, "it is rare to find a study of FDI and wages in any host country that does not find that foreign owned firms pay higher wages, on average, than at least privately owned local firms. That is the case not only in developing countries…but also in developed, high wage countries…" Foreign-owned firms pay higher wages because they hire superior workers or because they acquire high wage plants or firms, or because they concentrate their activity in high wage industries (Lipsey, 2002).

Figure 1.6: Employees' compensation per employee: U.S. Parents versus U.S. Affiliates



In the following sections an empirical analysis will further investigate the economic activity of U.S.-based multinational firms. By empirical estimations, differences and similarities between U.S. Parents and U.S. Affiliates will be underlined. In addition, inter-relationships between the economic activity of U.S.-owned and foreign-owned multinationals will be further investigated.

1.4 Data and methodology

The present analysis is based on the motor vehicles manufacturing sector. The dataset used is from the U.S. Bureau of Economic Analysis (BEA). The BEA collects the most accurate dataset on the activity of multinational corporations in the U.S. Data are from the Operations of Multinational Companies section in the International Account. The time-series span over the period 1983–2007.[18] In 1997 the coding system used to collect data was changed. Until 1997 data were collected according to the Standard Industrial Classification system (SIC). From 1997 onwards data are collected according to the North America Industrial Classification System (NAICS). The two different coding systems differ in the methodology used to count establishments. The motor vehicles manufacturing sector is the three-digit 371 SIC "Motor Vehicles and Equipment" and the four-digit

[18] For 2008 only preliminary estimates are available. Accordingly the analysis lasts until the year 2007.

NAICS 3361 "Motor Vehicles Manufacturing", 3362 "Motor Vehicle Bodies and Trailers Manufacturing", and 3363 "Motor Vehicle Parts Manufacturing". Here homogeneous time series have been constructed according to the "bridge tables between SIC and NAICS" provided by the U.S. Census Bureau.[19] Data are on total assets, employees' compensation, total employment, export, import, capital expenditures, net income, research and development (R&D) expenditures, and total sales for both U.S. Parents and U.S. Affiliates.

The dataset will be used to estimate a system of simultaneous equations for both U.S. Parents and U.S. Affiliates. As Ma et al. (2000) stated, "despite the increasing importance of FDI and its multinational corporations, there has been little formal systematic econometric modeling of the multinational firms". The system explained here intends to fill this gap by giving a modeling framework of the available variables of U.S. multinational enterprises. The system will analyze the multinationals' activity by allowing for endogeneity through a complete specification (Mullen, 2007).[20] In addition it is important to analyze the relationship between FDI and multinationals' activity in a multivariate framework. Thus it is possible to get insights on indirect causality running from FDI through auxiliary variables to economic outcomes (Ajaga and Nunnenkamp, 2008).[21] This is likely to be the first attempt in constructing a system to investigate all the available variables on multinational companies in the U.S. automotive sector from a macroeconomic perspective.

First of all, given the absence of a pre-specified model to estimate the variables investigated, each variable was estimated through OLS by a two-step procedure. In the spirit of the LSE Approach (Sargan, 2001; Hendry, 2003), each variable is first estimated by constructing a general *unrestricted* model. The *unrestricted* specification includes all the regressors likely to impact on the dependent variable. Based on the results of this first estimation, a *restricted* model has been developed. The *restricted* model resulted from the *unrestricted* specification by eliminating the regressors not statistically significant. In such a way all the redundant variables have been eliminated, and the correct specification able

[19] www.census.gov

[20] Mullen and Williams (2007) assume exogeneity in order to analyze the impact of FDI on domestic productivity through OLS. They stated explicitly: "a more complete specification might explore the determinants of inward FDI as part of a simultaneous system."

[21] Ajaga and Nunnenkamp (2008) investigate "the long-run relationships between inward FDI and economic outcomes in terms of value added and employment" by applying Johansen's co-integration technique and Toda and Yamamoto's Granger causality tests. They recognized that extending the analysis in a multivariate framework "would raise complex data and methodological issues".

to explain the dependent variable has been found. For each model several diagnostic tests have been performed in order to assess the consistency of each regression by avoiding autocorrelation and non-normality of the residuals.[22] Finally, each *unrestricted/restricted* pair of models has been tested in order to identify the correct specification and to eliminate redundant variables. The *unrestricted/restricted models F-test* was performed. For all the specifications' pairs the *restricted* models have passed the *F-test*. Accordingly, the *unrestricted* specifications were rejected and the *restricted* models were taken as the correct specifications to construct the system.

The system specification has been constructed by aggregating the models used to estimate the single variables. The risk of endogeneity and simultaneously correlated residuals is deterred through the construction of a simultaneous equations system, treating as endogenous all the dependent variables and handling at the same time all the coefficients to be estimated. Being investigated the activities of both US Parents and US Affiliates, two different systems were elaborated. The two systems were estimated through Two Stages Least Squares (2SLS) and Three Stages Least Squares (3SLS). As it is known, the 2SLS procedure does not estimate the variance–covariance matrix, taking it as given. The 3SLS procedure provides asymptotically more efficient estimates than 2SLS, because it accounts for possibly correlated residuals. It estimates the variance–covariance matrix and gives standard errors lower than those provided by the 2SLS technique. As expected, 3SLS estimates give lower standard errors and higher t-statistics than 2SLS, providing the consistency of both the specifications and the dataset used in the present analysis. Indeed the 3SLS technique is feasible only if the model specification is correct and the sample presents an appropriate number of observations.[23]

[22] A general test for the first order autocorrelation is the *Durbin–Watson* statistic (DW). When the lag of the dependent variable is among the regressors, the DW statistic is no more valid. Accordingly, in such cases the generalization of the DW proposed by Durbin (1970) has been used, i.e. the *h-test*. Further order serial correlation is checked through the *Breusch–Godfrey serial correlation LM test*. The normality assumption is checked through the *Jarque-Bera Normality* test.

[23] In the case in which the specification is not correct or the number of observations is not appropriate to estimate the variance-covariance matrix, 3SLS does not provide standard errors lower than 2SLS and the estimation results have to be considered not statistically correct.

Note that during the period 1983–2007 many financial troubles occurred.[24] Accordingly, the estimates are likely to be biased during the financial crises. The bias usually occurs as an over- or under-estimation of the data. In such cases the graph of the residuals is shifted upward or downward based on the bias. The use of dummy variables is the fastest way to prove the occurrence of a crisis and to solve its estimation bias. The use of dummy variables improves the fit of the models but reduces at the same time their level of generality and their number of degrees of freedom. The decrease in the number of degrees of freedom can severely alter the results, especially in such cases where two or more dummies are needed. Here specific financial variables are introduced as reasonable alternative to reduce the bias due to financial crises. Indeed through the use of financial variables it is possible to account for financial instability as well as real economic conditions and monetary policy decisions influencing firms' activity. The variables in question refer to the stability of the Dow Jones Industrial Average Index, U.S. money supply (seasonally adjusted M2),[25] and both short-term and long-term U.S. interest rates. Financial data are from the Federal Reserve, the Dow Jones Industrial Average, and the International Monetary Fund. The presence of such variables and their economic relationship with the dependent variable will be discussed in presenting the results.

Additional regressors are the level of U.S. Parents' import shipped by their own

[24] A financial crisis occurred in 1987. On October 19 1987 the stock markets around the world crashed, shedding a huge value in a very short time. It was the largest one-day percentage decline in the stock market history. About ten years later, in 1996, a financial slowdown occurred at world's level starting from the South East Asian stock market, the Hong Kong Exchanges and Clearing Limited. It spread immediately to the world's principal stock markets. In 2001 the United States registered a period of market closure following the terrorist attack, from September 11 to September 17. That caused a period of financial and economic instability not only in the American region but also in the whole world. From 2007 to present several financial institutions collapsed, with many downturns around the world. It has been considered the worst financial crisis (the so called Great Recession) since the Great Depression of the 1930s.

[25] As defined by the Federal Reserve Bank, "M2 consists of M1 plus (1) savings deposits (including money market deposit accounts); (2) small-denomination time deposits (time deposits in amounts of less than $100,000), less individual retirement account (IRA) and Keogh balances at depository institutions; and (3) balances in retail money market mutual funds, less IRA and Keogh balances at money market mutual funds. Seasonally adjusted M2 is constructed by summing savings deposits, small-denomination time deposits, and retail money funds, each seasonally adjusted separately, and adding this result to seasonally adjusted M1… M1 consists of (1) currency outside the U.S. Treasury, Federal Reserve Banks, and the vaults of depository institutions; (2) traveler's checks of nonbank issuers; (3) demand deposits at commercial banks (excluding those amounts held by depository institutions, the U.S. government, and foreign banks and official institutions) less cash items in the process of collection and Federal Reserve float; and (4) other checkable deposits (OCDs), consisting of negotiable order of withdrawal (NOW) and automatic transfer service (ATS) accounts at depository institutions, credit union share draft accounts, and demand deposits at thrift institutions. Seasonally adjusted M1 is constructed by summing currency, traveler's checks, demand deposits, and OCDs, each seasonally adjusted separately". Available at www.federalreserve.gov.

foreign affiliates;[26] the U.S. Gross Domestic Product (GDP) in its absolute and per capita value; and the dummy WHLE.[27]

Estimations have been run using data in levels. In economics, the major problem related to the use of level data is the high probability of having a unit root in the time-series. The unit root makes the series a non-stationary process for which the standard asymptotic theory is no more valid.[28] Non-stationary series are usually differentiated, in order to find a stationary process to be estimated. Here standard Unit Root tests have been run on the BEA time series. The tests failed in rejecting the null hypothesis of unit root in the series in level, while rejecting the unit root for the series in first difference. Many authors show that unit root tests have low power in finite samples. Indeed unit root tests are said to be unable in finite samples to distinguish the unit root null from nearby stationary alternatives (Hamilton, 1994; Christiano and Eichenbaum, 1990; Diebold and Kilian, 2000; Levin, Lin, and Chu, 2002). The question of whether a time series has a unit root is inherently unanswerable on the basis of a finite sample of observations (Hamilton, 1994).[29] In fact, "application of unit root tests without consideration of their low power and for the restrictions that they inevitably impose in a finite sample can be misleading" (Cochrane, 1991). Hamilton (1994) adds that "unit root and stationary processes differ in their implications at infinite time horizons, but for any given finite number of observations on the time series, there is a representative from either class of models that could account for all the observed features of the data." Indeed it is possible to have consistent results from the estimation of non-stationary series. The point is that the linear combination of two or more non-stationary processes can give a stationary process with constant mean and variance. When the linear combination of two I(1) variables is an I(0) series, the two variables are said to be co-integrated (Johnston and Di Nardo, 1996). Indeed Johnston and Di Nardo (1996) pointed out that, "I(1) variables display a tendency to wander. When two I(1) variables are co-integrated, however, they will tend to wander together. The zero mean

[26] The level of import shipped to U.S. Parents by their own foreign affiliates is taken to account for the U.S. firms' foreign production of small and compact cars sold in the U.S. under the American brand.

[27] This variable is in order to account for the cars' import related bias on the early years of the analysis.

[28] A stationary process is defined as a process having mean, variance, and auto-covariance constants independent of time. In the presence of unit root the unconditional mean and variance of the series do not exist and the series is said to be non-stationary (Johnston and Di Nardo, 1996).

[29] "…for any unit root process there exists a stationary process that will be impossible to distinguish from the unit root representation for any given sample size T. Such stationary process is found easily enough by setting one of the Eigen values close to but no quite equal to unity…the converse proposition is also true…" (Hamilton, 1994).

and constant variance of their linear combination prevent them from drifting too far apart." Here the specifications have been estimated following Hamilton's suggestion, that is, "one practical guide is to estimate both with and without the unit root imposed. If the key inferences are similar, so much the better" (Hamilton, 1994). Surprisingly, results from estimations of the BEA series in levels and in first differences are very similar to each other. In addition, the level specifications passed the standard tests for auto-correlation, serial correlation, and non-normality of the residuals. For this reason, here results from levels' estimations will be presented, given that the level model is preferred until 70 annual observations (Diebold and Kilian, 2000).

The following are the system to be estimated. Section 1.5 presents the results of 3SLS estimation, first for the U.S. Parents, and then for the U.S. Affiliate companies.

Table 1.1: Systems' Specifications: U.S. Parents and U.S. Affiliates

U.S. Parents	
Dependent Variables	**Regressors**
Total Asset	c(1) + c(2)**employmentUSP*(-1) + c(3)**importUSP*(-1) + c(4)**salesUSP* + c(5)**assetUSA*(+1) + c(6)**gdp_us* + c(7)**importUSPbyaff* + c(8)**ir_us*(-1) + c(9)**m2_us*
Employees' Compensation	c(10) + c(11)**employmentUSP* + c(12)**exportUSP* + c(13)**importUSP* + c(14)**rdUSP*(+1) + c(15)**m2gr_us*
Total Employment	c(16) + c(17)**employeescompensationUSP* + c(18)**employmentUSP*(-1) + c(19)**importUSP* + c(20)**netincomeUSP*(-1) + c(21)**rdUSP*(-1) + c(22)**salesUSA*(-1) + c(23)**importUSPbyaff*(-1) + c(24)**irst_us*(-1) + c(25)**m2gr_us* + c(26)**dummy83_98*saleswhle*(-1)
K Expenditure	c(27) + c(28)**employeescompensationUSP*(-1) + c(29)**exportUSP* + c(30)**importUSP*(-1) + c(31)**netincomeUSP*(-1) + c(32)**salesUSP*(-1) + c(33)**kexpenditureUSA*(-1) + c(34)**gdppcgr_us*(-1) + c(35)**ir_us*(-1) + c(36)**salesUSA*(-1) + c(37)**importUSP*
R&D	c(38) + c(39)**assetUSP*(-1) + c(40)**employeecompensationUSP* + c(41)**empoymentlUSP*(-1) + c(42)**exportUSP*(-1) + c(43)**importUSP*(-1) + c(44)**netincomeUSP*(-1) + c(45)**salesUSP*(-1) + c(46)**rdUSA*(+1) + c(47)**importuspbyaff*(-1) +c(48)**irst_us*(-1)
Total Sales	c(49) + c(50)**assetUSP* + c(51)**employeecompensationUSP*(-1) + c(52)**kexpenditureUSP* + c(53)**netincomeUSP*(-1) + c(54)**salesUSP*(-1) + c(55)**salesUSA*(-1) + c(56)**gdppcgr_us*(-1) + c(57)**ir_us*(-1)
Export	c(58) + c(59)**assetUSP* + c(60)**importUSP* + c(61)**netincomeUSP*(-1) + c(62)**rdUSP*(-1) + c(63)**djia*(-1) + c(64)**kexpenditureUSA*(-1) + c(65)**m2gr_us*
Import	c(66) + c(67)**assetUSP* + c(68)**employmentUSP*(-1) + c(69)**exportUSP*+ c(70)**netincomeUSP*(-1) + c(71)**rdUSP* +c(72)**dummy83_98*saleswhle*(-1) + c(73)**m2_us*
U.S. Affiliates	
Total Asset	c(1) + c(2)**assetUSA*(-1) + c(3)**employeecompensationUSA*(-1) + c(4)**employmentUSA*(-1) + c(5)**exportUSA*(-1) + c(6)**importUSA*(-1) + c(7)**netincomeUSA* + c(8)**salesUSA*(-1) + c(9)**dummy83_98*
Employees' Compensation	c(10) + c(11)**assetUSA* + c(12)**employmentUSA*(-1) + c(13)**salesUSA*(-1) + c(14)**dummy83_98*saleswhle*
Total Employment	c(15)+c(16)**assetUSA*(-1) + c(17)**employeecompensationUSA* + c(18)**rdUSA* + c(19)**djia*
K Expenditure	c(20) + c(21)**assetUSA*(-1) + c(22)**exportUSA*(-1) + c(23)**importUSA* + c(24)**rdUSA* + c(25)**salesUSA* + c(26)**kexpenditureUSP*(-1) + c(27)**djiahlc*
R&D	c(28) + c(29)**assetUSA*(-1) + c(30)**employeecompensationUSA*(-1) + c(31)**employmentUSA*(-1) +c(32)**importUSA* + c(33)**kexpenditureUSA*(-1) + c(34)**netincomeUSA* + c(35)**salesUSA*(-1)
Total Sales	c(36) + c(37)**assetUSA* + c(38)**employeecompensationUSA* + c(39)**employment*USA(-1) + c(40)**importUSA* + c(41)**netincomeUSA* + c(42)**rdUSA*(-1) + c(43)**gdppcgr_us*(-1) + c(44)**m2_us*
Import	c(45) + c(46)**employeecompensationUSA* + c(47)**exportUSA*(-1) + c(48)**kexpenditureUSA* + c(49)**importUSP* + c(50)**irst_us* + c(51)**djia*(-1)
Export	c(52)+ c(53)**assetUSA*(-1) + c(54)**employeecompensationUSA* + c(55)**employmentUSA* + c(56)**importUSA*(-1) + c(57)**kexpenditureUSA*(-1) + c(58)**netincomeUSA* + c(59)**salesUSA*(-1) + c(60)**xrydgr*(-1) +c(61)**djia* + c(62)**exportUSA*(-1)

Note: The variables and their sources are described in Appendix 1 in the variables' list.
USP: U.S. Parents
USA: U.S. Affiliates
The lag operator, i.e. (-1), represents the variable lagged one year, given that here it is dealing with annual data.

1.5 Estimation results

Estimation results are presented here separately for U.S. Parents and U.S. Affiliates. As earlier, the systems have been developed treating all the dependent variables as endogenous in order to deter from correlation between the residuals. The following are the 3SLS estimation results.

1.5.1 U.S. Parents

U.S. Parents' total sales (Table 1.2) are positively driven by the current level of assets, while the current capital expenditures have a negative influence. Total assets are the cumulative stock of current expenditures in both R&D and capital. Capital expenditures have a negative sign because they represent investments undertaken to develop domestic plants focused on family-size cars (Nelson, 1996).[30] R&D expenditures, included in total assets, are aimed at increasing the variety of products supply and consequently entered the sales regression with a positive sign. Indeed, after the two oil shocks, US consumers changed their preferences toward small and compact cars, imported in the US mainly by Japanese and European firms, as introduced in Section 1.2. U.S. firms left the production of small and compact cars outside the U.S. to subsequently import and assemble them domestically (Nelson, 1996). Given the trend in consumer preferences, the enlargement of domestic plants producing big cars obviously has a negative influence on the sales performance. The U.S. Parents' lagged sales level is negatively related to actual total sales, while the lagged value of U.S. Affiliates' total sales positively affects the U.S. Parents' current sales. It can be a matter of product demand that determines such an opposite result for the two lagged sales levels. Indeed an increase in U.S. Affiliates' total sales represents an increasing demand for small and compact cars. The demand for small cars positively affects the U.S. Parents' total sales which are moving from the family-size to the small cars segment. On the other hand, the negative influence of the lagged level of sales can be also due to the delay in the adjustment process in consumers' demand due to external factors such as an increase in the interest rates or a decrease in the purchasing power.

U.S. Affiliates' total sales one year lagged shows that the U.S. demand of small cars is increasing thus positively affecting the share of U.S. firms producing those cars. On

[30] The Big Three maintained in the U.S. the production of family-size cars because it offered a greater profitability than the production of small and compact cars (Nelson, 1996).

the other hand, U.S. Parents' total sales, principally based on family-size cars, faced a continuously decreasing demand. This is likely to be the case given the established marketing networks and good reputation of foreign competitors in the small and compact cars segment. As expected the growth rate of U.S. per capita GDP enters the regression with a positive sign, while the U.S. interest rate is strictly negative.

Expenditures in R&D activities by U.S. Parents are negatively influenced by the lag of the assets variables (Table 1.2). The more the R&D undertaken in year *t-1,* the lower the R&D in year *t*.[31] Current employees' compensation is positively related to current R&D expenditures. The wage level is a reasonable proxy for the workers' skill level.[32] An increase in the skill level is required to deal with innovations deriving from the R&D activities. The lagged employment level enters the R&D regression with a negative sign. It seems that increasing the labor-intensity impacts negatively on the investment in R&D. This relationship is also due to the fact that R&D is usually devoted to develop innovative and labor-saving production technologies. The lags of both the trade-related variables are negatively related with U.S. Parents' R&D. The higher the level of sales in the previous year, the greater the expenditures in R&D in the current year. Also the lag of import shipped to U.S. Parents by their own foreign affiliates is positively related to current R&D expenditures. Taking the import shipped by foreign affiliates as proxy for outsourcing, and the R&D as proxy for models' variety, it has been shown that increasing variety implies a productivity decline, while outsourcing production processes help in lowering the productivity penalty (Van Biesebroeck, 2007). So the positive sign of the outsourcing proxy is in line with previous findings. The expectation on U.S. Affiliates' R&D is instead negatively related to U.S. Parents' R&D. U.S. firms seem to improve foreign-based facilities' innovative products to compete with foreign-owned companies. That is because foreign competitors are leaders in the small and compact cars sector. As expected, the interest rate variable enters the regression with a negative sign.

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[31] Remind that total assets include also intangible rights deriving from R&D activities, as defined by BEA.

[32] Here the employees' compensation is taken as proxy for the skill level. It would be more appropriate to use the percentage of R&D workers or the ratio between white-collar and blue-collar workers. Unfortunately the BEA dataset does not provide such information, so that it is not possible to find a precise proxy for the workers' skill level.

Table 1.2: U.S. Parents and U.S. Affiliates estimation results: Total sales; R&D expenditures

U.S. Affiliates		**U.S. Parents**	
Dependent variable: Total sales			
Asset	0.445***	Asset	0.22***
	(0.04)		(0.036)
Employees' compensation	1.298*** (0.34)	Employees' compensation-1	6.4*** (0.616)
Employment -1	294.3***	K Expenditures	-2.8***
	(36.9)		(0.463)
Import	0.31***	Net income -1	0.69***
	(0.05)		(0.24)
Net income	1.32***	Sales -1	-0.89***
	(0.31)		(0.14)
R&D -1	-20.2***	Sales of US Affiliates -1	2.24***
	(3.1)		(0.25)
US per capita GDP growth rate-1	860.1* (453.2)	US per capita GDP growth rate-1	9157*** (2136)
M2 US	0.01***	US Long Term Interest rate -1	-7329.9**
	(0.002)		(2525)
R^2	0.999	R^2	0.993
Adjusted R^2	0.998	Adjusted R^2	0.990
Dependent variable: R&D expenditures			
Asset -1	0.024***	Asset -1	-0.02***
	(0.004)		(0.004)
Employees' compensation-1	-0.182*** (0.055)	Employees' compensation	0.011*** (0.02)
Employment -1	22.66***	Employment -1	-11.96***
	(4.80)		(1.88)
Import	0.008**	Export -1	-0.437***
	(0.003)		(0.031)
K Exp -1	-0.058***	Import -1	-0.16***
	(0.015)		(0.038)
Net income	0.082***	Net income -1	0.08***
	(0.02)		(0.01)
Sales -1	-0.023***	Sales -1	0.063***
	(0.008)		(0.0069)
		R&D US Affiliates +1	-0.827***
			(0.223)
		Import shipped by foreign aff. -1	0.634*** (0.05)
		US short term interest rate -1	-373.6*** (94.4)
R^2	0.989	R^2	0.985
Adjusted R^2	0.985	Adjusted R^2	0.971

Notes: Instruments are used following H. Theil (1971).
For each variable the estimated coefficient is reported. The respective standard error is given within brackets.
* significant at 10%
** significant at 5%
*** significant at 1%.

U.S. Parents' employees' compensation (Table 1.3) is positively driven by the current level of employment as expected. Also the export variable exerts a positive influence on the dependent variable as well as the expected level of R&D expenditures. It is likely that the more the expected R&D in time $t+1$, the higher the workers' skill level at time t in order to improve best practices and to deal with innovations. As hinted in the R&D case, and found in the literature, an increase in the skill level is required to exploit innovation-related advantages. It is puzzling that the growth rate of the U.S. money supply negatively affects the employees' compensation level.

U.S. Parents' capital expenditures (Table 1.3) are positively driven by the lagged level of compensation of employees. The increase in employment and consequently in the compensation of employees requires investment in plants' enlargement. The export variable enters the regression negatively, suggesting that U.S. firms prefer to serve foreign markets with foreign-based production. It is likely that foreign markets are focused on the small cars segment, which U.S. Parents supply by their foreign-based production. On the other hand, the past import level supports current expansion and capital investments to develop new assembly plants or to expand existing facilities. It is likely that U.S. companies enlarge their American plants to fine-tune the imported products to specific characteristics of the domestic market. The current imports negatively influence capital expenditures. The latter relationship stands for the fact that the current disposable income is split based on the tradeoff between in-sourcing and out-sourcing activities, that is, increasing U.S. production facilities or importing foreign-based products to serve the local market. A large literature focuses on this trade-off showing that import, taken as proxy for outsourcing, is negatively related with in-sourcing activities. The lagged level of total sales influences the investments in fixed capital negatively. As U.S. demand for automobile production shifted toward the small and compact cars, U.S. Parents find much more profitable to import their foreign affiliates' small cars production. As in Section 1.2, the Big Three maintained the production of big cars in the U.S. in order to gain higher markups. U.S. Parents' total sales are likely to be biased toward family-size cars, not in line with the new consumers' preferences. The past level of U.S. Affiliates' capital expenditures is also negative. U.S. Parents are losing market shares and profitability over the period analyzed, and they seem not able to react effectively to a foreign expansion. Instead, the effect of U.S. Affiliates' sales is positive, representing an expansion of the U.S. small cars' market, which can induce U.S. firms to enlarge assembly establishments. The growth rate of the per capita GDP is still positive in the regression. It is generally used as proxy for the consumers' purchasing power. The lagged level of U.S. long-term interest rate enters the regression with a negative sign, as expected.

Table 1.3: U.S. Parents' and U.S. Affiliates' estimation results: Employees' compensation, capital expenditures.

U.S. Affiliates		**U.S. Parents**	
Dependent variable: Employees' compensation			
Asset	0.055***	Employment	57.06***
	(0.012)		(6.53)
Employment -1	115.56***	Export	0.756***
	(12.04)		(0.084)
Sales -1	−0.1303***	Import	−0.343***
	(0.026)		(0.048)
Sales USA WHLE	0.042***	R&D +1	1.38***
	(0.012)		(0.2)
		US M2 growth rate	−150258***
			(22024)
R^2	0.98	R^2	0.926
Adjusted R^2	0.976	Adjusted R^2	0.903
Dependent Variable: Capital Expenditures			
Asset -1	0.079***	Employees' Compensation -1	1.49***
	(0.006)		(0.12)
Export -1	0.221***	Export	−0.67***
	(0.021)		(0.103)
Import	0.288***	Import -1	0.842***
	(0.015)		(0.112)
R&D	3.85***	Net Income -1	0.377***
	(0.51)		(0.049)
Sales	−0.90***	Sales -1	−0348***
	(0.011)		(0.023)
K Exp US Parents -1	−0.232***	K Exp US Affiliates -1	−1.06***
	(0.014)		(0.279)
Dow Jones Instability Index	21065***	GDP per capita growth rate -1	1289***
	(5950)		(390.7)
		US Long Term Interest Rate -1	−3676***
			(641.04)
		Sales US Affiliates -1	0.716***
			(0.051)
		Import	−0.582***
			(0.139)
R^2	0.996	R^2	0.987
Adjusted R^2	0.994	Adjusted R^2	0.976

Notes: Instruments are used following H. Theil (1971).
For each variable the estimated coefficient is reported. The respective standard error is given within brackets.
* significant at 10%
** significant at 5%
*** significant at 1%

Total employment (Table 1.4) is positively related to the current compensation of employees, U.S. money supply, and the lags of total employment, net income, and that of the import shipped to U.S. Parent by their foreign affiliates. This shows that U.S. Parents increased the U.S. production of medium cars, and their assembly lines in order to refine the products imported from the foreign affiliates. The influence of total import and lags of R&D, U.S. Affiliates' total sales, U.S. short-term interest rate, and U.S. Affiliates' wholesale total sales is negative. Current total import affects the employment negatively as it did in the capital expenditures regression. Current total import is likely to consist of final product (small and compact cars) substituting for the firms' enlargement. R&D seems mainly focused on labor-saving techniques and practices or it can be related to product variety. As an increase in the variety of products supplied decreases productivity, it is standard practice to outsource some intermediate production in order to reduce the productivity penalty. U.S. Affiliates' total sales and wholesale total sales lower U.S. Parents' market shares and negatively influence U.S. firms' expansion as expected. The U.S. short-term interest rate is strictly negative influencing both the demand and supply sides of the market.

U.S. Parents' total assets (Table 1.4) are negatively related to the lagged level of employment. On the other hand, import lagged at one period, current sales, import shipped to U.S. Parents by their foreign affiliates, and U.S. money supply, all have a strictly positive influence on the firms' size. U.S. Parents started to react to foreign competition by importing foreign-based production (Eden and Molot, 1996). In the second step U.S. firms invested in the U.S. in order to start local production of small cars and fine tune imported products. This pattern is particularly underlined by the strictly positive and significant sign related to the imports shipped to U.S. Parents by their foreign affiliates. On the other hand, the expected value of investment in total assets made by foreign competitors influence U.S. Parents' total assets negatively. It seems that the more the expected foreign presence in the U.S., the less the U.S. Parents' investment in domestic facilities. In this line U.S. Parents will try to fight foreign competition on the small and compact cars market by importing these from abroad. As it has been introduced while foreign producers were entering the small and compact car market, U.S. automakers remained focused on family-size cars, where they had much greater profitability (Nelson, 1996). U.S. GDP influences the investments in total assets negatively, while U.S. money supply has a positive effect. As expected, the U.S. long-term interest rate lagged one period enters the regression with a negative sign.

Table 1.4: U.S. Parents' and U.S. Affiliates' estimation results: Total employment, total assets.

U.S. Affiliates		U.S. Parents	
Dependent variable: Total employment			
Asset -1	−0.0004** (0.0001)	Employees' compensation	0.005*** (0.0004)
Employees' Compensation	0.0081*** (0.001)	Employment -1	0.182*** (0.036)
R&D	0.051*** (0.007)	Import	−0.004*** (0.0007)
Dow Jones Index	0.008*** (0.0014)	Net income -1	0.003*** (0.0003)
		R&D -1	−0.009*** (0.0015)
		Sales US Affiliates -1	−0.003*** (0.0004)
		Import shipped by foreign affiliates -1	0.006*** (0.0012)
		US short term interest rate -1	−20.05*** (2.299)
		US M2 growth rate	1645*** (177)
		Sales USA WHLE-1	−0.0044*** (0.0003)
R^2	0.995	R^2	0.983
Adjusted R^2	0.994	Adjusted R^2	0.968
Dependent variable: total assets			
Asset -1	2.77*** (0.113)	Employment -1	−501.4*** (76.97)
Employees' compensation -1	−12.4*** (1.15)	Import -1	5.99*** (1.27)
Employment -1	1462*** (107.2)	Sales	0.864*** (0.181)
Export -1	−4.02*** (0.345)	Asset US Affiliates +1	−0.86*** (0.17)
Import -1	2.694*** (0.19)	US GDP	−0.0002*** (0.00002)
Net Income	4.53*** (0.495)	Import shipped by Foreign Affiliates	11.75*** (1.81)
Sales -1	−2.44*** (0.21)	US long term interest rate -1	−29513*** (5161)
Dummy 83_98	88048*** (8965)	M2_US	0.29*** (0.024)
R^2	0.998	R^2	0.994
Adjusted R^2	0.997	Adjusted R^2	0.991

Notes: Instruments are used following H. Theil (1971).
For each variable the estimated coefficient is reported.
The respective standard error is given within brackets.
* significant at 10%
** significant at 5%
*** significant at 1%

The import regression (Table 1.5) shows a positive impact of the firm's size, export and net income. Since the import is related to the production of small cars to be sold in the U.S., the greater the firm's size, the greater the market share, and consequently the greater will be the import of product to the market. The same mechanism works for the positive sign related to the export variable. That between the two trade variables is a two-way relationship as it is shown by the export regression. U.S. Parents' R&D negatively influences their imports, given that through innovations U.S. firms can implement a new U.S. production line, which will substitute for cars' import from foreign affiliates. Also the U.S. Affiliates' wholesale total sales negatively affect the import of U.S. Parents. It is likely that both U.S. Affiliates' wholesale total sales as well as U.S. Parents' import meet the same sector demand. As expected an increase in the money supply is positively related to import of products.

U.S. Parents' export (Table 1.5) is negatively related with current total assets, suggesting that U.S. establishments are mainly aimed at serving the domestic market. Firms' enlargements are aimed at producing U.S. marketed cars. The sign of the import variable is strictly positive, confirming the two-way relationship between the trade variables. The lagged R&D expenditures and the Dow Jones Industrial Average index are positive and significant. Negative influence is from the U.S. Affiliates' capital expenditures, which can substitute for U.S. Parents' export in the nearest countries, enlarging foreign-owned U.S. plants.

1.5.2 U.S. Affiliates

U.S. Affiliates' total sales (Table 1.2) are positively driven by the firm's size. Indeed the current levels of total assets and employees' compensation, and the lag of total employment, all have a positive and significant influence on total sales. Still the import variable is positive and significant. Importing final and intermediate production from abroad allows U.S. Affiliates to be more competitive than domestic firms. In addition, imports lower production costs, given that in the period analyzed it was much cheaper to import from Japan than produce in the U.S. because of the high Yen/Dollar exchange rate. The money supply (M2 U.S.) and the growth rate of U.S. consumers' purchasing power (here proxied by the per capita GDP) are both positively related to total sales as expected.

Table 1.5: U.S. Parents and U.S. Affiliates estimation results: import and export

U.S. Affiliates		**U.S. Parents**	
Dependent variable: Import			
Employees'	−1.2***	Asset	0.04***
compensation	(0.32)		(0.005)
Export -1	−1.32***	Employment -	−10.8***
	(0.18)	1	(4.6)
K Exp	2.12***	Export	0.5***
	(0.31)		(0.06)
Import US	−0.58***	Net income -1	0.12***
Parents	(0.11)		(0.035)
US short term	1814.5***	R&D	−0.47***
interest rate	(474.1)		(0.19)
Dow Jones	13.2***	Sales USA	−0.08***
Index -1	(1.33)	WHLE-1	(0.014)
		M2 US	0.007***
			(0.001)
R^2	0.965	R^2	0.997
Adjusted R^2	0.952	Adjusted R^2	0.995
Dependent variable: Export			
Asset -1	0.27***	Asset	−0.05***
	(0.073)		(0.006)
Employees'	−8.1***	Import	0.6***
Compensation	(1.14)		(0.07)
Employment	760.3***	Net Income -1	0.17***
	(99.2)		(0.03)
Import -1	1.07***	R&D -1	1.4***
	(0.23)		(0.21)
K Exp -1	1.36***	Dow Jones	5.06***
	(0.3)	Index -1	(0.51)
Net Income	−2.26***	K Exp US	−1.02***
	(0.46)	Affiliates -1	(0.14)
Sales -1	−0.3***	US M2 growth	−188610***
	(0.1)	rate	(211039
xr growth -1	−16752*		
	(9705)		
Dow Jones	−5.2***		
Index	(1.1)		
Export -1	−2.4***		
	(0.4)		
R^2	0.948	R^2	0.991
Adjusted R^2	0.904	Adjusted R^2	0.987

Notes: Instruments are used following H. Theil (1971).
For each variable the estimated coefficient is reported.
The respective standard error is given within brackets.
* significant at 10%
** significant at 5%
*** significant at 1%

The lags of total assets and total employment are strictly positive in the R&D expenditures equation (Table 1.2). An expansion of U.S. facilities has a positive influence on the research and development activities. Lagged levels of employees' compensation are instead negatively related to R&D expenditures. It is likely that U.S. Affiliates engage in R&D activities through direct investments or indirectly by hiring high-wage workers such as engineers and development managers. A similar tradeoff is also seen between R&D expenditures and lagged investment in fixed capital, while actual R&D and capital expenditures are positively related in the capital expenditures regression. It seems both the investments are directed to improve the firms' productivity and profitability and that high levels of investments in year *t* imply a lowest level in year *t +1*. Concerning the import variable, an increase in import can be associated with an increase in outsourcing activities. The increase in outsourcing activities in low cost countries allows a productivity gain and a consequent increase in R&D expenditures aimed at differentiating the products and offering a greater variety of models.[33] The lagged sales level has a negative effect on R&D expenditures. Taking R&D activities as proxy for models' variety, a good sales performance in the previous period does not require additional investment in the current period.[34] The positive sign of the net income variable is the results of a two-way relationship between net income and R&D expenditures. First, the greater the returns of a firm, the greater the investments undertaken. Second, the greater the R&D investments, the greater the firm's competitiveness and the consequent returns. Managers strive for R&D to create excess returns in the competition process, given that R&D can be seen as a measure of corporate innovation (Ito and Rose, 1999).

The employees' compensation (Table 1.3) is positively dependent on the past level of employment and the current level of assets. The variable assets includes among the others the intangible rights developed through R&D to improve the firm's performance.[35] Accordingly, it is likely that the employees' compensation increases not only for an increased employment level, but also because of the increase in the skill level to support the R&D expenditures undertaken to improve the firm's result and labor saving practices. The lagged sales level impacts negatively on total employees' compensation. On the other hand, the sales of the wholesale sector exert a positive and strictly significant effect on the

[33] For the relationship among outsourcing activities, productivity, and models' proliferation see Van Biesebroeck (2007).

[34] It is also likely that well-performing firms in time *t* do not invest in innovative activities to improve their performances in time *t+1*.

[35] As defined by BEA, total assets include "any owned physical object or intangible rights having economic value to a firm". (www.bea.gov)

dependent variable. This suggests that the expansion of the retail industry implies an expansion of the manufacturing establishments in order to respect VERs program.[36]

U.S. Affiliates' capital expenditures (Table 1.3) are positively driven by the lags of total assets and export, and by the current levels of import, R&D expenditures, and the Dow Jones Industrial Average Index. The positive sign of the import variable is likely to be related to the trade restriction policy sustained by the U.S. until the mid-1990s. In order to import foreign-produced cars, automakers were required to invest in the U.S. and hire American workers to sustain U.S. economy. At the same time the negative sign related to the current level of sales testify that an increase in U.S. demand is faced by imports from abroad without expanding U.S. facilities. R&D is likely to involve investments in fixed capital in order to develop new products specifically developed for the American consumers' preferences. The Dow Jones Index is a proxy for U.S. economic development and registers the expected positive sign. Strong negative influence on foreigners' capital expenditures is from the expansion of domestic producers. Indeed investments in fixed capital by U.S. Parent companies are likely to impact negatively on U.S. Affiliates' investments.

The negative sign of the lagged level of total assets on the employment regression (Table 1.4) suggests that U.S. Affiliates invest mainly in labor saving technologies and machineries. Indeed U.S. Affiliates started their production in the southern states, in order to take advantage of low wages, weak trade unions, and liberal work rules. During the period analyzed the UAW unionized the new plants, and many pants were closed during the 1980s and 1990s. In this line it is likely that U.S. Affiliates tried to lower employment costs by introducing advanced machinery and production techniques. The positive sign of the R&D and employees' compensation variables confirms that U.S. Affiliates hired R&D personnel to innovate production and white-collar workers in order to introduce best practices and innovative management techniques.

Total assets (Table 1.4) are strictly and positively driven by their lagged value and the lags of employment and import. Still positive are the effects of current values of net income and the *dummyWHLE* variable. Strictly negative are the lags of employees' compensation, export, and sales. The positive impact of the lagged import level is in line

[36] Remember that the sales of the wholesale sector are interacted with the period dummy 1983–98 in order to account for the fact that during 1983–1998 many manufacturing firms could be registered as in the wholesale industry.

with the Japanese VERs framework.[37] It is likely that foreign MNCs established retail and service networks in the U.S. before introducing foreign-owned production, as it is also suggested by the positive coefficient of the dummy variable. The negative impact of the employees' compensation is straightforward as foreign-owned plants are usually located where production costs are the lowest. The export variable is likely to have a negative impact on FDI into the U.S. As discussed in Section 1.2, FDI in the U.S. automotive industry are mainly from Japan. Japanese MNCs tend to export home production and not to invest in the U.S. as export platform, given that they face much lower production costs in Japan because of the relatively high Yen/Dollar exchange rate, especially in the first years of the period analyzed. The negative sign related to the lagged sales' level suggests that increasing U.S. demand for foreign cars does not imply an increase in U.S. inward FDI. It is likely that foreign MNCs continue to import home production in order to have much lower production costs, as it is from the signs related to employees' compensation and import.

As regards total imports (Table 1.5), U.S. Affiliates are likely to import high-skilled home production in order to compete with U.S. automakers. An upgrading in workers' skill level will reduce import from abroad. This is likely to be the motivation for the negative sign related to the employees' compensation in the import equation.[38] On the other hand, the negative impact exerted by the export variable suggests that the U.S. is not taken as an export platform by foreign MNCs. Actual levels of capital expenditures are strictly positive given that fixed investments have been the prerequisite of import in the U.S. at least until the end of the VERs program.[39] As expected, the influence of U.S. Parents' import is strictly negative. Indeed, U.S. automotive firms outsourced the production of small and compact cars to their foreign affiliates, especially in Europe and Japan, in order to be competitive with respect to foreign MNCs in the domestic markets. So the import of U.S. Affiliates and U.S. Parents are competing in the U.S. in the same market segment. The U.S. interest rate impacts positively on import, given that an increase in the interest rates consequently increases the production costs and subsequent outsourcing activities. The Dow Jones Index stands for an expansion of the U.S. economy.

[37] As previously discussed, VERs were imposed in order to stimulate local U.S. production by foreign multinationals.

[38] In economics it is common to use the average wage as proxy for the workers' skill level.

[39] In this respect it must be reminded that the VERs program regarded not only Japanese firms. Also Volkswagen has invested in the US in order to maintain US market shares.

It enters the regression with a positive sign because import of cars is used by U.S. Affiliates to satisfy an increased market demand.

U.S. Affiliates' size, proxied here by total assets, total employment, and capital expenditures, exerts a positive influence on the export regression (Table 1.5). It is likely that large foreign-owned firms are used to serve the markets close to the U.S. Also the lag of import variable has a positive sign, suggesting that the U.S. Affiliates' imports are complementary to final production, as it is the case also in the sales regression. Employees' compensation enters the regression with a negative sign, given that an increase in the labor cost decreases the competitiveness of U.S. Affiliates' production in the world market. Lagged level of U.S. sales is negatively related with export given that an increase in U.S. demand decreases the number of cars to be exported. Negative is also the sign of the Yen/Dollar exchange rate growth even if it is statistically significant only at 10 percent level. An appreciation of the U.S. dollar makes it more expensive to produce in the U.S. than in Japan. In this line Japanese automakers prefer to serve foreign market with domestic production, not by U.S.-based facilities. As shown earlier, the Dow Jones Industrial Average index is taken as a proxy of U.S. economic development. An increase in the index has a negative effect on the export variable given that it suggests an increase in domestic demand. The negative sign related to the lagged export variable may show that foreign MNCs establish plants in the U.S. to serve the local market, supplying the foreign demand with different production.

1.6 Conclusions

In the literature there has been little formal systematic modeling on FDI. The present analysis is likely to be the first attempt in filling this gap. Here MNCs' activity in the U.S. automotive industry has been analyzed in detail through a system of simultaneous equations. In addition, in the analysis multinational enterprises have been distinguished between domestic (U.S.)-owned (U.S. Parents) and foreign-owned companies (U.S. Affiliates).

In the 1960s foreign automakers became strong competitors in the U.S. automotive market against the American Big Three. Foreign firms entered the U.S. market through the import of small and compact cars, which were not produced by American firms. U.S. Big Three continuously decreased their market shares until the 1980s, when international trade agreements limited U.S. car imports. In the early 1980s, in order to retain their market shares, foreign competitors, especially Japanese firms, started U.S. cars production through the lens of FDI. Foreign-owned U.S. firms continuously increased their market shares by producing small and compact cars. Indeed after the two oil shocks, U.S. consumer preferences tilted toward small cars, powered by a smaller engine than the traditional U.S. family-size cars in order to reduce fuel consumption. U.S. Big Three were competing in the small and compact cars sector by importing these from their European affiliates, and continue to produce family-size cars in the U.S. U.S. MNCs' market shares continued their declining trends in favor of foreign competitors (Section 1.2).

The U.S. Bureau of Economic Analysis (BEA) collects the most accurate dataset on the operations of multinationals in the U.S. Data from BEA are used here in order to analyze MNCs' activity in the U.S. automotive sector over the period 1983–2007. From a first glance, the data reveal that U.S. Parents and U.S. Affiliates differ a lot in their structure and economic activity (Section 1.3).

The analysis is deepened through the estimation of a simultaneous equations system. To the best of our knowledge this is the first attempt to construct such a system by investigating all the available variables on the operations of MNCs in the U.S. automotive sector. In addition, the present work further analyzes the multinationals' topic by distinguishing between domestic (U.S.)-owned and foreign-owned multinationals. In the spirit of LSE approach each variable has been estimated by a "two-step procedure". First of all a very general model including all the possible relevant variables has been created. Then a *restricted* model is reached by eliminating all the redundant variables. Several tests were run on both *unrestricted* and *restricted* models to deter from non-normality of the residuals, serial correlation, and autocorrelation. Then an *F-test* between unrestricted and restricted models has been run in order to single out the correct specification. The restricted model passes the *F-test* for all the variables. Once the appropriate specifications have been identified, two simultaneous equations systems have been elaborated, one for U.S. Affiliates and the other for U.S. Parents. The use of simultaneous equations is very useful in empirical analysis because it deters endogeneity in the estimation by treating all the variables as endogenous (Section 1.4).

Three Stages Least Squares (3SLS) results (Section 1.5) confirm that the systems have been constructed with the correct specifications and that the dataset used is consistent for correct estimations. Empirical results show that U.S. Parents' (Section 1.5.1) and U.S. Affiliates' (Section 1.5.2) economic activities are substantially different from each other and they are explained in a very different way. Indeed all the investigated variables are explained through greatly different specifications for U.S.-owned and foreign-owned companies. At the same time both types of multinationals strongly influence each other on their economic activities. In particular there exists a positive relationship between the U.S. Parents' sales and the lag of U.S. Affiliates' total sales, and between the latter and the U.S. Parents' capital expenditures. These positive relationships suggest an increased U.S. market for small and compact size cars, as foreign automakers are the leaders in this sector. However, the relationships among the actual U.S. Parents' capital expenditures and the lagged levels of U.S. Affiliates' capital expenditures, between U.S. MNCs' employment and the lagged levels of foreigners' sales, and between the U.S. Parents' export and the lagged capital expenditures of foreign firms are negative. In addition, U.S. Parents are strongly influenced also by their expectation on foreigners' R&D expenditures and expansion (as it is from the negative sign related to the expected level of U.S. Affiliates' total assets in the assets regression and to their expected level of R&D expenditures in the R&D equation). Accordingly with estimation results, it is likely that U.S. MNCs are strongly and negatively affected by the foreign presence in the U.S. It is likely that the increasing foreign presence in the U.S. reflects the new demand for small and compact cars, which are mainly imported to the U.S. by American firms. This pattern is likely to reduce U.S. Parents' activity in the domestic market. On the other hand U.S. Affiliates are influenced at the margin by U.S. MNCs' activity. Negative influence exists only from the U.S. Parents' lagged capital expenditures and import. This stands for the fact that U.S. Affiliates' and U.S. Parents' imports are competing for the same demand, and that a part of U.S. Parents' capital expenditures is devoted to establish small cars production.[40]

In addition, U.S. Parent companies strongly react on the expectations of U.S. Affiliates' behavior. This is a very important point given that in the literature very few studies analyzed MNCs' inter-relationships and none of these have taken into account the rational expectations on competitors' behavior.

[40] As has been underlined, the U.S. Parents import small and compact cars from abroad to sell them under the American brand.

Appendix 1: Variables

Variables from the International Economic Account of the American Bureau of Economic Analysis. Available at http://www.bea.gov

- *Total Assets*: Any owned physical object or intangible right having economic value to a firm. It typically includes items such as cash, inventories, receivables, and property, plant, and equipment. It also includes equity investments in unconsolidated domestic and foreign businesses.
- *Capital Expenditures*: The expenditures made by a firm to acquire, to add to, or to improve property, plant, and equipment (PP&E). PP&E includes land, timber, mineral and like-rights owned; structures, machinery, equipment, special tools, and other depreciable property; construction in progress; and tangible and intangible exploration and development costs. It excludes the changes in PP&E that are due to changes in the entity--such as mergers, acquisitions, and divestitures--or that are due to changes in accounting methods. The expenditures are measured on a gross basis; sales and other dispositions of fixed assets are not netted against them.
- *Employment*: The number of full-time and part-time employees on the payroll at year-end. If the employment of a parent or an affiliate was unusually high or low because of temporary factors (such as a strike) or large seasonal variations, the number that reflected normal operations or an average for the year is shown.
- *Compensation of Employees*: The income received from an employer as remuneration for work. It includes cash payments, payments-in-kind, and employer expenditures for employee benefit plans including those mandated by government statute, such as employer contributions for government social insurance.
- *U.S. Exports of Goods*: Exports are valued on an f.a.s. (free alongside ship) basis--they exclude transit costs, such as the costs of shipping and insurance.
- *U.S. Exports of Goods Shipped by U.S. Parents to Foreign Affiliates*: Exports are valued on an f.a.s. (free alongside ship) basis--they exclude transit costs, such as the costs of shipping and insurance.
- *U.S. Imports of Goods*: Imports are valued on an f.a.s. (free alongside ship) basis—they exclude transit costs, such as the costs of shipping and insurance.
- *U.S. Imports of Goods Shipped to U.S. Parents by Foreign Affiliates*: Imports are valued on an f.a.s. (free alongside ship) basis--they exclude transit costs, such as the costs of shipping and insurance.
- *Net Income*: The profits that a firm earns in a given time period. It equals total sales or gross operating revenues and other income less total expenses. It is net of, i.e. after deduction of, income taxes and includes income from equity investments.
- *Research and Development Expenditures*: Includes expenditures for the following: (1) The planned, systematic pursuit of new knowledge or understanding toward general application (basic research); (2) the acquisition of knowledge or understanding to meet a specific, recognized need (applied research); and (3) the application of knowledge or understanding toward the production or improvement of a product, service, process, or method (development). It excludes quality control, routine product testing, market research, sales promotion, sales service, and other nontechnical activities; routine technical services; and research in the social sciences or psychology. Note that there are discontinuities in the time series which begin in 1997 for foreign direct investment in the United States and in 1989 for U.S. direct investment abroad: The estimates for these years and later years measure

R&D performed by the firm, either for itself or for others under contract; the estimates for earlier years measure R&D performed for the firm.

- *Total Sales*: The value of goods and services sold and, for financial firms, also includes investment income. It is net of returns, allowances, and discounts and excludes sale or consumption taxes levied directly on the consumer and excise taxes levied on manufacturers, wholesalers, and retailers.

Other Variables:

- *IR_US*: U.S. long-term interest rate: source: OECD Statistics, Country Statistical Profiles. Available at http://stats.oecd.org/Index.aspx.
- *IRST_US*: U.S. short-term interest rate: source: OECD Statistics: Country Statistical Profiles, available at: http://stats.oecd.org/Index.aspx.
- *GDP_US*: U.S. Gross Domestic Product: source: The World Bank, available at: http://data.worldbank.org/
- *GDPPCGR_US*: growth rate of U.S. Gross Domestic Product: source: The World Bank, available at: http://data.worldbank.org/
- *M2_US*: U.S. money stock M2: Federal Reserve Bank, available at: http://www.federalreserve.gov/
- *XRYD*: Japanese Yen/U.S. Dollar exchange rate: Japanese Yen per units of U.S. Dollar: source: OECD Statistics: Country Statistical Profiles, available at: http://stats.oecd.org/Index.aspx
- *DJIA*: Dow Jones Industrial Average: source: Dow Jones Indexes, available at: http://www.djindexes.com/

Chapter 2

Is the Productivity of Multinational Companies in the Automobile Industry Affected by Complementarities?

A Macroeconomic Perspective

Abstract

The main goal of this paper is to see if the results on productivity in the U.S. automotive industry discussed in the recent microeconomic literature can be confirmed when macroeconomic data are used.

Using the BEA dataset on multinational corporations, the productivity model presented in Van Biesebroeck (2007) has been re-estimated for both U.S. and foreign firms.

Empirical results show that it is possible to infer similar conclusions using data at different aggregation levels even if some differences will persist between the micro and macro analysis. Surprisingly the difference in firms' ownership does not imply different models to explain multinationals' productivity. In addition the main variable involved in the productivity analysis show the presence of spillovers and strong interrelationships between U.S.- and foreign-owned companies, while the productivity variable does not show any spillover effect.

2.1 Introduction

Many studies in the literature show how firms' performance is affected by internal organizational design choices. The potential importance of interactions between different elements of organizational design has been recently emphasized. It has been additionally shown that the adoption of organizational design practices is correlated across firms and that some practices appear together. Theory suggests that such clustering arises if the organizational choices are complements (Athey and Stern, 2003). Complementarities are defined as a positive dependency between groups of activities (Milgrom and Roberts, 1990).[41] This topic has been largely analyzed at microeconomic level, while little macroeconomic modeling exists in the complementarities' analysis.

Among others, in his "Complementarities in automobile production", J. Van Biesebroeck (2007) analyzes the automobile industry in North America during the period 1994–2004 using plant level data. The author focuses on the increase in cars' and light trucks' models produced in North America and its impact on firms' productivity. He infers that the increase in models' variety could not be due to innovations in production technology. On the contrary it mainly represents the firms' reaction to changes in consumers' demand. This process will result in severe production difficulties. Indeed a great variety of models can be produced at minimal extra costs by the leading firms, while less competitive firms will incur in much greater productivity penalty in order to follow the market trend and to preserve their market shares.

Do these microeconomic results hold in a macroeconomic context? Can Biesebroeck's "productivity penalty" be detected and measured when industry level data, as those published by the U.S. Bureau of Economic Analysis (BEA), are used? In addition, the present work will separately consider U.S.- and foreign-owned multinational corporations (MNCs). To the best of our knowledge this is the first attempt to compare the plant-level productivity analysis of Van Biesebroeck with industry-level results in the U.S. automotive industry.

[41] As in Milgrom and Roberts (1990) "the defining characteristic of these groups of complements is that if the levels of any subset of the activities are increased, then the marginal return to increases in any or all of the remaining activities rises."

Section 2.2 will briefly review Van Biesebroeck's 2007 work. First, his plant-level dataset and the problem of models proliferation will be discussed. The author identifies three activities, which affect productivity in the automotive industry, namely product variety (Variety), technological flexibility (Flexibility), and Insourcing, that is, the opposite of outsourcing. Even though these activities are associated with productivity penalties, firms carry them out in order to adapt their production to new consumers' preferences. Then he "investigate(s) the potential complementarities between these three activities on the universe of all car and light truck assembly plants in North America over the 1994–2004 period" (Van Biesebroeck, 2007). Finally the firm-level results on productivity will be discussed.

In Section 2.3 the industry dataset from BEA will be discussed. Here proxies for the investigated activities will be constructed, given that the available dataset does not provide the same information. Then a specification very similar to that used by Van Biesebroeck at plant-level is estimated, in order to see if results similar to those discussed in Section 2.2 continue to hold. Section 2.4 introduces the econometric procedure under estimations. First, the productivity specification is estimated through Least Squares. Then, in order to deal with the problem of endogenous adoption decisions on the three activities at the plant level, a simultaneous equations system for productivity will be constructed for each type of MNC. This procedure will result in the estimation of two systems, one for U.S. Parents (Section 2.4.1) and the other for U.S. Affiliates (Section 2.4.2). Systems estimation represents a novelty in the MNCs' analysis (Ma et al., 2000) and it is very important because by a complete specification it is possible to account for endogeneity and unobservable bias (Mullen, 2007). Section 2.5 concludes the analysis.

2.2 Plant level evidence

In his 2007 paper, Van Biesebroeck analyzes the impact on productivity deriving from the different models proliferation on the automotive industry in North America from 1994 to 2004.

Firms engage in three main activities in order to supply a much greater variety of models and maintain their market power. These are (i) the increase in the number of models produced in a single plant: Variety; (ii) Flexibility, i.e. the adoption of flexible technology; and (iii) In-sourcing, i.e. the adoption of multi-task plants, which is the opposite of out-sourcing. The author first investigates the impact of each activity on productivity, then their joint influence through the inclusion of interaction terms between the three activities in the estimated model.

2.2.1 The general framework

The number of different models supplied in the North American automotive market followed an increasing trend over the last decades. The number of different models of cars and light trucks rose enormously from 1974 to 2004. It was in 1994 that the car models increased the most. In that period the number of variations per model, that is Variety, also increased a lot. In addition, while the number of models produced in the North American countries has caught up with the number of models for sale in those markets, the number of plants did not change as much. Accordingly the average number of models produced in a single plant increased enormously. Furthermore, the increase in the models supplied has been greater than the increase recorded by total sales (Van Biesebroeck, 2007).

Therefore, firms offer an increasing variety of different models by producing several models in the same assembly plant (Van Biesebroeck, 2007). This phenomenon implies an increase in manufacturing complexity in the production line as well as several changes in the organization of the production processes inside the firms. Indeed, while models proliferation starts by differentiating models in appearance, in a little time the market will need to differentiate further the products supplied. Accordingly, a reduction in similarities among vehicles produced by the same assembly plant will result. The process will develop into increasing assembly lines per plant or into assembling on the same platform models derived from different production lines. The adoption of flexible technology will result as the principal way to make it feasible. Flexible technology is taken only as an efficient way to produce a greater variety of vehicles per assembly line. Given the data reported by Van Biesebroeck, this is likely to be the case from 1994 onwards. In addition, the activity of assembling models from different production lines induces the firm to solve the “make or buy dilemma”. That is the option to carry out in the same plant all the production chain (In-sourcing) or to out-source some intermediate steps to other plants, accordingly to factor-cost advantages. Data analysis suggests that firms adopt multi-task plants, i.e. they In-source intermediate stages of the production chain to maintain their competitiveness in the market.

2.2.2 The dataset

Van Biesebroeck (2007) uses a plant level dataset from *The Harbour Report North America*, which is available for 1980, 1981, 1989, and every year from 1994 onwards. The dataset is collected by integrating information supplied by the firms with plant visits by representatives of Harbour Consulting. The data analyzed refer to all car and light track assembly plants in U.S., Canada, and Mexico over the period 1994–2004.

The dependent variable is "hours-per-vehicle," that is, the number of hours taken by each plant to assemble a single vehicle. "Hours-per-vehicle" represents the principal output of the Harbour Consulting report. This productivity measure is anomalous, given that it represents exactly the inverse of the standard labor productivity.[42] Indeed it is standard practice in the literature to use a measure of productivity expressed in value and not in hours. In addition the use of hours-per-vehicle as productivity proxy can be misleading given that the product, i.e. automobiles, is not homogeneous. Indeed the production of different car models requires different production techniques and skill levels. The author uses it as an informative measure of the firms' productivity by "assuming that other inputs are fixed over time and across plant or vary proportionally to output." Note that prior to 1998 the productivity measure was computed as workers-per-vehicle, as underlined by the author. That procedure "ignored daily fluctuations in production and converted employment to full-time equivalent workers. Given that both measures (of productivity) are available in 1998 and 1999," Van Biesebroeck converts the workers-per-vehicles into hours-per-vehicles using a conversion factor influenced by ownership (firm) and location (country). In the regressions he includes a pre-1998 dummy to control for that.

[42] The author also recognized this feature. In order to take hours-per-vehicle as an informative productivity measure, Van Biesebroeck implicitly assumes that the other inputs are fixed over time and across plants or vary proportionally to output.

Additional control variables are location dummies (U.S., Canada, and Mexico); ownership dummies; segment dummies, in order to distinguish between the production of compact cars, mid/full size cars, sport/specialty cars, luxury cars, SUVs, pickup, trucks, mini vans, and full-size vans; a year trend; and a scale economies index, measured by the logarithm of production capacity.[43]

2.2.3 Methodology

According to the general scenario, the three phenomena involved are the following: (i) increasing Variety in models supplied, (ii) the adoption of Flexible Technology in production, and (iii) the In-sourcing processes. Van Biesebroeck investigates the impact of the three activities on firms' productivity and to what extent they are likely to create positive or negative externalities. The following are the ways in which the author measures the three variables and the instruments used in the estimation.

Variety is measured by "the sum of the number of body styles and chassis configurations produced in the plant." As an instrument for a plant variety "the average number of varieties produced by plants of other firms, limited to models that compete in the same segment" is used.

The adoption of flexible technology is proxied by the number of platforms per line.[44] Instruments for flexibility are the inside area of the plant and the way in which shift relief is organized. These are indeed the two phenomena mainly involved in the adoption of flexible technology. As in Van Biesebroeck (2007), "size is important as only larger plants have the option to duplicate assembly lines, an alternative approach to producing more variety." The organization of the shift relief is also crucial because it reflects the interaction among blue-collar and white-collar workers. This interaction is very important in the adoption decision, given that flexibility requires high-skilled workers. As with the size of the plant, the shift relief organization is also likely to be uncorrelated with unobservables in the plant-level productivity, once controlled for ownership.

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[43] The scale economy index is calculated using a constant line rate and the regular shift pattern followed during the year (Van Biesebroeck, 2007).

[44] Note that a plant adopts flexible technology, but it could or could not have been exploited. As from the author, "one has to somehow distinguish between *acquiring* and *exploiting* the capability".

The In-sourcing strategy is measured as the share of materials in final sales.[45] Note that the author does not find a time trend in the outsourcing decision, or peculiarities among different plants. As reported, "the range of materials and components each assembly plant receives from other plants is relatively similar. Much of the changes in sourcing are likely to happen at the firm instead of the plant level." Instruments are the distances between each plant from the center of the industry computed by year for the entire North American industry and by country. Indeed plants located far away from the industry's center are likely to find the availability of intermediate suppliers more costly.

The author shows that each of the mentioned phenomena creates a productivity penalty in its own, but their joint adoption can produce positive externalities reducing the productivity penalties through a complementary effect.

2.2.4 Results

Van Biesebroeck's analysis shows that the model proliferation phenomenon, that is, producing a number of different models, increases labor requirement. An increase in direct labor requirement is also due to the adoption of "flexible technology," because of a complication of the production process, and by the In-sourcing decision, because of the carrying out of more activities in the same plant. The analysis was conducted through the following steps:

First, the author focuses on the productivity penalties associated with the production of a greater Variety. In the estimated model hours-per-vehicle is the dependent variable, and several measures of Variety are the regressors one at a time, with the inclusion of the mentioned control variables.[46] In the Least Squares (LS) estimation all the coefficients are significantly positive, demonstrating a strictly negative impact on productivity.

[45] Materials mean the sum of raw materials, intermediate inputs, and purchased business services in final sales.

[46] In this first regression the indices of variety are the number of platforms, models, body styles, chassis configurations, and the sum and product of styles and configurations.

Then the author elaborates an additional model to include the measures of Flexibility, In-sourcing, and their interaction terms in the set of regressors.[47] Estimation is run by LS and by Generalized Method of Moments (GMM) after instrumented the regression as in the previous section.[48] GMM estimations are run in order to treat the three activities as endogenous one at a time, and, in a second step, all together to account for the firms' endogenous adoption decisions. The different regressions differ from the point estimates, the coefficients' p-values, and R^2 of the regression. However, all the estimates report the same signs of the coefficients, suggesting similar conclusions. Given the dependent variable, all three activities have a positive impact on it, increasing labor requirement. In conclusion, the three activities are associated with productivity penalties. On the other hand, their joint adoption brings about positive externalities in the productivity equation, given that each interaction term reports a negative sign. This stands for the complementary effects between the three activities. In fact the joint occurrence of the three phenomena reduces the productivity penalties deriving from their single adoption. The idea is that the increased labor requirement to produce additional variety can be reduced because of flexible technology and positive spillovers from In-sourcing activities. As pointed out by the author, "increasing one activity tends to decrease productivity, but this reduction is diminished if other activities are increased as well. In particular, while flexibility and performing more tasks in-house increases direct labor requirements, they reduce the marginal labor requirement associated with increases in variety." In conclusion, the negative effect on productivity due to the production of greater variety is more than offset by the positive effect of the interactions between variety, flexibility and in-sourcing. On the other hand, the total increase in labor requirement due to the adoption of the three activities is greater than the positive effects of their interaction.

[47] Here Variety is measured as the sum of the number of body styles and chassis configurations produced in the plant. Among the regressors the controls described before are included.

[48] For Variety the instrument is the average number of different models produced at plant level by competing firms in the same market segment. For Flexibility the instruments are the area of the plant and the shift relief organization. For In-sourcing the distance from the plant to the center of the industry is used as instrument.

2.3 Productivity from a macroeconomic perspective

Here the industry-level dataset from the U.S. Bureau of Economic Analysis (BEA) will be used. The time considered spans from 1983 to 2007. From the available data it is possible to construct proxies for the activities investigated in the plant-level analysis. The general framework is taken as given from Van Biesebroeck (2007). As in the previous section, attention will be focused on the analysis of complementarities between the three activities of Variety, Flexibility, and In-sourcing influencing the firms' productivity. Using data from BEA productivity will be investigated at a much more aggregated level, as introduced in Section 2.3.1. To the best of our knowledge this is the first study comparing macro- and micro-level productivity analysis. In addition, MNCs will be distinguished as U.S.- and foreign-owned companies to investigate whether the difference in ownership implies difference in productivity. Indeed data from BEA are divided among U.S. MNCs and foreign-owned MNCs. Obviously it is not possible to estimate exactly the same models because of differences in data characteristics. However, reasonable proxies will be found (Section 2.3.2) and the same issue will be analyzed at different levels of data aggregation (Section 2.4). The present paper is very important because it shows that it is possible to carry out similar analyses from such different perspectives.

2.3.1 The dataset

As already mentioned, the data are from BEA. They span over the 1983–2007 period. The dataset concerns total assets, total employment, compensation of employees, Research and Development (R&D) expenditures, capital expenditures, total sales, import, and export. For all the variables, the values are in millions of chained 2005 U.S. dollars. The investigated companies are from the SIC 371 "Motor Vehicles and Equipment Manufacturing" and NAICS 3361, 3362, 3363 "Motor Vehicles, Bodies and Trailers, and

Parts" sectors.[49] The dataset is distinguished by ownership between U.S. Multinational Companies (MNCs), that is U.S. Parents, and U.S. Affiliates of foreign MNCs, that is U.S. Affiliates. This allows investigating whether the different ownership also implies different firms' organization and economic behavior. Van Biesebroeck also distinguishes among firms' ownership, but he does not focus the attention on the difference between them. The author only refers to the superiority in productivity of foreign-owned firms. He does not discriminate estimations among domestic-owned and foreign-owned companies. This distinction is very important, given that different firms' types are likely to be influenced by different factors. This is expected to be the case, especially in this framework where differently owned firms produce different products. Indeed U.S. automakers have mainly focused on the production of big-sized cars while foreign-owned transplants in the U.S. were producing small and compact cars (Cooney and Yacobucci, 2005). Both U.S. Parents and U.S. Affiliates follow different patterns in the available variables that are explained by different models for U.S.- and foreign-owned firms (Chapter 1). In order to investigate the impact of Variety, Flexibility, and In-sourcing and their interactions on productivity, the following procedure has been used according to Van Biesebroeck (2007). The model used by Van Biesebroeck is:

$$hpv = \acute{a}_v\ Variety + \acute{a}_f\ Flexibility + \acute{a}_I\ Insourcing + (\hat{a}_{vf}\ Flexibility + \hat{a}_{vI} Insourcing)*Variety$$
$$+\ \acute{a}_{fI} Flexibility*Insourcing + \acute{a}_s\ Scale + Other\ controls$$

Hours-per-vehicle (*hpv*) is the dependent variable. As it is the case in economic literature, productivity is generally measured by a value index. It is anomalous to use *hpv* in order to measure labor productivity.[50] Many studies in the macroeconomic literature use the ratio Value Added over Total Employment or Total Sales over Total Employment to proxy for labor productivity. Given data availability from BEA, the series Value Added

[49] As it is well known, the Standard Industrial Classification (SIC) system starts in 1930 and lasts until 1997, when the North America Industrial Classification System is introduced. The main difference between the two codes is that the SIC groups establishments by their primary types of activity, while the NAICS classifies establishments according to similar production processes. Here homogeneous time series have been created by using the "bridge tables between SIC and NAICS" provided by the US Census Bureau at http://www.census.gov/epcd/ec97brdg/. In the "bridge tables" the U.S. Census Bureau provides a correspondence between the two coding systems for the year 1997, providing a double classification in SIC and NAICS codes.

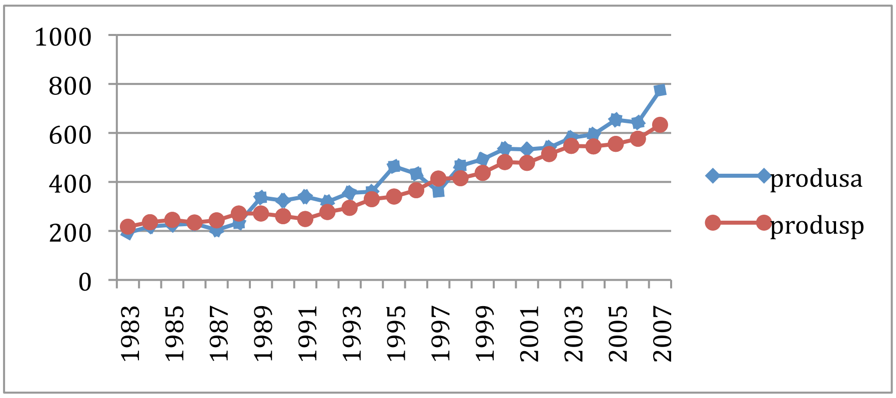
[50] The use of hours-per-vehicle to measure productivity is not the ordinary way, given that it represents exactly "the opposite of the standard measure of labor productivity" (Van Biesebroeck, 2007).

shows many missing values.[51] Accordingly the ratio Total Sales over Total Employment is used here as proxy for productivity. In this way it is possible to count in U.S. dollars the value to be attributed to each unit of labor.

According to data availability, the terms Scale and Other controls will be dropped from the models. Indeed Scale refers to a proxy for scale economies and the other controls used are location dummies, a year trend, and segment dummies, which are not present in the BEA dataset. Therefore, the analysis will only focus on the effects of the three variables and their interaction terms. In addition, the U.S. Gross Domestic Product (GDP) is included among the regressors to account for exogenous factors.

Figure 2.1 shows that both U.S. Parents' and U.S. Affiliates' sales per employee start the period analyzed with almost the same level.[52] After 1989 foreign firms registered a higher level of productivity with respect to domestic companies. Both types of MNCs follow an increasing trend, with domestic firms being characterized by a lower rate of growth than foreign plants. The 1997 abnormal point in the U.S. Affiliates' trend is likely due to the SIC/NAICS shift, while data for U.S. Parents do not suffer from this bias.

Figure 2.1: Sales per employee for U.S. Parents and U.S. Affiliates – 1983–2007 (millions of chained 2005 U.S. dollars)



[51] Data on Value Added are available only from 1993 to 2001 for U.S. Affiliates and from 1993 to 2007 for U.S. Parent companies.

[52] The low levels of U.S. Affiliates' sales per employee in the early 1980s are likely to be biased. Indeed when the first transplants were established in the U.S., their majority was registered as wholesale trade motor vehicles, while here the attention is focused on the manufacture of motor vehicles.

2.3.2 Macro level proxies

The three activities under analysis in the productivity regression are Variety, Flexibility, and In-sourcing. At plant-level, Van Biesebroeck constructs the variables using the number of body styles and chassis configurations produced in a plant for Variety; platforms per line for Flexibility; and the share of raw materials in final sales for In-sourcing. Here the different data aggregation does not offer the same information. The proxies proposed for the three activities are the following.

Variety: In this thesis the BEA dataset has been chosen for econometric estimation because of both its homogeneity and accuracy in collecting data on operations of multinational corporations in the U.S. The BEA dataset offers a great variety of macroeconomic variables. Among the others Research and Development Expenditures is the main variable representative of innovation processes. Expenditure in R&D is a reasonable proxy for input innovation (Dodgson and Hinze, 2000), even if it includes effort for both process and product innovations (Rosekranz, 2003). In order to use this variable as proxy for Variety, it is assumed here that both types of innovation, i.e. process and product innovation, are held in constant ratio on firms' R&D projects. Therefore, there is a strong link between R&D and output innovation (Chen and Mohnen, 2009; Aw and Batra, 1998). Obviously this is a strong assumption. In future research it will be interesting to construct a proxy for Variety by combining expenditures in R&D and the new models introduced year by year. Here such an analysis is over the goal of the paper, and the previous hypothesis is assumed to ensure data homogeneity. In line with microeconomic results, the variable should enter the productivity regression with a negative figure, that is, increasing Variety reduces labor productivity.

Flexibility: The main characteristics of flexible technology are the availability of flexible capital and skilled labor. Capital must be flexible in the sense that production machineries must be useful to apply for different production processes in order to implement the production of different models in the same plant. High-skilled labor is required to face an increasing production complexity, to have problem solving skills, and to interact with manager, in order to implement flexibility in production (Van Biesebroeck, 2007). Accordingly the proxy for Flexibility has been constructed here through the following interaction:[53]

$$Flex = \left(\frac{CapitalExpenditures}{TotalEmployment} \right) * \left(\frac{Employees' Compensation}{TotalEmployment} \right)$$

In-sourcing: In-sourcing activities are the opposite of out-sourcing (Van Biesebroeck, 2007). The import variable could be a reasonable proxy for out-sourcing. In fact here import consists of raw materials and intermediate goods, given that this framework is dealing with the production side of the economy. The trade of goods among affiliates of the same MNC located in different countries is registered here as import. This allows using import as proxy for outsourcing at plant-level. This is in line with the In-sourcing index of Van Biesebroeck, as he accounted for the plant-level import. Then the import variable is taken as proxy for the opposite of In-sourcing. Accordingly with plant level analyses, it should enter the productivity regression with a positive sign. All the variables are taken in their per capita values.[54]

2.4 Estimation and results

Can Biesebroeck's "productivity penalty" be detected (and measured) when industry level data, as those published by BEA, are used? Here the first goal is to see if the results on productivity in the U.S. auto industry reported in the microeconomic literature (e.g. Van Biesebroeck, 2007) continue to hold when a macroeconomic perspective is used. In addition, the present work will separately consider U.S.- and foreign-owned MNCs. For the first time a specification very close to that used at plant level by Van Biesebroeck (2007) is estimated using the dataset from BEA to analyze the impact of product Variety, technological Flexibility and In-sourcing on firms' productivity at industry level. Two

[53] In the literature white-collar workers, or the share of total employment devoted to R&D, are usually taken as proxy for the labor's skill level. The BEA dataset on operations of multinational corporations does not collect data on the composition of the labor force. Accordingly, here the compensation per employee has been taken as reasonable proxy for the labor's skill level.

[54] Per capita values are values per employee.

estimations will be run, one for U.S. Parents and the other for U.S. Affiliates. The double estimation will allow operational differences for the two different MNCs. Surprisingly using exactly the same specification, the productivity of both U.S. Parents and U.S. Affiliates is explained up to over 97 percent. This is very surprising given that U.S. Parents and U.S. Affiliates are structurally very different. Indeed U.S. Parents are "headquarters companies" while U.S. Affiliates are productive transplants ruled from abroad. Section 2.4.1 shows the results of the productivity equations for both U.S. Parents and U.S. Affiliates. Then the results of the estimated productivity models will be presented separately for both U.S. Parents (Section 2.4.2) and U.S. Affiliates (Section 2.4.3).

2.4.1 Plant-level modeling

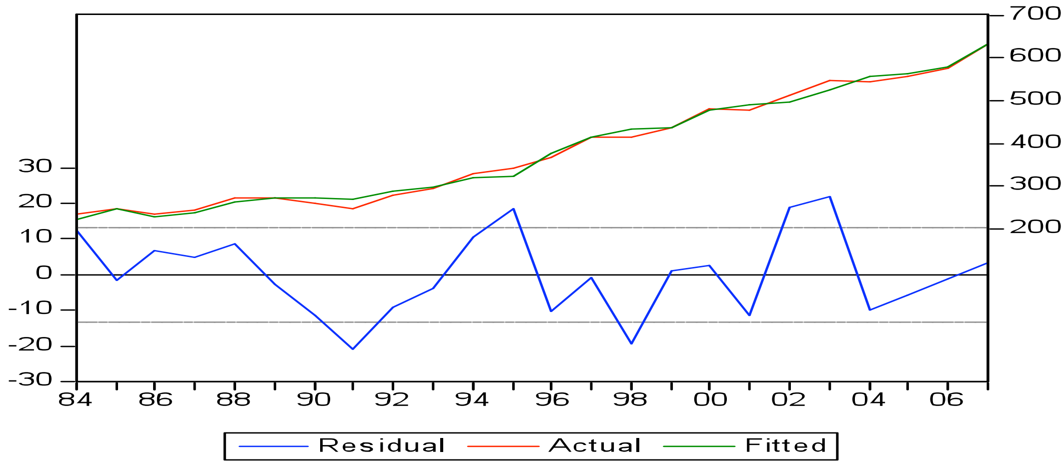
For both U.S. Parents and U.S. Affiliates, a model very close to that of Van Biesebroeck has been estimated using the BEA dataset. The regressions contain the values of R&D expenditures per employee as proxy for Variety, those of Import per employee as proxy for the opposite of In-sourcing, and those of the constructed Flexibility index. In the spirit of the LSE approach (Sargan, 2001; Hendry, 2003), each specification has been constructed by a "two-step" estimation procedure. First an unrestricted model has been elaborated including all the regressors above and their interaction terms. The U.S. GDP has been included in both U.S. Parents' and U.S. Affiliates' regressions in order to account for the effect of exogenous economic factors.[55] Then a restricted model results from the elimination of the variables not strictly significant.[56] The restricted models exclude the level of import per employee for U.S. Parents, and the interaction term between R&D and flexibility for U.S. Affiliates. Therefore the resulting productivity equations are estimated by LS. The residuals' graphs of the two restricted models, that is, U.S. Parents (Figures 2.2 and 2.3) and U.S. Affiliates (Figures 2.4 and 2.5) are given below.

[55] The GDP of the economy can be taken as representative of economic expansion and increased market demand, that can influence the firms' adoption decisions in terms of more efficient production technologies.

[56] Each model has been tested for autocorrelation and normality of the residuals through the *Jarque–Bera Normality test*, the *Breusch–Godfrey serial correlation LM test*, and by the Durbin–Watson (*DW*) statistics. When the lagged dependent variable is included among the regressors the *DW* is no more valid. In such cases the normalization of the *DW* has been used, i.e. the *h-test* proposed by Durbin (1970). For each unrestricted/restricted pair of models an *F-test* has been computed to individuate the correct specification. For both kinds of MNCs, the *F-test* singled out the restricted specifications as the correct model to be estimated.

U.S. Parents reach a very good fit (Figure 2.2), except in 1991, 1995, and 2002–2003, when the residuals lie outside the predefined range. In 1995 and 2002–2003 there is an under-estimation of the actual data, while in 1991 an over-estimation is presented. However, the bias is negligible and the model is representative of the actual trend.[57]

Figure 2.2: U.S. Parents' productivity: Fitted LS residuals



The productivity equation results (Figure 2.3) show that U.S. Parents' productivity is positively but not significantly related to the lag of R&D expenditures per employee, and to the current values of the flexibility index, statistically significant at 1 percent level. Positive influence is also from the interaction between lagged R&D per employee and import per employee, and from the U.S. current GDP, all significant at 1 percent level. On the other hand, the interaction term between lagged R&D per capita and flexibility enters the regression with a negative sign. Negative is also the influence of the interaction between flexibility and import per employee, but it is not statistically significant.

In order to investigate interrelationship between U.S. Parents and U.S. Affiliates productivity and to account for the spillover mechanism, a Granger causality test has been conducted. Foreign firms' productivity has been tested up to three lags. The test failed in the sense that all the regressors were not statistically significant. For this reason they have been dropped from the final regression. This suggests that U.S. Parents' productivity is not influenced by that of foreign firms and that the spillover mechanism is not at work. The

[57] The U.S. Parents' residuals' graph apparently suggests autocorrelated residuals, nevertheless the regression has been tested with the *Breusch-Godfrey serial correlation test* with the inclusion of up to ten lags. The test rejects the hypothesis of autocorrelation.

main explanation is that domestic and foreign companies produce different-segment cars, whose production techniques are likely to differ and to imply different production processes. Indeed the Big Three's U.S. production is mainly focused on family-size cars, while foreign-owned U.S. transplants are the leading producers of small and compact cars. It has been well recognized that U.S. Parents outsource the production of small cars in their European affiliates, to be imported and sold under the American brand (Nelson, 1996; Eden and Molot, 1996; Cooney and Yacobucci, 2005).

Figure 2.3: U.S. Parents' Productivity Equation: LS results

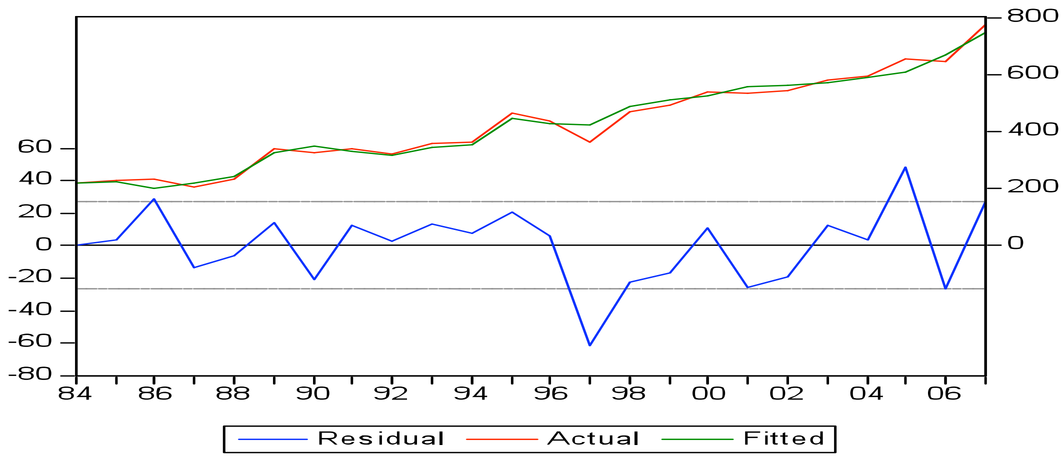
U.S. Parents'Productivity Equation (LS)	
R&D (−1)	−2.75 (1.49)
Flexibility	0.128*** (0.037)
R&D (−1) * Flex	−0.005** (0.001)
R&D (−1) * Imp	0.148*** (0.03)
Flex * Imp	−0.0001* (0.0001)
gdp_us	0.00001* (0.000008)
R^2	0.992
Adjusted R^2	0.989

Notes: For each variable the estimated coefficient is reported.
The respective standard errors are given within brackets.
Values are in chained 2005 US dollars.
* significant at 10% level
** significant at 5% level
*** significant at 1% level

Also for U.S. Affiliates the fit is very good, even if the residuals trend is outside the range in 1997 and 2005 (Figure 2.4). The peak of 1997 in the U.S. Affiliates' residuals is likely due to the strong financial crisis that affected the South East Asian countries, given that the majority of U.S. Affiliates are from Japanese multinationals.[58] An additional motivation for this abnormal point is the SIC/NAICS shift in the coding system occurred in 1997.

58 In 1996 a financial crisis occurred at the world level and it is likely to be shown by data one period later. The 1996 financial crisis started from the South East Asia stock market, that is the Hong Kong Exchanges and Clearing Limited. Accordingly it is likely to interest especially Japanese and Asian automakers.

Figure 2.4: U.S. Affiliates' productivity: Fitted LS residuals



U.S. Affiliates' productivity (Figure 2.5) is positively influenced by the lag of R&D expenditures per employee, and by the current levels of import per employee and that of the interaction term between the flexibility index and import per employee. Negative influence is from the flexibility index and from the interaction between the lag of R&D expenditures per employee and import per employee. As in the U.S. Parents' case, the interaction term between R&D and Flexibility has been dropped in the first step of the estimation procedure because it was not significant at all. As for U.S. Parents, also for U.S. Affiliates, a Granger causality test for productivity has been conducted. The productivity of U.S. Parents has been included in its current and lagged values. It has been subsequently dropped because it was not significant in the regression. Also for U.S. Affiliates the presence of U.S. MNCs is not likely to influence their productivity level excluding any spillover effect. Strictly positive and significant is the influence of current U.S. GDP, accounting for exogenous economic factors.

Figure 2.5: U.S. Affiliates' productivity equation: LS results

U.S. Affiliates'Productivity Equation(LS)	
R&D (−1)	56.04*** (15.7)
Flexibility	−0.09*** (0.028)
Import	1.55*** (0.46)
R&D (−1) * Imp	−0.41*** (0.117)
Flex * Imp	0.001*** (0.0002)
GDP_US	0.00005*** (0.00001)
R^2	0.978
Adjusted R^2	0.971

Notes: For each variable the estimated coefficient is reported.
The respective standard errors are given within brackets.
Values are in chained 2005 US dollars.
* significant at 10% level
** significant at 5% level
*** significant at 1% level

Van Biesebroeck allows for endogeneity treating the three activities as endogenous by instrumenting the regressions as described in Section 2.2.3. Here endogeneity will be dealt with by constructing a simultaneous equations system. Indeed it is recognized that by a complete specification it is possible to account for endogeneity (Mullen, 2007). The system specification will be elaborated by treating all the three phenomena under analysis as endogenous in addition to productivity. The final models for Variety, Flexibility, and In-sourcing will still be reached through the LSE approach. As has already been discussed two systems will be constructed in order to investigate the influence of different firms' ownership. The systems will be estimated applying Two Stages Least Squares (2SLS) and Three Stages Least Squares (3SLS), in order to deal with endogeneity and unobservables bias. The construction of the system will fill the gap of little formal systematic modeling in the FDI literatures (Ma et al., 2000). As expected 3SLS give standard errors lower than those by 2SLS, confirming the consistency of the dataset and the models used. Indeed 3SLS estimate the variance-covariance matrix, for which it occurs a given number of data to be feasible. 3SLS results are very similar to the productivity equations' results. Estimated coefficients register the same sign and similar magnitudes. 3SLS results will follow for U.S. Parents (Section 2.4.2) and U.S. Affiliates (Section 2.4.3).

2.4.2 U.S. Parents

As in the productivity equation, U.S. Parents' productivity (Figure 2.6) is positively but not significantly related to the lag of R&D expenditures per employee, and to the current values of the flexibility index, statistically significant at 1 percent level. Positive influence is also from the interaction between lagged R&D per employee and import per employee, and from the U.S. current GDP, all significant at 1 percent level. On the other hand, the interaction term between lagged R&D per employee and flexibility enters the regression with a negative sign. Negative is also the influence of the interaction between flexibility and import per employee, but it is not statistically significant.

In light of the analysis of Van Biesebroeck (2007), the R&D expenditures, used here as a proxy for Variety, and the flexibility index register the opposite sign than in the plant level analysis. In addition, the coefficient of R&D expenditures is not statistically significant at standard levels, as in Van Biesebroeck (2007) when treating the three activities as endogenous. The interaction term between R&D and flexibility is strictly negative and significant, while in the plant level it was positive but not significant at all. The interaction between flexibility and import has a negative influence on productivity and it is not significant at standard levels, while in the plant level study it reduced the productivity penalties deriving from the single activities. The interaction term between R&D expenditures (i.e. Variety) and import (i.e. opposite of out-sourcing) enters the regression with the expected positive sign and it is statistically significant at 1 percent. The import variable has been dropped from the regression because it was not statistically significant in the first step of the procedure followed to construct the system. The Granger causality test failed to show any inter-relationship between U.S. Parents' and U.S. Affiliates' productivity. U.S. Parents' productivity is not influenced by foreign firms' productivity and the spillover mechanism is not at work.

U.S. Affiliates' activity strongly influences the three activities investigated on the U.S. Parents' productivity regression. The flexibility index (Figure 2.6) is significantly and positively affected by the lagged levels of foreigners' flexibility and productivity, and by their current capital expenditures. This suggests that domestic companies invest in flexible technology as a way to respond to foreign competition and expansion, in order to increase their productivity and to react quickly to changes in consumers' demand.[59] Also the negative influence of U.S. Parents' productivity on the flexibility index suggests that investments in flexible technology are aimed at increasing the firms' productivity levels. The higher the actual productivity, the lower the investment to increase it in the near future. The influence of U.S. Parents' capital expenditures per employee and the lagged growth rate of the Yen/Dollar exchange rate are also strictly negative.[60] The latter suggests that U.S. Parents' investment in U.S. plants' flexibility substitutes for investment in foreign production facilities. The lagged values of employees' compensation per employee and import enter the flexibility regression with a positive and significant sign.

The influence of U.S. Affiliates' sales and export in the import regression (Figure 2.6) is likely to represent market characteristics. Indeed U.S. Parents focus on the production of big-size cars and leave the small and compact segment production to their foreign affiliates, while foreign MNCs mainly produce small and compact vehicles. The sales of foreign companies enter the import regression with a strictly positive sign, suggesting that an increase in the foreigners' sales in the U.S. represents an increase in the U.S. demand for small and compact cars. Foreign firms' export registers a negative sign. It suggests that domestic automakers supply small and compact vehicles in the foreign countries directly by their foreign affiliates. Given that U.S. Parents produce domestically big-size cars and import small vehicles from their foreign affiliates, also their current capital and R&D expenditures per employee, and the lagged levels of sales are negatively related to import per employee, because they respond to different production. U.S. Parents lagged flexibility index, productivity, current level of the Dow Jones index, and the U.S. long-term interest rate, all enter the import regression with a positive coefficient.

U.S. Parents' R&D expenditures per employee (Figure 2.6) are strongly influenced by the foreign MNCs' productivity, R&D, and import. Indeed lagged values of U.S. Affiliates' productivity and import both enter the R&D regression with a positive sign, still suggesting that U.S. consumers are increasingly demanding small and compact cars. In this line is the negative influence of the U.S. GDP per capita, suggesting that the greater the

[59] The U.S. Affiliates' capital expenditures is taken here as representative of an increase in demand for foreign cars. Given that foreign automakers are specialized in the production of small and compact vehicles, it is likely that an increase in the demand for foreign vehicles is representative of a change in consumers' preferences toward small and compact cars.

[60] Obviously the Yen/Dollar exchange rate growth implies an appreciation of the U.S. Dollar, and a consequent increase in the purchasing power in foreign countries.

consumers' purchasing power, the greater the demand for small and compact cars. On the other hand the lag of the foreign firms' R&D registers a negative coefficient. This suggests that U.S. Parents' R&D are focused on the development of different products and that they engage in foreign affiliates' R&D investment to develop small vehicles. Domestic average employees' compensation, productivity, and import from their own foreign affiliates all enter the R&D regression with a positive and statistically significant sign.

Figure 2.6: U.S. Parents' productivity model: 3SLS results

US Parents' Productivity Model 3SLS results

Dependent Variables:

Productivity		***Import PC***		***Flexibility***		***R&D PC***	
R&D (-1)	1.266 (1.94)	Capital Exp PC	-0.65*** (0.108)	Employees' Comp PC (-1)	70.91*** (6.44)	Employees' Comp PC	0.191*** (0.023)
Flexibility	0.103*** (0.029)	Sales (-1)	-0.0002*** (0.00004)	Capital Exp PC (-1)	-37.85*** (6.22)	Productivity (-1)	0.106*** (0.009)
R&D (-1) * Flex	-0.005*** (0.001)	R&D PC	-1.37*** (0.247)	Import (-1)	0.058*** (0.009)	US Affiliates Productivity (-1)	0.019*** (0.003)
R&D(-1) * Imp	0.1*** (0.031)	Flexibility (-1)	0.000003* (0.000001)	US Affiliates Flexibility (-1)	0.0023*** (0.0003)	US Affiliates R&D (-1)	-0.003*** (0.0003)
Flex * Imp	-0.0001 (0.0001)	Productivity (-1)	0.433*** (0.038)	Productivity	-12.7*** (1.79)	US GDP PC	-0.003*** (0.0003)
gdp_us	0.0001*** (0.00001)	US Affiliates Sales (-1)	0.0001*** (0.00004)	US Affiliates Productivity (-1)	4.12*** (1.06)	Y/D x-rate growth rate	-6.45*** (1.39)
		Dow Jones Index	0.0046*** (0.0009)	Y/D x-rate growth rate	-2813*** 466.7	Import PC	-0.06*** (0.02)
		US Interest Rate	3.438*** (0.839)	US Affiliates Capital Exp	0.09*** (0.14)	US Affiliates Import (-1)	0.0001*** (0.00001)
		US Affiliates Export	-0.0006*** (0.0001)			Import shipped by foreign affiliates	0.0004*** (0.00004)
R^2 Adjusted R^2	0.9936 0.9912	R^2 Adjusted R^2	0.992 0.986	R^2 Adjusted R^2	0.981 0.971	R^2 Adjusted R^2	0.971 0.951

For each variable the estimated coefficient is reported with in brackets the respective standard errors. Values are in chained 2005 US Dollars. * significant at 10% level, ** at 5%, *** at 1%.

2.4.3 U.S. Affiliates

As in the productivity equation (Figure 2.5), U.S. Affiliates' productivity (Figure 2.7) is positively influenced by the lag of R&D expenditures per employee, and by the current levels of import per employee and that of the interaction term between the flexibility index and import per employee. Negative influence is from the flexibility index and the interaction between the lag of R&D expenditures per employee and import per employee. As in the U.S. Parents' case, the interaction term between R&D and Flexibility has been dropped in the first step of the estimation procedure because it was not significant at all. Also a Granger causality test for productivity has been conducted here. The productivity of U.S. Parents has been included in its current and lagged values. It has been subsequently dropped because it was not significant in the regression. Also for U.S. Affiliates the presence of U.S. MNCs is not likely to influence their productivity level excluding any spillover effect. Strictly positive and significant is the influence of current U.S. GDP, accounting for exogenous economic factors.

From the results on U.S. Affiliates' productivity (Figure 2.7) it is possible to infer conclusions close to those of Van Biesebroeck (2007). Indeed the flexibility index, taken on its own, has a negative and strictly significant effect on productivity. The import variable enters the regression with a positive sign. It represents the opposite of the In-sourcing process, so it has a negative and significant influence on labor productivity as at the plant level. Also the interaction term between flexibility and import (opposite of In-sourcing) registers a positive and statistically significant coefficient. On the other hand, the lagged levels of R&D as proxy for Variety enter the productivity regression with a positive and significant sign. In the plant-level regression it registered a negative sign but it was not statistically significant when the three investigated activities were treated as endogenous all together. Also the interaction between R&D and import is in contrast with the study of Van Biesebroeck. Here it registers a negative sign, significant at 1 percent level, while in the microeconomic analysis it was positive and significant at 5 percent level. As before the Granger causality test for productivity between U.S. Affiliates and U.S. Parents rejects the hypothesis of any spillover effect between them.

As discussed earlier, the U.S. Affiliates' Variety, Flexibility, and In-sourcing are also strongly influenced by the U.S. Parents' behavior. Indeed the flexibility index of foreign firms (Figure 2.7) is negatively influenced by the U.S. Parents' sales and positively by their lagged R&D per employee. The negative sign of the domestic sales level is due to the different production between U.S. and foreign MNCs. Indeed an increase in U.S. Parents' sales suggests an increase in the demand for big cars, which implies a lower flexibility to differentiate further U.S. Affiliates' production of small and compact cars. Strictly negative are the foreigners' employees' compensation and productivity lagged one period. Also the current level of U.S. long-term interest rate enters the flexibility regression with a negative sign. Positive and statistically significant at 1 percent level are instead the coefficients of import per employee and total sales with one-period lag. It is likely that the more the import from the home country, the more the flexibility needed to assemble different models. In the same direction the more the sales level, the greater the demand for small vehicles, the more the flexibility required to differentiate products.

U.S. Affiliates' import per employee (Figure 2.7) is strictly related to U.S. Parents' current productivity and R&D with one period lag. Negative and significant are the coefficients of foreign companies' employees' compensation, and the lags of both total export and total sales. It is likely that foreign automakers supply the U.S. market by enlarging their American facilities and leaving foreign-based plants to serve foreign countries, as suggested also by the negative sign related to the export level. In this respect it must be reminded that from the early 1980s foreign MNCs, especially Japanese companies, have undertaken investments in the U.S. in order to retain their market shares and to lower their levels of exports to U.S. according to the Voluntary Export Restraints (VERs) program imposed by the Japanese Ministry of International Trade and Industry (MITI). The VERs program consisted in a quantitative restriction on Japanese automobile export toward the U.S. unless the imports were followed up by productive investments in the U.S. The U.S. Government pressed Japan to impose such restrictions in order to stimulate U.S. automakers' competitiveness by relaxing the foreign competition favored by the high Yen/Dollar exchange rate and the low Japanese production costs. Accordingly MITI imposed VERs in order to avoid further U.S. actions against Japanese auto imports (Bhagwaty et al., 1992; Eden and Molot, 1996; Nelson, 1996; Carbaugh, 2002; Cooney and Yacobucci, 2005). As expected the flexibility index, the productivity and the past level of R&D, all enter the import regression with a positive sign. It seems that U.S. Affiliates import basic production to be finished and assembled according to U.S. consumers' preferences. Positive influence is also from the Dow Jones Industrial Average Index taken as proxy for an expansion of the U.S. market.

U.S. Affiliates' R&D per employee (Figure 2.7) is positively driven by the lag of flexibility and total employment, as proxy for firms' enlargements. Positive is the influence of the current level of export suggesting a diversification between U.S. and foreign markets' demand. As expected, the U.S. Parents' productivity enters the R&D regression with a positive sign. R&D is a proxy for models variety. It is likely that an increase in the productivity of the competitors induces an increase in investments aimed at supplying a greater variety of models and to adapt the products to the consumers' preferences. Negative are the sign of import per employee and capital expenditures. Indeed the more the outsourcing process the less the R&D at home, and the more the investment in fixed capital, the less the investment in intangible assets. As expected the R&D lagged one period is negatively related to its current level. The Yen/Dollar exchange rate enters the R&D regression with a negative sign, given that an appreciation of the dollar implies lower costs for Japanese imports and services. The negative and statistically significant coefficient related to the per capita U.S. GDP is puzzling.

Figure 2.7: U.S. Affiliates' productivity model 3SLS results

US Affiliates' Productivity Model 3SLS results

Dependent Variable:

Productivity		***Import PC***		***Flexibility***		***R&D PC***	
R&D (-1)	57.23*** (15.22)	Emplyees' Comp	-0.006*** (0.001)	Employees' Comp (-1)	-0.123*** (0.04)	Employment (-1)	0.056*** (0.011)
Flexibility	-0.102*** (0.0289	Export (-1)	-0.003*** (0.0004)	Imp PC (-1)	11.41*** (2.26)	Export	0.0002*** (0.00005)
Import	1.53*** (0.399)	Flexibility	0.00008*** (0.00002)	Sales (-1)	0.063*** (0.006)	Capital Exp PC	-0.075*** (0.021)
R&D (-1) * Imp	-0.41*** (0.11)	Productivity	0.57*** (0.06)	Productivity (-1)	-18.5*** (2.41)	Import PC	-0.064*** (0.01)
Flex * Imp	0.0008*** (0.0002)	US Interest Rate short term Growth Rate (-1)	36.01*** (8.435)	US Parents Sales	-0.017*** (0.004)	Flexibility (-1)	0.004*** (0.0005)
GDP_US	0.00005*** (0.000001)	Sales (-1)	-0.003*** (0.0003)	US Interest Rate (-1)	-446.5*** (80.05)	US Parents Productivity (-1)	0.069*** (0.013)
		R&D (-1)	0.08*** (0.014)	US Parents R&D PC (-1)	112.7*** (29.9)	R&D (-1)	-0.005*** (0.0009)
		Dow Jones index (-1)	0.038*** (0.004)			GDPPC_US	-0.002*** (0.0004)
		US Parents Productivity	-0.56*** (0.107)			X Rate Y/D	-0.08*** (0.012)
		US Parents R&D (-1)	0.004*** (0.001)			US Interest Rate short term Growth Rate (-1)	5.001*** (0.86)
R^2 Adjusted R^2	0.976 0.968	R^2 Adjusted R^2	0.951 0.910	R^2 Adjusted R^2	0.935 0.905	R^2 Adjusted R^2	0.951 0.911

For each variable the estimated coefficient is reported with in brackets the respective standard errors. Values are in chained 2005 US Dollars. * significant at 10% level, ** at 5%, *** at 1%.

2.5 Conclusions

During the period analyzed, the American Big Three lost their market shares continuously in favor of foreign competitors, especially from Japan. Foreign firms had a greater productivity level and they were based on more efficient production techniques (Chung et al., 2003). Japanese automakers started creating U.S. Affiliates in 1982 (Singleton, 1992; Park, 2003; Chung et al., 2003) developing specific products for the new American market (Cooney and Yacobucci, 2005). Both U.S. Parents and U.S. Affiliates showed almost the same productivity level in 1983 and this is the same case in the early years of foreigners' U.S. production. From 1989 onwards U.S. Affiliates started raising their productivity, registering the highest level among all the years under analysis. At the same time from 1980 and even more from 1994, a great increase in models' variety supplied in the market has registered a negative impact on the firms' productivity (Van Biesebroeck, 2007). Microeconomic studies showed that productivity is severely affected by complementarities among organizational design choices.

As in the introduction, the goal of this paper is to see if the results on productivity in the U.S. auto industry reported in the microeconomic literature (e.g., Van Biesebroeck, 2007) continue to hold when a macroeconomic perspective is used. For the first time a model very close to that used at plant level by Van Biesebroeck (2007) is estimated using the dataset from BEA to analyze the impact of product Variety, technological Flexibility and In-sourcing on firms' productivity at industry level (Section 2.3). As it is a very different aggregation level, different proxies are used to account for the three investigated activities (Section 2.3.2). At the best of our knowledge this is the first attempt in pairing such different analytical levels. Multinational corporations (MNCs) are distinguished in U.S.-owned (i.e. U.S. Parents) and foreign-owned companies (i.e. U.S. Affiliates) to see if they are characterized by a different behavior. First a productivity equation has been estimated for the two types of multinationals treating all the other variables as exogenous. Then a simultaneous equations system has been constructed treating as endogenous both productivity and Variety, Flexibility, and In-sourcing. The system is intended to account for endogeneity, that is, endogenous adoption decisions of the three organizational activities (Mullen, 2007). In addition, by the construction of a system it is intended to fill the gap of formal systematic modeling in the FDI literature (Ma et al., 2000).

Specifications of both the productivity equation and the productivity model are very close to those generally estimated in the microeconomic literature (Section 2.4). Estimation results show that the microeconomic specification is able to explain more than 97 percent of the macroeconomic productivity of both U.S. Parents and U.S. Affiliates even if the two types of MNCs are very different from each other. Indeed U.S. Parents are headquarters enterprises, while U.S. Affiliates are productive transplants. Nevertheless it is surprising that both their specifications are exactly the same. The estimated specifications have been augmented by the inclusion of current and lagged levels of U.S. Affiliates' productivity for U.S. Parents, and vice versa for U.S. Affiliates in order to account for the spillovers mechanism among differently owned companies and to test for Granger causality between them. Still surprisingly, both U.S. Parents' as well as U.S. Affiliates' productivity does not show any spillover effects between the two types of MNCs. As in the macroeconomic literature the total sales over total employment ratio is taken as proxy for productivity. As regards U.S. Parents (Section 2.4.2) the productivity results are different in sign with respect to the microeconomic analysis. Here, the firms' productivity is positively influenced by both Variety, proxied by R&D expenditures, and the Flexibility index, constructed by the interaction of capital expenditures per employee, and compensation per employee. These results contrast with the microeconomic analysis, where both Variety and Flexibility negatively influence the productivity proxy. The interaction between Variety and Flexibility and between Flexibility and Import exert a negative influence on the dependent variable still in contrast with the plant-level work. Import per employee is taken as proxy for outsourcing activities, that is, the opposite of In-sourcing. Therefore, it must be interpreted with the opposite sign. In the microeconomic analysis In-sourcing enters the productivity regression with a negative sign, while in the present work it has been dropped from the productivity specification because it was not statistically significant. On the other hand, the interaction term between In-sourcing and Variety registers a positive sign as expected, while that between In-sourcing and Flexibility has a negative sign in contrast with the microeconomic study. In the case of U.S. Affiliates (Section 2.4.3) macro results are similar to plant level evidence. Indeed the flexibility index is strictly negative, as also the in-sourcing proxy. The coefficient of the interaction between flexibility and import is positive as expected, while that between R&D and import enters the regression with a negative sign in contrast with the plant-level analysis. The positive sign of the Variety proxy is still contrasting with the microeconomic study. The interaction term between Variety and Flexibility has been dropped from the productivity specification because not significant at all. The combined effect on productivity of In-sourcing and Variety is negative in contrast with the plant-level analysis, while that between In-sourcing and Flexibility registers the expected positive sign.

Strong spillover effects are suggested from the models used to estimate the three activities of Variety, Flexibility, and In-sourcing. The significant inter-relationships between U.S.- and foreign-owned firms are present in both the U.S. Parents' and U.S. Affiliates' regressions. Indeed U.S. Parents' Import, taken here as proxy for outsourcing, is positively influenced by the U.S. Affiliates' lagged sales level, and negatively by the U.S. Affiliates' export.[61] U.S. Parents' Flexibility index is positively related to the U.S. Affiliates' lagged Flexibility and Productivity levels and by their current capital expenditures. U.S. companies' R&D is positively influenced by the foreigners' lagged Productivity and imports levels, and negatively by U.S. Affiliates' lagged R&D.

U.S. Affiliates' Import is positively related to the U.S. Parents' lagged R&D expenditures, and negatively by the U.S. companies' Productivity proxy. The foreigners' Flexibility index is positively influenced by U.S. Parents' R&D, while U.S. Parents' sales register a negative sign in the U.S. Affiliates' Flexibility specification. U.S. Parents' Productivity one-year lagged influences positively the U.S. Affiliates R&D expenditures.

[61] Given the different production of U.S.- and foreign-owned firms, the relationship suggests an increase in U.S. consumer preferences toward small and compact cars.

Chapter 3

Towards a Qualitative Meso-economic Analysis:

A Micro-Macro Perspective

Abstract

From the early 1990s stringent environmental regulations induced car manufacturers to develop alternative fuel vehicles. Current macro data relative to U.S. Parents and U.S. Affiliates do not allow distinguishing the portion of R&D expenditures devoted to the development of each technology. In this paper we exploit the micro-evidence on firms' patenting activity from Oltra and Saint Jean (2009) in order to decompose the macro-data from BEA on aggregated US R&D expenditures of U.S. Parents and U.S. Affiliates by technology. The interval including the real firms R&D strategy at country level will result by accounting for the two principal FDI strategies, i.e. technology-sourcing versus technology-seeking FDI.

To the best of our knowledge this is the first attempt to exploit microeconomic results to improve the macro-perspective on firms' innovation activity in the U.S. automotive industry. This procedure leads to an innovative and much more integrated analytical level, which can be qualified as a Qualitative Meso-economic perspective. Finally this work improves the research on multinational activity in the U.S. automotive sector by investigating the innovation strategies of the different-owned U.S. MNCs and the aggregated expenditures.

3.1 Introduction

During the period 1983–2007 several changes involved the U.S. automotive industry in terms of environmental regulations, technological innovation, increasing competition, and changes in consumers' preferences. In the early 1980s the great publicity about gasoline shortages after the two oil shocks of the 1970s tilted the consumers' cars preferences in favor of small and compact cars (Eden and Molot, 1996). In 1990 the California Air Resources Board approved the Zero Emission Vehicles program (ZEV) in order to limit fuel consumption and pollution.[62] For the first time the private transportation sector was directly involved. The act was aimed at shifting private transportation to public transportation and at changing the traditional engine technology towards clean fuels. The ZEV program was based on the provision that a given percentage of passenger cars and light-duty vehicles under 3750 pounds sold by any major car manufacturers should be of zero emission. ZEV requirements would start in 1998 with the 2 percent of ZEVs over the total fleet sold. This percentage was planned to increase to 10 percent in 2003.[63] In view of the automakers' pleas to alter the ZEV regulation, the ZEV-obligations for the period 1998–2002 was skipped although the 10 per cent requirement for 2003 persists (Hekkert and Van den Hoed, 2006).

Automakers have been encouraged to shift from the traditional Internal Combustion Engine Vehicles fueled with gasoline (ICEVs) or diesel engines (DEs) to Alternative Fuel Vehicles (AFVs). The internal combustion engine produces air-polluting emissions because of the incomplete combustion of carbonaceous fuel causing emissions of carbon monoxide, particulate matter, nitrogen oxides, and other non-combusted hydrocarbons. The auto-related noise pollution is another issue against the traditional technology. Environmental performances of traditional engines can well be improved, especially concerning DEs. Nevertheless they will not reach the ZEV requirements because of fuel combustion. Accordingly, from 1990 car manufacturers developed alternative technologies (i.e. Low Emission Vehicles LEVs) such as battery electric vehicles (BEVs), hybrid

[62] The California Air Resources Board is a California Government agency. It is aimed at attaining healthy air quality, researching on air pollution issues and solving them, managing the motor vehicles regulations concerning environmental interests.

[63] ZEV rules were applied to automakers producing more than 35,000 vehicles per year, that is, General Motors, Chrysler, Ford, Honda, Mazda, Nissan, and Toyota.

vehicles (HVs), and fuel cell vehicles (FCVs) powered by hydrogen. They are all competing with the traditional ICEVs and DEs.

The ongoing competition among different engine technologies increases the competition among the firms' technological innovations. Firms continuously develop innovative technologies through their R&D centers, whose output is represented by the firms' patenting activity. At firm level the direction of firms' patenting activity in new technology is increasingly important in order to be competitive in the market. The firms' R&D expenditures is the main input of their patenting activity (Dodgson and Hinze, 2000). Indeed there is a strong link between R&D and output innovation (Chen and Mohnen, 2009; Aw and Batra, 1998). At a macroeconomic level, the firms' R&D expenditures are the only proxy for technological innovation. In this line it is important to analyze the direction of the companies' R&D expenditures by technology in order to find differences and similarities in their innovation strategies. Accordingly, the present work is aimed at analyzing for the first time how R&D expenditures are split among the different technologies in the U.S. automotive industry. It is also investigated how technological investments of U.S. MNCs differ among different firms' ownership. It is important to analyze the firms' R&D effort in order to infer on the competitiveness and operational strategies of different firms. Indeed during the period 1995–2005 U.S. automakers lost around 10 percent of their market shares in favor of foreign competitors. R&D is crucial in the development of new engine technologies that are responsible for the increasing competition in the U.S. automotive market. Through interacting micro-level results from previous research on technological patent applications and macro-level data on R&D expenditures by U.S. MNCs, the technological specializations of U.S. R&D centers will be inferred. MNCs will be distinguished between U.S. MNCs, that is U.S. Parents, and U.S. affiliates of foreign MNCs, that is U.S. Affiliates, in order to investigate the difference in R&D activity according to different firms' ownership. The microeconomic results on patenting activity will be aggregated in order to qualitatively decompose the macro data on total R&D expenditures of U.S. companies by technology. The aggregated R&D activity will be split by technology among U.S. Parents and U.S. Affiliates. In the case of U.S. Affiliates, R&D expenditures will be divided by technologies following the two extreme hypotheses suggested by the literature on FDI, that is, technology-exploiting FDI versus technology-sourcing FDI. Finally the macroeconomic dataset will be aggregated again. The results will infer the technological specialization of U.S. R&D centers at the country level by accounting for the real firm level strategy.

At the best of our knowledge this is the first attempt to integrate data from different aggregation levels in order to improve the analysis of innovative technologies on a meso-economic perspective. Indeed micro-level results are exploited here in order to qualitatively improve the macroeconomic analysis. The disintegration of macro data and the consequent integration with micro-evidence will result in an innovative, more integrated, analytical perspective. This procedure can well be qualified as a Qualitative Meso-economic Analysis.

Section 3.2 shows the main innovations in terms of alternative fuel vehicles. The development of new technologies increases models variety and competition. Section 3.3 discusses a microeconomic analysis by Oltra and Saint Jean (2009) on automakers' patent application for the period 1990–2005. In Section 3.4 data from Oltra and Saint Jean (2009) are used to deepen the analysis of macroeconomic data on R&D expenditures by multinationals from the BEA. U.S. Parents' R&D is split according to the technological specialization of the U.S. Big Three (Section 3.4.2). U.S. Affiliates' R&D is divided in two extreme ways. First, assuming technology-exploiting FDI, R&D is split following the home-based firms technological specialization (Section 3.4.3.1). Then, in the technology-sourcing FDI hypothesis, R&D is divided according to the U.S. automakers' technological specialization (Section 3.4.3.2). By these two extreme hypotheses U.S. Affiliates' real R&D is guessed by computing the interval between the two FDI strategies. Finally the U.S. R&D expenditures will be split by technology at country-level. The technological composition of the aggregate figure results by combining the R&D expenditures of U.S. Parents and U.S. Affiliates split as before. Also the total U.S. R&D expenditures is split by technology in two extreme ways in order to find the real R&D strategy followed by U.S.-based firms with no ownership distinction (Section 3.4.4). Conclusions are given in Section 3.5.

3.2 Technological framework and competition

Traditional and alternative engines compete each other on the strategic agenda of the leading firms. Each engine has different characteristics, which in turn differ in the use and implementation costs concerning both the demand and supply side of the market. Technologies are clustered in two groups, that is, traditional technologies, such as gasoline or diesel ICEVs,[64] versus alternative technologies, i.e. EVs, HVs, and FCVs.[65]

The development of alternative technologies gives rise to competition involving both car and infrastructure. Competition among different car models is related to technical issues. That related to infrastructure concerns the organizational complexity of the innovation, that is required network changes. Changes in technical complexity are divided among incremental and radical innovations. Organizational innovations are divided into modular and system innovations.

Incremental innovations refer to small technical changes to the incumbent technology. Radical innovations are based on changes in technological paradigms to substitute the incumbent design (Hekkert and Van den Hoed, 2006). In the case of different engines, a radical innovation implies structural changes in the scientific principles of the mechanical power train.

From the organizational perspective, an innovation is modular when it does not imply a radical change in the general framework, that is the fuel supply chain. When the relationship among the principal actors is affected by many changes, the innovation is classified as a system innovation. A system innovation implies different fuel production techniques and distribution networks.

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[64] The internal combustion engine (ICEV) is the traditional technology powering vehicles. It is distinguished between standard ICEV using gasoline and diesel engine (DE), using diesel fuel. Even if many improvements have been made in order to lower polluting emissions, doubts arise whether it can respect the ongoing environmental regulations on air pollution standards.

[65] Electric vehicles are powered by electricity stored in batteries and they do not produce emissions during use. The ZEV program introduced EVs because of their zero emissions features. On the other hand, the batteries needed are very expensive, they have a short lifecycle and a limited storage capacity. Because of their narrow range of use, they are limited to niche market (Oltra and Saint Jean, 2009) and not to be used intensively (Hekker and van den Hoed, 2006)

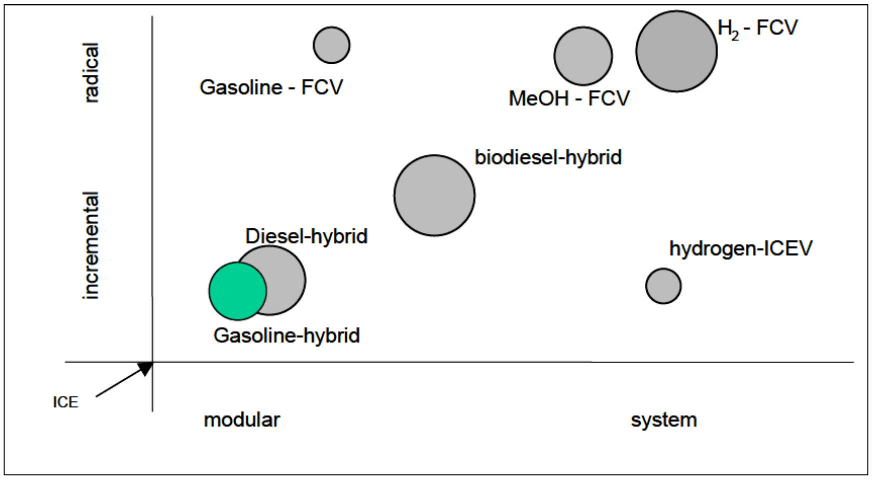
Hybrid vehicles (HVs) are powered by an internal combustion engine and an electric engine. They are fueled with traditional and alternative fuels. The two engines can be alternatively or simultaneously used to drive the car offering many options of hybrid configuration. HVs can be taken as a transition technology undertaken by automakers as a research platform to develop innovations.

Fuel cell vehicles (FCVs) are driven by an electric engine powered by a fuel cell. When the fuel is hydrogen, the FCV emits only water vapor. When other fuels are used to produce hydrogen, the fuel conversion gives rise to polluting emissions (Frenken et al., 2004). On the other hand, the direct storage of hydrogen requires strong and costly changes in the actual fueling infrastructures.

In the automotive industry, the ICEV represents the incumbent technology (i.e. dominant design) and the reference point. HVs are the most common examples of incremental and modular innovations. They maintain the conventional principles of the mechanical power train, integrating the oil engine with an electric propulsion system. Electricity is generally recovered from braking and stored in a battery. HVs do not require changes in fuel distribution infrastructures, or fuel production.

The fuel cell technology represents the most radical innovation. It implies the development of an electrochemical cell in order to convert the chemical energy of a fuel into electricity. From the organizational point of view it is located among modular and system innovations depending on the fuel used to generate electricity. When the fuel is gasoline, no particular network changes are implied. Nevertheless, it is considered to be fueled only by hydrogen, given that it is dealing with environmental performance. Hydrogen fueling requires structural changes in both the production and distribution dimensions of the fuel supply implying a system innovation. It is an example of radical and system innovation. The fuel cell technology is likely to experience numerous barriers in its development and marketability given the great changes required in both the technical and the organizational perspective. At the same time hybrid vehicles will experience much less barriers given their compatibility with both the traditional technology and the current infrastructures (Hekker and van den Hoed, 2006).

Fig. 3.1: Innovation characteristics of fuel chains



Note: These characteristics are based on technological changes (incremental→ radical) and network changes (modular→system). Circle sizes indicate carbon emission reduction relative to gasoline ICEV fuel chain (Hekkert and van den Hoed, 2006).

The tradeoff between environmental performance and range of use of the vehicle is another crucial issue in the competition among alternative vehicles. Traditional technologies cannot be easily substituted. Electric and fuel cell vehicles do not conform well to an intensive use. Electric engines are strongly limited by the storage capacity and the long recharge times of the batteries used.[66] Fuel cell vehicles' range of use depends on the fuel used to produce electricity. If powered by hydrogen, they will be traded only when adequate infrastructures will be available. The hybrid engine is likely to be the most promising technology in the short run. By combining the traditional design with an electric engine, it presents a very good combination of fuel consumption, polluting emissions, and range of use of the vehicle. Accordingly numerous studies recognize the hybrid technology as the intermediate step between the traditional design and the future "hydrogen society". Diesel ICEV is the only technology competing with the hybrid engine in the short term. Indeed diesel engines have increased a lot their environmental performances and European automakers are still improving DEs in order to reach the same standards of hybrid engines.

Finally, "each LEV technology differs according to the performance package (pollution, fuel efficiency, price, and range of use) they are able to achieve, but no technology is better on all the criteria" (Oltra and Saint Jean, 2009). The crucial problem of premature lock-in of suboptimal technology arises. Evolutionary economics shows how the market can select a suboptimal long-run technology because of increasing returns to adoption and random historical events. Increasing returns to adoption and historical events can lead to path-dependency and unpredictability of the technology-selection process (Arthur, 1989; Foray, 1997; Mulder et al., 2001). Technological competition will become a stochastic, non-ergodic process.[67] A two-step competition will arise. First a competition between traditional and alternative technologies (i.e. old-versus-new competition) arises because traditional engines benefit from increasing returns to adoption.[68] Then, when technological substitution takes place (i.e. new-versus-new competition), a suboptimal technology can be selected because of path-dependency of adoption decision. Path-dependency gives rise to a certain degree of irreversibility of the adopted design that will

[66] Electric vehicles are the best technologies for niche markets, where cars do not need large range of use and are not used intensively or during the night (Frenken et al., 2004).

[67] Non-ergodic processes are mainly characterized by their non-automatic convergence to a fixed-points distribution of outcomes (David, 1985), given that their function possesses multiple stable fixed points (Arthur, 1989).

[68] Increasing returns to adoption take place because the value of adopting a particular technology rises with the degree of adoption of that technology (Foray, 1997).

allow a given technology to be locked-in to a technological paradigm (Mulder et al., 2001).[69] High technological variety and organizational competition can avoid the premature lock-in problem. A high technological variety implies an R&D equally distributed among the different technologies. The high organizational competition reduces the risk of technological lock-in within a technology developed by a few dominant actors (Frenken et al., 2004).

3.3 Patenting activity: A microeconomic analysis

Many studies analyze the development of innovative engine technologies (Frenken et al., 2004; Hekkert and van den Hoed, 2006; van den Hoed, 2006; Oltra and Saint Jean, 2009). Patents application is usually taken as proxy for innovation activities. The use of patents application implies a bias because not all patents result in innovation activity, nor all innovations are patented. In addition, patent activity tends to vary among countries, given that countries differ in their patent application systems with respect to the degree of novelty required.[70] Nevertheless, patent data is preferred to R&D expenditures to investigate innovation activity because it represents the output rather than input of the innovation process (Frenken et al., 2004).

Among the others, Oltra and Saint Jean (2009) make a very important analysis of car manufacturers' innovation activity in engines' technology. Here their work has been taken as a reference point because of the accuracy and precision of the analysis. The authors investigate firms' patenting activity related to new environmental standards in the automotive industry.[71] They collect data on patent applications from 1990 to 2005 from the

[69] When the returns increase with the number of adopters of a given design, a little dominance of one technology at the starting point will be self-reinforcing, and the irreversibility problem will arise (Frenken et al., 2004).

[70] Oltra and Saint Jean (2009) underline that "…national differences exist between patent systems in terms of required degree of novelty and constraint attached to the patent system in its whole… it is less expensive to patent in Japan than in the US or in Europe such that it results an over-representation of Japanese patents."

[71] "Several studies have shown the correlation, if not the causality, between environmental regulation and patenting" (Oltra and Saint Jean, 2009).

European network of patent databases based on the European Patent Office (EPO).[72] Their analysis is on patents applied by the 11 major car manufacturers ranked according to the top sales units in 2002 by the European Commission (European Competitiveness Report, 2004).[73] They compare innovation activity among Japanese, American, and European companies. As countries differ in their environmental standards and patents regulations, companies located in different countries are expected to vary in their patenting activity. In addition, a different level of patent applications is likely to reflect a difference in strategies and relative specialization at the firm level depending on the main characteristics of the target market. Indeed the American, Japanese, and European automotive markets greatly differ each other with respect to consumer preferences, fuel costs, and environmental regulations.

3.3.1 Technology level

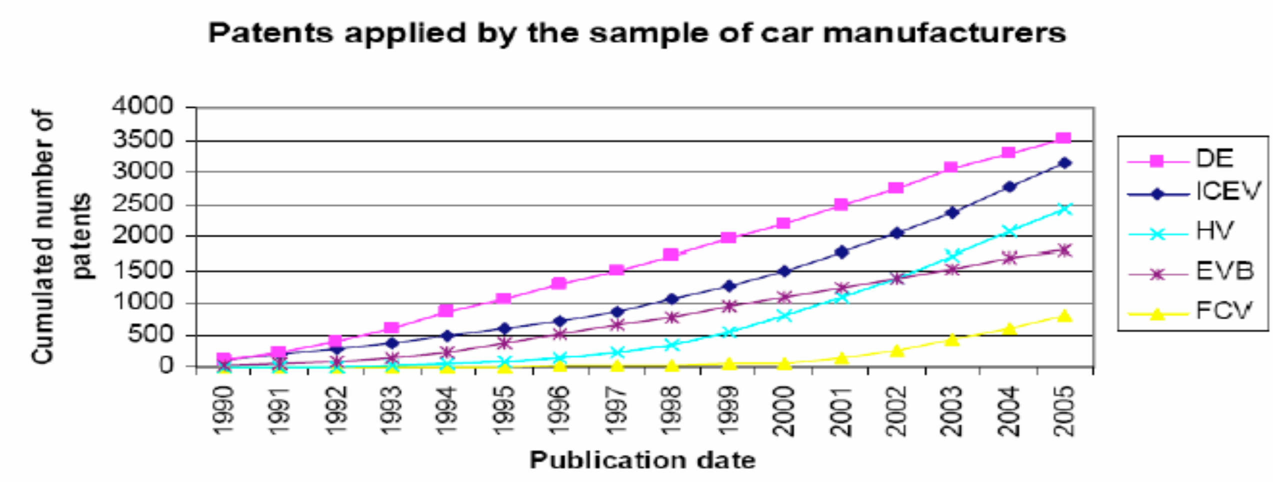
The analysis of Oltra and Saint Jean (2009) shows an increasing trend for patents on traditional technologies in the whole period. They were the leading technologies from 1990 to 2005. For all the 1990s, R&D activities greatly involves also electric engines, while from the end of the century patents application in hybrid and fuel cell vehicles register a sharp increase. The hybrid technology is attracting companies' R&D the most. Patents applications in fuel cell are the lowest, but they rose sharply after 2002 (Figure 3.2).

The two traditional designs are still attracting the principal innovation effort of the major car manufacturers as the most promising technologies. This path reflects the increasing returns to the incumbent design. The traditional technologies present high levels of environmental innovations, as confirmed by the abstract of the patents applied (Oltra and Saint Jean, 2009).

[72] http://ep.espacenet.com

[73] Accordingly Toyota, Honda, Renault, Ford, Nissan, Mitsubishi, Hyundai, General Motors, Peugeot, Daimler-Chrysler, and Volkswagen form the sample.

Fig. 3.2: Patents applied by the sample of car manufacturers



Source: Oltra and Saint Jean, 2009

The analysis shows that in the early years, among alternative technologies, electric engine was the leading design mainly because it is the most feasible green technology in the short term. Through the spillover mechanism[74] the hybrid design was gradually improved until the shift of the firms' R&D from electric to hybrid technologies in 2002.[75] Indeed the hybrid design is equipped with two different engines and it is likely to fulfill much larger demand characteristics than electric vehicles. It allows a larger range of use, lower electricity storage and consequently lower battery costs, shorter recharge time because of conversion of kinetic energy, and much greater power depending on the combination of the two subsystems.[76] These characteristics allow the hybrid technology to serve larger markets than electric vehicles, and respecting zero emission regulations for

[74] Concerning alternative technologies, Frenken et al. (2004) underline that R&D activity in a technology can produce technological spillovers to another design. More precisely, "when two technologies are technologically interrelated, an adoption of one technology contributes to increasing returns of the other, although to a lesser extent." Here this mechanism can well be at work given that hybrid vehicles are propelled by two propulsion systems: an internal combustion engine and an electric engine.

[75] While this is the trend of the patents activity of the eleven car manufacturers analyzed, the total number of patents applied follows a little different pattern. The total figures show that electric engine is the leading alternative technology from 1990 to 2004. Hybrid patents rise until 1998. During the early years of the new millennium they increased sharply until they caught up with the electric vehicles' patents in 2005 (Oltra and Saint Jean, 2009). This is an interesting point that shows that patent activity is carried out also from several additional agents as minor car manufacturers, engine producers, federal agencies, university departments and so on, and not just by leading firms. However, the total figures also reflect an increasing role of the hybrid design among the alternative technologies.

[76] There are two types of hybrid vehicles, that is, serial and parallel. In the first case the car is powered by the electric engine, while in the latter, the two engines work simultaneously delivering more power.

short distances.[77] Hybrid vehicles are taken as the transition technology between the traditional design and the fuel cell.

The fuel cell design registered the lowest R&D for the whole period. It represents a radical and system innovation with respect to the dominant design and the available infrastructure. Indeed in order to be zero emissions it is fueled with hydrogen. Hence it will imply great investments on both the technical perspective and the organizational structure, requiring completely new power train and fuel supply network. The different fuel supply network required by fuel cell vehicles is the determinant for their development.[78] Interest towards hydrogen vehicles started in 1990 with the ZEV mandate. The regulation was gradually changed over time because of lobbying by the leading automotive firms, and consequently the R&D in fuel cell technology remained at low levels. In the new century, car manufacturers refreshed their interest in fuel cell vehicles because of the approaching ZEV requirements and because of expectations that an increasing number of countries will adopt them.[79]

3.3.2 Firm level

Oltra and Saint Jean (2009) provide the share of patents by technology applied by each firm (Table 3.1). Toyota is the first mover in both the traditional as well as electric and hybrid engines. In 1990 Honda invested mainly in gasoline ICEVs and EVs, and then it moved its R&D towards diesel, fuel cell, and hybrid vehicles during the period analyzed. The great share of patents held by the two Japanese leaders shows a bias in patenting activities due to the countries' difference in patent regulation. "…It is less expensive to patent in Japan than in the U.S. or in Europe such that it results in an over-representation of Japanese patents…compared to the European and the U.S. ones" (Oltra and Saint Jean,

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[77] For a short distance, as it is in the case of urban use, hybrid vehicles can be classified as ZEVs as well as EVs. On the other hand, once outside the ZEV regulation area, they can be powered by the traditional engine guaranteeing standard performances in terms of power and range of use.

[78] The present expected value of a new engine technology is dependent upon the availability of the specific infrastructure (David, 1985).

[79] David (1985) stated: "intuitions suggest that if choices were made in a forward-looking way, rather than myopically on the basis of comparisons among the currently prevailing costs of different systems, the final outcome could be influenced strongly by expectations." In this line, expectations on worldwide regulations towards ZEV standards can strongly influence the sharp increase in FCV patent applications of the main car manufacturers after 2002.

2009). Because of this bias, the patents portfolio of each company is separately analyzed by computing an index of technological specialization.

Table 3.1: Share of patents applied by each car manufacturer by technology, selected years

Date	1990					1995					2000					2005				
	Traditional		*Alternative*			*Traditional*		*Alternative*			*Traditional*		*Alternative*			*Traditional*		*Alternative*		
Technology	ICEV	DE	FCV	HV	EVB	ICEV	DE	FCV	HV	EVB	ICEV	DE	FCV	HV	EVB	ICEV	DE	FCV	HV	EVB
Toyota	0.34	0.27	1	0	0.59	0.27	0.33	0.36	0.28	0.28	0.3	0.32	0.27	0.36	0.2	0.27	0.27	0.19	0.29	0.24
Renault	0	0.01	0	0	0	0.04	0.01	0	0.01	0.01	0.1	0.01	0.03	0.04	0	0.07	0.03	0.09	0.04	0.02
Ford	0.01	0.02	0	0	0.04	0.1	0.02	0	0.11	0.03	0.1	0.02	0.03	0.03	0	0.1	0.03	0.04	0.08	0.04
Nissan	0.11	0.28	0	1	0.11	0.11	0.25	0.07	0.1	0.18	0.1	0.24	0.06	0.24	0.2	0.1	0.22	0.26	0.21	0.23
Honda	0.3	0.03	0	0	0.11	0.17	0.01	0.07	0.04	0.25	0.2	0.01	0.08	0.15	0.2	0.17	0.01	0.17	0.2	0.22
Mitsubishi	0.09	0.19	0	0	0.11	0.17	0.26	0.07	0.23	0.15	0.1	0.23	0.09	0.1	0.1	0.09	0.19	0.02	0.07	0.12
Hyundai	0	0	0	0	0	0	0.01	0	0	0	0	0.04	0	0.01	0	0	0.11	0.03	0.03	0.05
GM	0.01	0.03	0	0	0.04	0.02	0.02	0	0.01	0.01	0	0.02	0.05	0.02	0	0.02	0.02	0.07	0.02	0.02
PSA	0.03	0.02	0	0	0	0.03	0.02	0	0.01	0.01	0	0.02	0	0	0	0.03	0.04	0.02	0.02	0.01
Daimler	0.09	0.11	0	0	0	0.06	0.06	0.43	0.14	0.05	0.1	0.07	0.37	0.05	0	0.1	0.06	0.08	0.03	0.04
Volkswagen	0.04	0.05	0	0	0	0.03	0.02	0	0.07	0.02	0	0.02	0.03	0.01	0	0.05	0.03	0.04	0.01	0.01
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Source: Oltra and Saint Jean, 2009

General Motors and Renault are relatively specialized in fuel cell technology, while Hyundai, Mitsubishi, and PSA direct their R&D expenditures mostly towards traditional diesel engine. Traditional gasoline is strongly supported by Volkswagen, Daimler-Chrysler, Renault and Ford, while Japanese firms are likely to be the most involved in EVs and HVs, with the exception of Nissan that strongly supports also the fuel cell engine. The specialization index shows that Toyota holds a balanced patent portfolio, while General Motors is highly specialized on fuel cell vehicles, trading its products mainly in the U.S., where ZEV regulations are binding.

In conclusion, the traditional designs are still under improvement, as more than 50 percent of the patent portfolios are on traditional technologies. This confirms that increasing returns to adoption make it hard to substitute the dominant design with an alternative technology. Second, almost all car manufacturers direct R&D to develop alternative technologies. HVs and FCVs are likely to be the most promising of these. Electric vehicles lost their initial importance on companies' patents portfolios as their advantages are exploited mainly in niche markets. Finally, among the three alternative engines, hybrid designs seem to be preferred over fuel cell ones by large car manufacturers. Indeed HVs imply much less radical innovations than FCVs. The hybrid technology does not imply a system innovation as fuel cell technology does. It does not require fundamental changes in fuel supply and it can achieve strict environmental regulations for a limited range of use. This makes the hybrid design as the most promising technology in the short and medium term.

3.4 Micro and macro interaction: Toward a qualitative meso-economic analysis

From 1990 to 2005 in the motor vehicles sector U.S. Parents lost about 13 percent of their market power in favor of their foreign-owned competitors. The ongoing globalization process allows a growing presence of foreign competitors and several changes in the production chain. New production techniques, operational strategies, and relocations of production strongly impact the supply side. On the other hand, the demand side is changing according to new consumer preferences, different use of vehicles, different costs, new technologies, improved safety devices, and more and more strict environmental regulations. R&D and technology innovations are the main drivers of firms' competitiveness. To the best of our knowledge it is for the first time that the number of car manufacturers' patent applications is being integrated with macro-data on R&D expenditures of U.S. MNCs. The goal is to match micro and macro analysis to qualitatively differentiate R&D expenditures by technology between U.S. Parents and U.S. Affiliates. Discussion of R&D patterns will result in important considerations on U.S. firms' strategies.

Economic theory suggests that MNCs diversify their production and distribution according to the relative advantage of the reference country and with the different demand characteristics of the target markets. By analyzing the worldwide patenting activity it is not possible to infer whether firms follow different R&D strategies in different countries. Micro-level analyses investigate how firms' spread their innovation effort among the different designs by reporting the number of patents by technology applied by each firm all over the world. On the other hand these analyses do not investigate whether firms diversify their technological specialization in different countries as suggested by literature on MNCs. Accordingly, the focus here is on the different technological specialization of automakers in the U.S. Following sections are arranged thus: data used and the rationale of the analysis will be discussed in Section 3.4.1. Then intuitive results on R&D expenditures of U.S. Parents and U.S. Affiliates will be presented. It is assumed that U.S. Parents invest in R&D following their technological specialization (Section 3.4.2). As regards U.S. Affiliates, two alternative scenarios will be assumed. The first hypothesis is that U.S. Affiliates' R&D is split among different technologies following the technological specialization of the foreign headquarters (Section 3.4.3.1). Under this assumption foreign MNCs will exploit their R&D advantages in the U.S. market through their U.S. Affiliates (i.e. technology-exploiting FDI). The second hypothesis is that U.S. Affiliates invest in R&D following U.S. Parents' technological specialization. In this case foreign MNCs undertake technology-seeking FDI into U.S. to draw advantages from the American leading technology (Section 3.4.3.2). Once the macroeconomic perspective is disintegrated and qualitatively improved with microeconomic results, data on U.S. R&D expenditures will be aggregated again. The U.S. firms' technological specialization will be drawn at the country level through the firm-level integration. The two hypotheses will allow find an interval containing the real composition of R&D expenditures (Section 3.4.4).

3.4.1 Data and methodology

Worldwide patents application activity of the major car manufacturers is analyzed in the previous study.[80] Data on patents application are from Figure 3.2 (Oltra and Saint Jean, 2009). The share of patents by technology applied by each car manufacturer is available from Table 3.1 (Oltra and Saint Jean, 2009). Table 3.1 presents data at five-year intervals. Here firms are assumed to follow a linear trend in the five-year intervals. Hence the linear trend has been computed for the time intervals 1990–1995, 1995–2000, and 2000–2005 (Table A.1). The interaction between Figure 3.2 and Table A.1 will result in the number of patents applied by each car manufacturer by technology and the total number of patents applied by each automaker (Tables A.2 and A.3). Data on R&D expenditures of U.S. MNCs are from BEA database.[81] Data collected by BEA are distinguished between U.S. Parents and U.S. Affiliates.[82]

[80] The sample is formed by the eleven major car manufacturers according to the top sales ranking in output units in 2002 by the European Commission. Hence the sample includes Toyota, Honda, Renault, Ford, Nissan, Mitsubishi, Hyundai, General Motors, Peugeot, Daimler-Chrysler, and Volkswagen.

[81] Data are from the International Account, Section "Operations of Multinational Corporations" at: http://www.bea.gov. R&D expenditures are defined by BEA as "expenditures for the following: (1) the planned systematic pursuit of new knowledge or understanding toward general application (basic research); (2) the acquisition of knowledge or understanding to meet a specific, recognized need (applied research); and

3.4.2 U.S. Parents

The annual reports of General Motors Company and Ford Motor Company provide statistics on U.S. Combined Cars and Trucks Market Shares.[83] From 1990 to 1995 Ford, General Motors, and Chrysler jointly account for 99.3 percent of the total U.S. car manufacturers.[84] From 1995 onwards Ford, General Motors, and Daimler-Chrysler[85] are the only U.S. companies reported.[86] Accordingly they are taken as representative of U.S. Parent companies.

Theory suggests that a country's comparative advantage depends on its relative factors endowment. It is assumed here that firms are "skilled" in the technology the most advanced in the home country and the most applied to goods traded in the home market. MNCs will develop in the home R&D centers the most improved technology in the home country and the most promising for the nearest markets, leaving foreign R&D centers to develop the most improved and applied technology in the foreign country/market. Then U.S. Parents' R&D expenditures are split according to the technological specialization of Ford, General Motors, and Daimler-Chrysler.

Figure 3.3 shows that in the 1990s U.S. car manufacturers focused their R&D on the traditional technologies. From 2001 onwards investments in alternative designs register a sharp increase until they caught up with expenditures on the traditional gasoline design.

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(3) the application of knowledge or understanding toward the production or improvement of a product, service, process, or method (development). It excludes quality control, routine product testing, market research, sales promotion, sales service, and other non-technical activity; routine technical services; and research in the social sciences or psychology.

[82] BEA defines a "U.S. parent company" as "the person, resident in the United States, that owns or controls 10 percent or more of the voting securities of an incorporated foreign business enterprise or an equivalent interest in an unincorporated foreign business enterprise". Note that A U.S. parent comprises the domestic operations of a U.S. multinational company. A "U.S. affiliate" is defined as a "U.S. business enterprise in which a single foreign person owns or controls, directly or indirectly, 10 percent or more of the voting securities if the enterprise is incorporated or an equivalent interest if the enterprise is unincorporated."

[83] Annual reports of General Motors and Ford Motor Company are available from the SEC Edgar website of the U.S. Securities and Exchange Commission available at http://www.sec.gov/edgar.shtml.

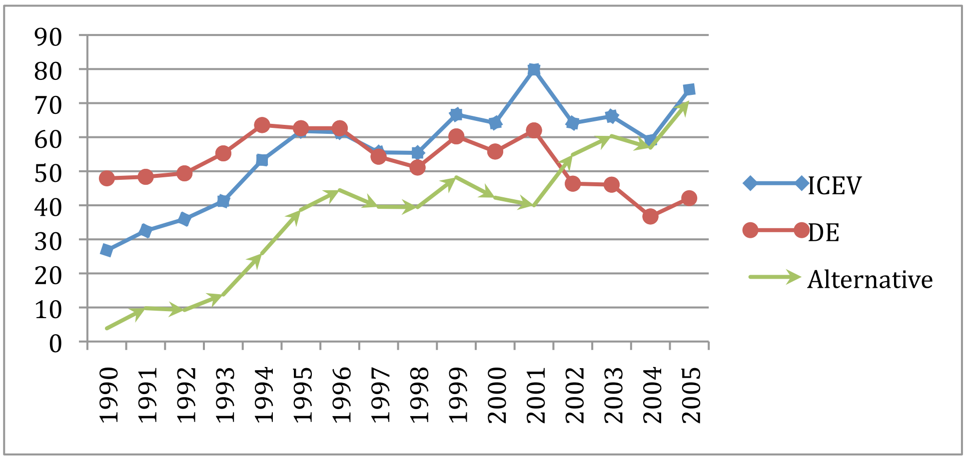
[84] For this period the statistics provide data for Ford, General Motors, Chrysler, Navistar, total U.S. manufacturers, Japanese, and all other foreign-based manufacturers.

[85] As reported, "Chrysler and Daimler-Benz merged in late 1998. The figures shown combine Chrysler and Daimler-Benz on a pro-forma basis for the periods prior to their merger."

[86] For this period statistics provide data for Ford, General Motors, and Daimler-Chrysler.

Diesel engines received a lot of R&D in the early 1990s, declining its R&D investments after 1995. The R&D in alternative technologies registers increasing trends in the periods 1993–1996 and from 2001 onwards. These paths are due first to the ZEV regulations, and then to the terrorist attacks of 9–11. Firms expected to improve diesel technology with promising environmental progress. When they realized that diesel vehicles were not able to reach the zero emissions required,[87] investments were re-directed toward alternative technologies that are able to meet ZEV standards in the short-run.[88] During the last years of analysis U.S. Parents' R&D efforts are based on traditional gasoline and alternative technologies.

Figure 3.3: U.S. Parents' R&D expenditures by technology: Traditional versus alternative technologies (in billion USD)



As regards alternative vehicles, the electric design was the dominant technology during the 1990s (Figure 3.4). Also the hybrid engine was developed from the early 1990s. From the new decade hybrid technologies have become the dominant alternative designs, even if investments in fuel cell vehicles increased sharply after 2000. The rise in R&D towards hybrid and fuel cell vehicles is due to ZEV requirements and to 9–11, both of which made exerted great pressure towards a "green-hydrogen society".[89] The hybrid design is the intermediate step between traditional and fuel cell vehicles.

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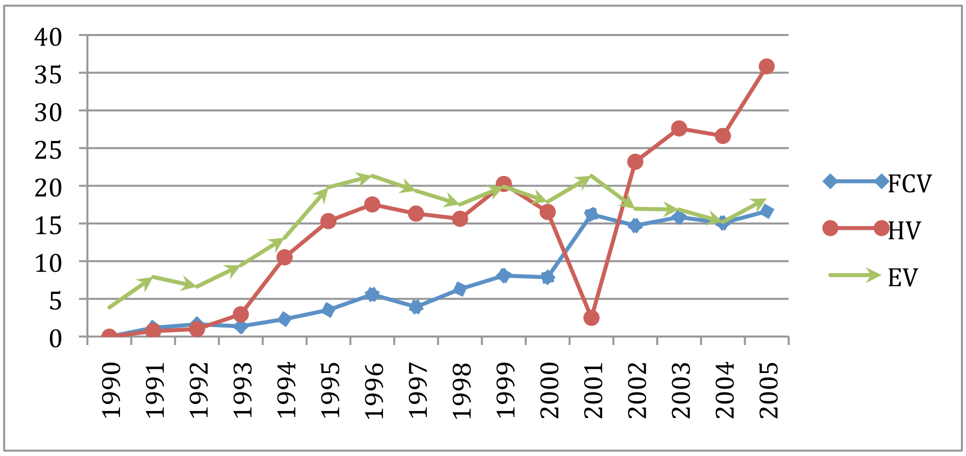
[87] Oltra and Saint Jean (2009) show that DE is not largely diffused in the U.S. because it has difficulties in meeting the environmental standards.

[88] This is at least the case for EVs and HEVs, while for FCVs the technical and organizational innovations are still needed in order to become zero emission ones.

[89] FCVs have been strongly supported by the ZEV regulation and by the American policy after the terrorist attack in 2001.

Figure 3.4: U.S. Parents' R&D expenditures by technology: Alternative technologies (billion USD)



3.4.3 U.S. Affiliates

In the literature many authors investigate whether an MNC undertakes FDI to exploit its ownership-specific advantages or to benefit from the relative specialization of the target country. An MNC invests abroad to exploit its technological superiority or to profit from the technological leadership of the reference country. In the microeconomic analysis the locations of patents applications are not investigated. Two alternative scenarios will be discussed in order to construct an interval to include the real values of MNCs' R&D expenditures in the U.S.

First, in the technology-exploiting FDI hypothesis, U.S. Affiliates' R&D expenditures are divided by technologies according to the technological specialization of non-American car manufacturers.[90] Here, U.S. Affiliates will perform R&D activities to refine the most developed technology in the home country. The R&D efforts will be aimed at fitting foreign consumer preferences and meeting the regulations of the target country. Second, U.S. Affiliates will invest in the most developed technology in the country where they are located (i.e. technology-seeking FDI [Barba Navaretti and Venables, 2004]). U.S. Affiliates' R&D expenditures are split by technology according to the U.S. Parents' technological specialization.

[90] Given that it is not possible here to distinguish among firms because of data availability, the sample is divided between U.S. and non-U.S. firms. As Ford, General Motors, and Daimler-Chrysler are demonstrated to account for 99.3 percent of U.S. Parents, U.S. Affiliates are reasonably taken as affiliates of the remaining firms of the sample. This is in line with Oltra and Saint Jean (2009), which states that the eleven car manufacturers in the sample are selected according to the top sales ranking in output units in 2002 from the European Commission.

The R&D expenditures of U.S. Affiliate companies will be divided in two extreme ways using the two hypotheses in order to find an interval including the real FDI strategy. Obviously the hypotheses imply a great level of generalization on the firms' R&D strategies. In addition, the analysis has the same limitations as reported by Oltra and Saint Jean (2009), given that the data used are from their work. Nevertheless the procedure is very important from an analytical point of view because it allows deepening the analysis of macro data in a qualitative way by exploiting micro level results, leading to an innovative, more integrated perspective. To the best of our knowledge this is the first attempt in matching micro and macro data toward a new level of analysis. This procedure can well be qualified as a Qualitative Meso-economic Analysis deriving from the micro–macro integration. The results of the two hypotheses are the following.

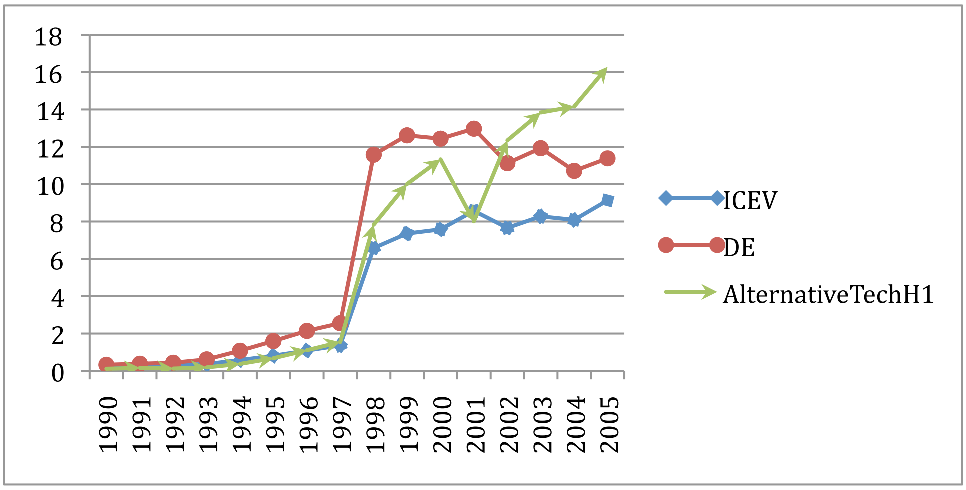
3.4.3.1 First hypothesis: U.S. Affiliates' R&D expenditures as technology-exploiting FDI

MNCs undertake technology-exploiting FDI into the United States. U.S. Affiliates will perform R&D activities in the most developed technologies in the home country following their home technological specialization. U.S. R&D will be aimed at improving specific features to fit at best U.S. consumers' preferences and market regulations.

As seen from Oltra and Saint Jean (2009), non-U.S. automakers' R&D activities are greatly based on diesel technologies because of a relative "diesel-specialization" of European firms. Japanese firms are, instead, the first mover on alternative designs, especially in electric and hybrid vehicles.

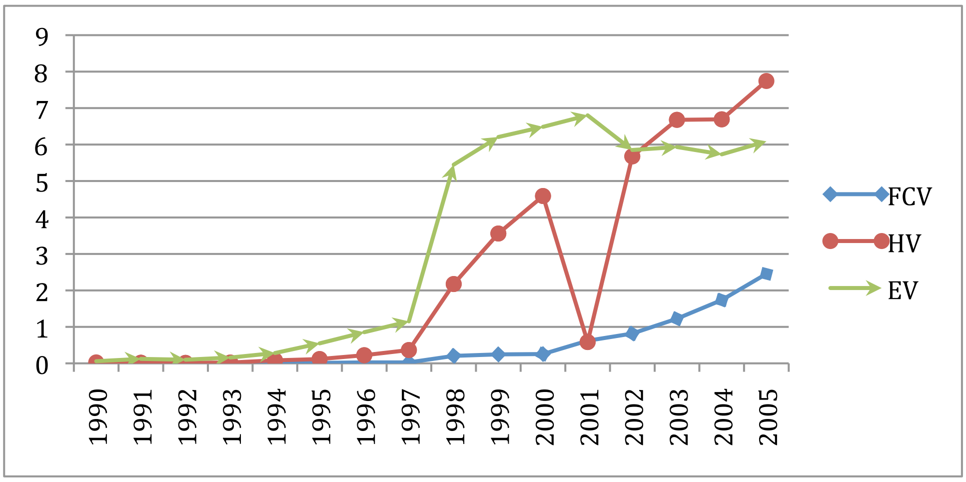
Minor R&D effort is devoted to standard gasoline engine. From 2001 onwards, alternative vehicles attract the most R&D efforts. This trend is in line with the European and Japanese specializations and with the shift towards alternative engine at the end of the 1990s (Figure 3.5).

Figure 3.5: U.S. Affiliates' R&D expenditures by technology: Technology-exploiting FDI case – Traditional versus alternative technology (billion USD)



Among alternative vehicles (Figure 3.6), electric technology was the leading design until 2002. Japanese firms were the first movers in ZEV designs, with the development of electric vehicle from the early 1990s. The shift from electric to hybrid vehicles in 2002 is due to the superior characteristics of hybrid engines in terms of range of use and performance. The shift is also strictly related to the spillover mechanism between the two technologies. Hybrid vehicles are indeed driven by an internal combustion engine and an electric one. Hence a great technological improvement from the development of the electric design is found in the hybrid configurations.

Figure 3.6: U.S. Affiliates' R&D expenditures by technology: Technology-exploiting FDI case – Alternative technologies (billion USD)

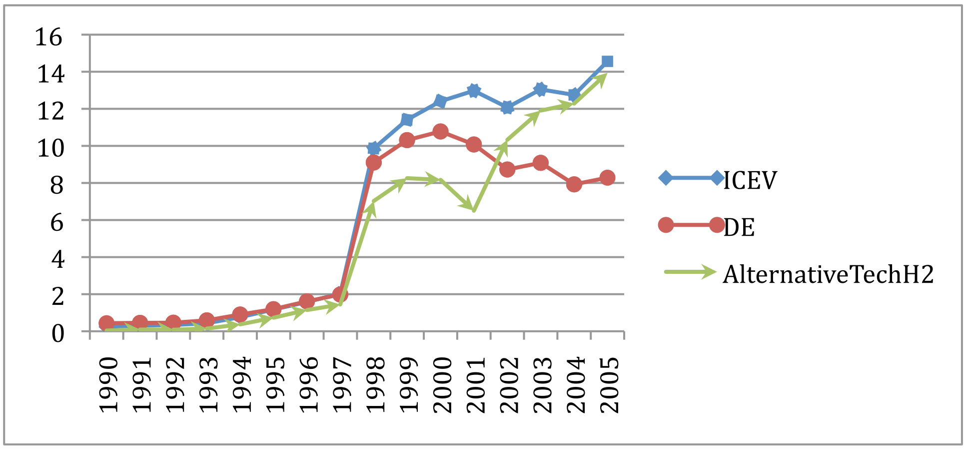


3.4.3.2 Second hypothesis: U.S. Affiliates' R&D expenditures as technology-sourcing FDI

"Technology sourcing would be a motive for FDI if the firm invests abroad in order to get access of foreign technologies. There are different ways a firm could source foreign technology through a foreign affiliate…(one way) would be to directly acquire a foreign firm with advanced technology, in which case knowledge only had to be transferred within the firm" (Barba Navaretti and Venables, 2004).[91] The U.S. is a capital-intensive country and it is among the leader countries on advanced technology. U.S. Affiliates are involved here in R&D activities according to the most developed technologies in U.S. In this line U.S. Affiliates' R&D expenditures is split among the different technologies as in the case of U.S. Parents.

Figure 3.7 shows the patterns of R&D expenditures in the two traditional designs and alternative technologies. As for U.S. Parents, the two traditional engines strongly dominate the automakers' innovative effort until 2001, when the approaching of ZEV mandate and the 9–11 terrorist attack induces a shift in R&D towards alternative engines. From 2001 onwards, alternative technologies sharply improved until they caught up with the R&D expenditures in the gasoline internal combustion engine. However, the traditional engine still attracts firms' R&D the most.

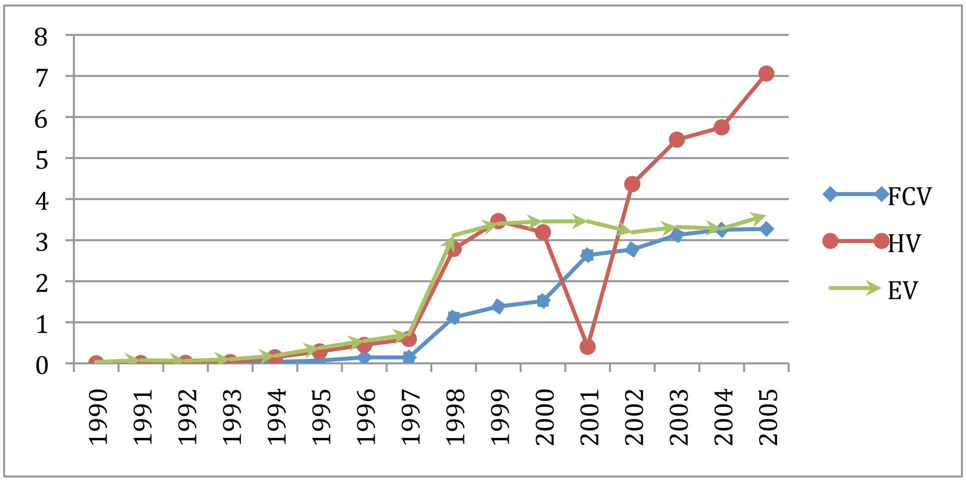
Figure 3.7: U.S. Affiliates' R&D expenditures: Technology seeking FDI case – Traditional versus alternative technologies (billion USD)



[91] Evidence of the positive impact of R&D intensity in the host country in attracting FDI is taken from Kogut and Chang (1991) in the case of Japanese FDI in the U.S., and from Neven and Siotis (1995) in the case of Japanese and U.S. FDI towards EU.

Among alternative engines (Figure 3.8) hybrid and electric vehicles followed almost the same trend until 1999. From 1998 onwards the firms' R&D expenditures were increasingly focused on fuel cell technology until those reached the same level as electric engines in 2004. Hybrid technology R&D has been growing until the end of the period analyzed. This stands for the fact that hybrid engines are taken as the most promising technology in the short run. Indeed hybrid vehicles are able to satisfy both consumers' utility (in terms of costs, range of use, and fuel supply) and environmental regulations, given that when powered by electricity they become zero emission vehicles.

Figure 3.8: U.S. Affiliates' R&D expenditures: Technology seeking FDI case – Alternative technologies (billion USD)



3.4.3.3 The interval of R&D FDI

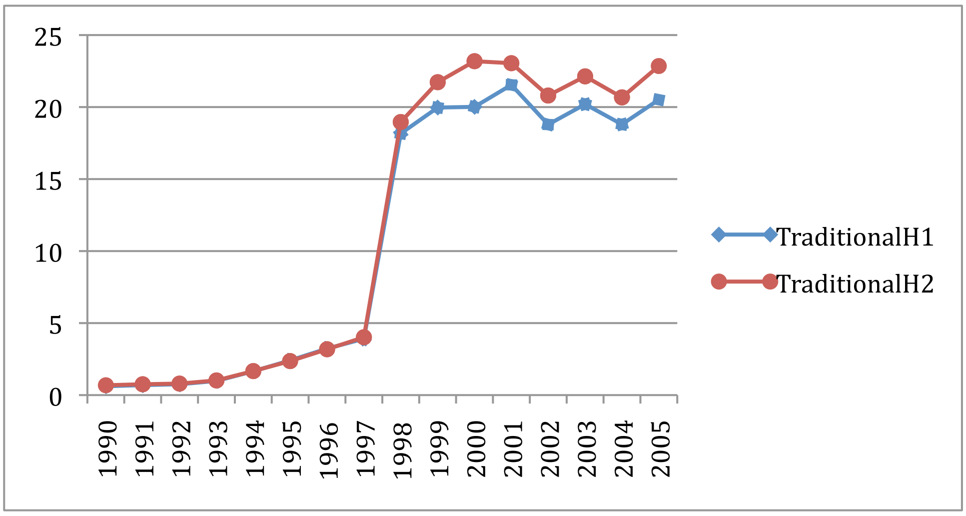
The interval including the real U.S. Affiliates' R&D expenditures will be discussed here (Figures 3.9 and 3.10) pairing the results under the two hypotheses discussed earlier.[92] H_1 is the hypothesis in which U.S. Affiliates invest in R&D to exploit their ownership-specific advantages. In this case U.S. Affiliates' R&D is split according to the technological composition of the non-American automakers. Under H_2, i.e. technology-

[92] The R&D expenditures of U.S. Affiliates and U.S. Parents differ very much in their magnitudes. Therefore, matching the R&D expenditures of the two types of firms does not give intuitive insights. In this line only the R&D expenditures of U.S. Affiliates is reported here. By depicting the two hypotheses, the figures will allow differentiating the strategies of U.S. Affiliates and U.S. Parents. It is possible to pair the paths of R&D expenditures between U.S. Parents and U.S. Affiliates by computing their growth rates. Growth rates of R&D expenditures by technologies are reported in Figures A.1 and A.2. It can be seen from the figures that U.S. Affiliates register growth rates greater than U.S. Parents for almost the whole period in traditional technologies both in the first as well as in the second FDI hypothesis. As regards alternative vehicles, U.S. Parents registered the lowest R&D growth rates from 1995 to 2001. After 2002 both types of MNCs follow similar trends.

sourcing FDI, U.S. Affiliates' R&D expenditures are divided by technology according to the American automakers' specialization.

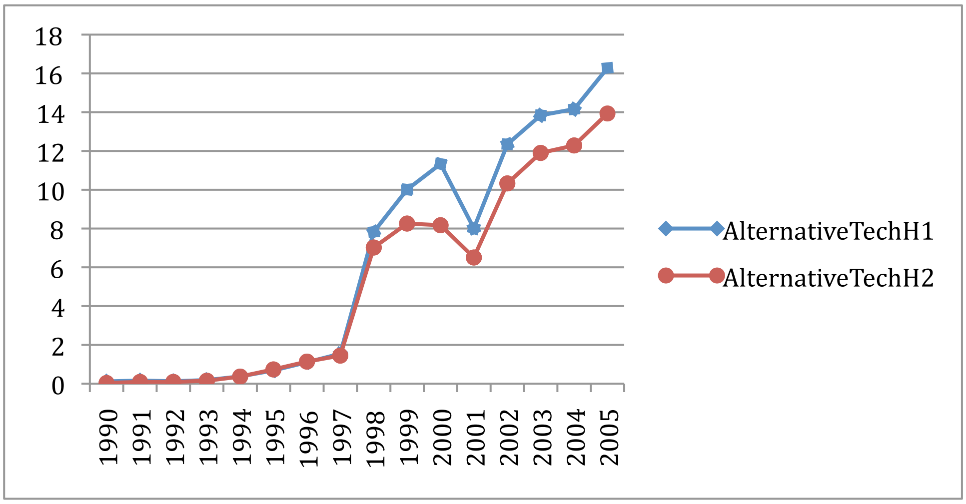
In the case of traditional designs both the American and non-American car manufacturers had almost the same technological specialization until 1998. From 1998 onwards U.S. car manufacturers specialized in traditional technologies more than non-American car manufactures. This can be seen from Figure 3.9, where the red line stands for the U.S. Affiliates' R&D expenditures under the technology-sourcing FDI hypothesis and the blue line for the U.S. Affiliates' R&D expenditures under the technology-exploiting hypothesis. This trend is mainly due to the investments of U.S. firms in the traditional gasoline ICEVs (Oltra and Saint Jean, 2009).

Figure 3.9: Interval for U.S. Affiliates' R&D expenditures: Technology-exploiting versus technology-sourcing FDI – Traditional technologies



In the case of alternative technologies, automakers followed similar technological specializations until 1997. From 1998 onwards, U.S. Affiliates' R&D expenditures under the first hypothesis is directed towards improvement of alternative technologies more than under the other hypothesis (technology-sourcing FDI). This pattern is due to strong technological specializations of Japanese and European firms in electric and hybrid vehicles (Figure 3.10).

Figure 3.10: Interval for U.S. Affiliates' R&D expenditures: Technology-exploiting versus technology-sourcing FDI – Alternative technologies



Figures 3.9 and 3.10 show the constructed interval including the real U.S. Affiliates' R&D expenditures by technology. Firms' technological specializations followed similar patterns until 1997 in both the traditional as well as alternative technologies. After 1998, non-American car manufacturers increased their investments in alternative technologies. At the same time U.S. firms continued to improve traditional engines. Among alternative vehicles, U.S. firms' R&D was mainly aimed at developing fuel cell engines according to ZEV requirements. Indeed ZEV requirements strongly support the improvement of hydrogen-fueled engines as the most promising zero emission vehicles. Fuel cell vehicles are still limited because of the non-availability of hydrogen's infrastructures. On the other hand, non-U.S. firms were the first movers in developing electric and hybrid vehicles. The first movers' advantage allows developing such alternative technologies as intermediate step between traditional and fuel cell vehicles. In addition, hybrid vehicles are also the most promising option in the short run. This fact induces Japanese automakers pursuing the improvement of such alternative vehicles.

3.4.4 Macroeconomic integration: Country-level evidence

Finally it is possible to differentiate the patterns of aggregate U.S. R&D expenditures separated by technology. Here the technological composition of the aggregate figure results by combining the R&D expenditures of U.S. Parents and U.S. Affiliates split as in the previous sections. The data aggregation will consider the two hypotheses used to decompose the U.S. Affiliates' R&D activity according to the tradeoff within technology-exploiting and technology-sourcing FDI. In this way the total U.S. R&D expenditures will also be split by technology in two extreme ways in order to find the real R&D strategy followed by U.S.-based firms with no ownership distinction.

The macro-data integration is the final and most important result of the analysis. In the previous sections the micro results on patenting activity have been aggregated in order to qualitatively decompose the macro data on total R&D expenditures of U.S. companies. The aggregated R&D activity has been split by technology in order to account for different strategies of foreign-owned U.S. Affiliates. Finally it is possible to aggregate the macroeconomic data resulting from the qualitative analysis. The integration of the resulting data will lead to a more accurate macroeconomic perspective. To the best of our knowledge this conclusion is very important because it allows differentiating car manufacturers' technological specialization in the U.S. at the country level by accounting for the real strategy followed at the firm level. Sections 3.4.4.1 and 3.4.4.2 will show the macro-level aggregation accounting for the two hypotheses on U.S. Affiliates' R&D path as in Section 3.4.3.2.

3.4.4.1 First hypothesis: U.S. Affiliates' R&D expenditures as technology-exploiting FDI: Aggregated perspective

As in Section 3.4.3.1, in the first hypothesis foreign MNCs undertake technology-exploiting FDI into the United States. U.S. Affiliates will perform R&D activities in the technologies already developed in the home country following their home technological specialization. U.S. foreign-owned R&D centers are aimed at improving specific features to fit at best U.S. consumers' preferences and market regulations (Figures 3.11 and 3.12). The relative technological specialization of non-American car manufacturers emphasizes the importance of traditional diesel, electric, and hybrid technologies while lowering that of traditional gasoline design.[93]

[93] European firms are relatively specialized in DE because of the large diesel market in the European countries. At the same time Japanese firms are likely to be the first mover in LEV technologies, especially as regards EV and HV. ICEV design attracts less R&D among the standard technologies in the non-US firms patenting activity (Oltra and Saint jean, 2009).

Figure 3.11: Aggregated R&D expenditures by technology: Traditional versus alternative technologies – Technology-exploiting FDI hypothesis

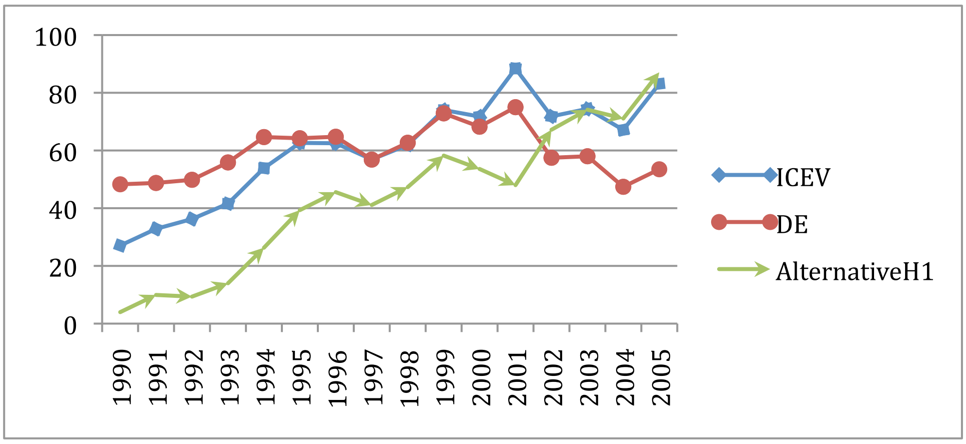


Figure 3.11 shows that the influence of U.S. Affiliates implies a great increase of R&D on alternative technologies in the last years of the analysis. Here the R&D expenditures on alternative vehicles catch up with those in traditional designs. From 2001 onwards the diesel engine is the technology attracting the lowest share of R&D.

Figure 3.12: Aggregated R&D expenditures by technology: Alternative technologies – Technology-exploiting FDI hypothesis

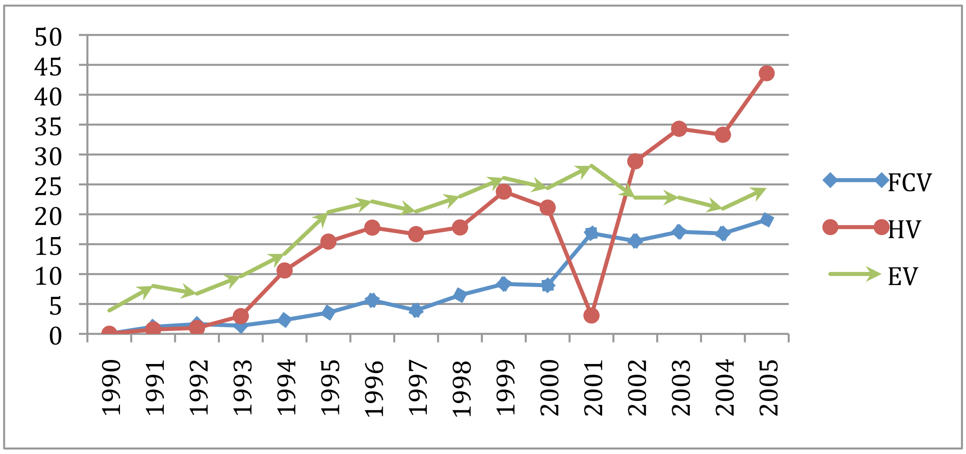


Figure 3.12 shows the case of alternative technologies. Here the presence of U.S. Affiliates under the first hypothesis leads to an increased role of EVs. Also the R&D expenditures in hybrid design increases because of the shift in R&D from EVs to HVs in 2001 by both U.S. and non-U.S. car manufacturers.

3.4.4.2 Second hypothesis: U.S. Affiliates R&D expenditures as technology-sourcing FDI: Aggregated perspective

As in Section 3.4.3.2, under the second hypothesis foreign-owned U.S. Affiliates are involved in R&D activities according to the U.S. Parents' technological specialization. In this line U.S. Affiliates' R&D expenditures are split by technologies as for U.S. Parents. The U.S. Affiliates will benefit from the technological leadership of the U.S. automakers in the traditional gasoline and fuel cell technologies. That is done in order to serve the U.S. market in line with consumer preferences and to transfer leading technologies through the multinational channel.

In the case of traditional versus alternative technologies (Figure 3.13), the trends of U.S. Parents is shifted upward by the R&D expenditures of U.S. Affiliates, which follow here the same technological specialization. From 1990 to 1995 R&D expenditures were mainly devoted to develop diesel engines. The approaching of ZEV requirements induces the shift from traditional diesel to traditional gasoline and alternative technologies. Traditional gasoline vehicles are still in progress in the car manufacturers' agenda to lower their environmental emissions. The sharp rise in alternative designs after 2001 is due to the 2003 term of the Californian ZEV program.

Figure 3.13: Aggregated R&D expenditures by technology: Traditional versus alternative technologies – Technology-sourcing FDI hypothesis

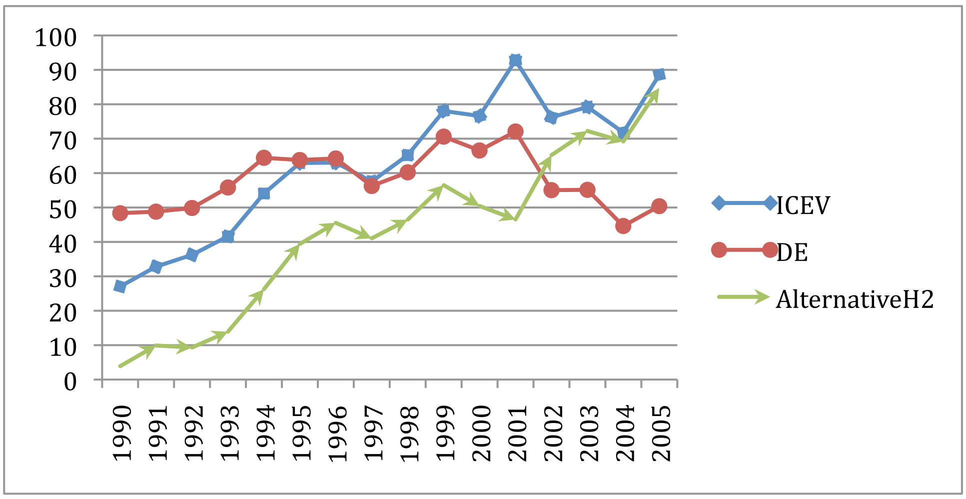
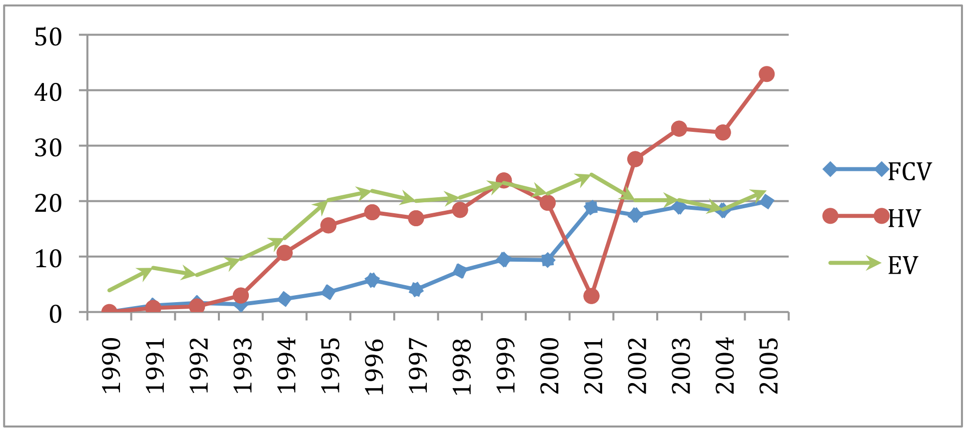


Figure 3.14 shows the aggregated U.S. R&D expenditures by alternative technologies under the hypothesis of technology-sourcing FDI. R&D expenditures in fuel

cell vehicles follow a continuous growing trend, while after 2001 investments have been mainly devoted to improve the hybrid technologies. Indeed hybrid vehicles are likely to be the most promising ZEV designs in the short-term (Oltra and Saint Jean, 2009).

Figure 3.14: Aggregated R&D expenditures by technology: Alternative technologies – Technology-sourcing FDI hypothesis



Figures 3.15 and 3.16 show the constructed interval for U.S. MNCs' R&D expenditures by technology at the country-level. As stated earlier, U.S. and foreign MNCs followed the same pattern until 1998. From 1998 to 2005 a little difference arose in technological specialization between the two hypotheses. U.S. car manufacturers strongly support R&D investments in traditional vehicles, while foreign automakers invest intensively in alternative engines, especially in electric and hybrid technologies. Despite the two extreme hypotheses, the constructed interval for MNCs' R&D expenditures is very narrow and it singles out the real pattern of R&D investment in the U.S. automotive industry. As shown in Figures 3.15 and 3.16, the difference in the R&D expenditures by technology under the two hypotheses is very small. This is mainly due to the fact that here it is dealing with country-level data, in which the impact of U.S. Affiliates' R&D expenditures is minor with respect to the U.S. Parents' expenditures. Indeed until 1997 U.S. Affiliates' R&D expenditures were very low. Only after 1998 does R&D performed by foreign-owned firms account for around 20 percent of the U.S. Parents' R&D expenditures.

Figure 3.15: Interval for U.S. MNCs' R&D expenditures, technology-exploiting (H1) versus technology-sourcing (H2) FDI: Traditional technologies

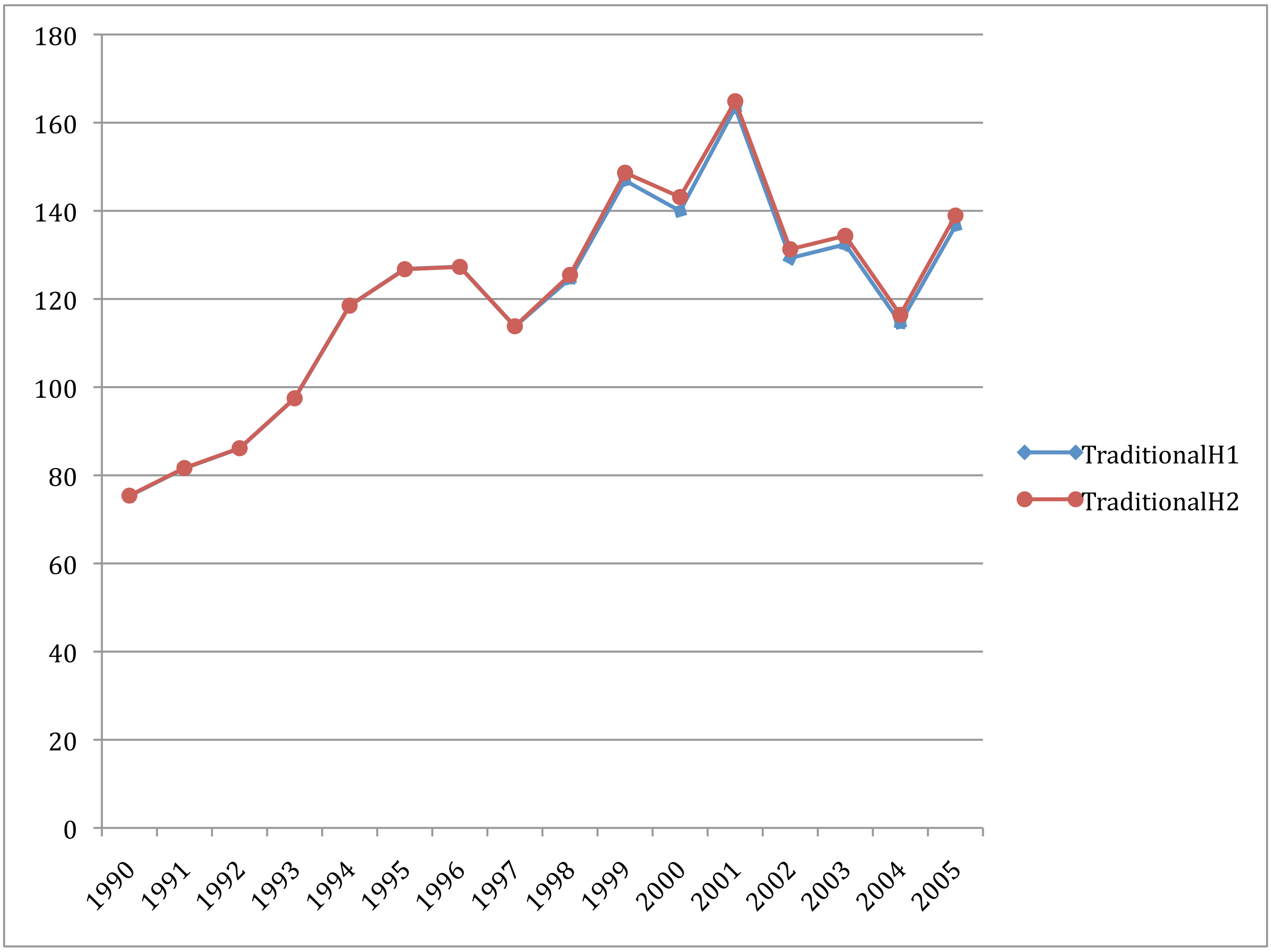
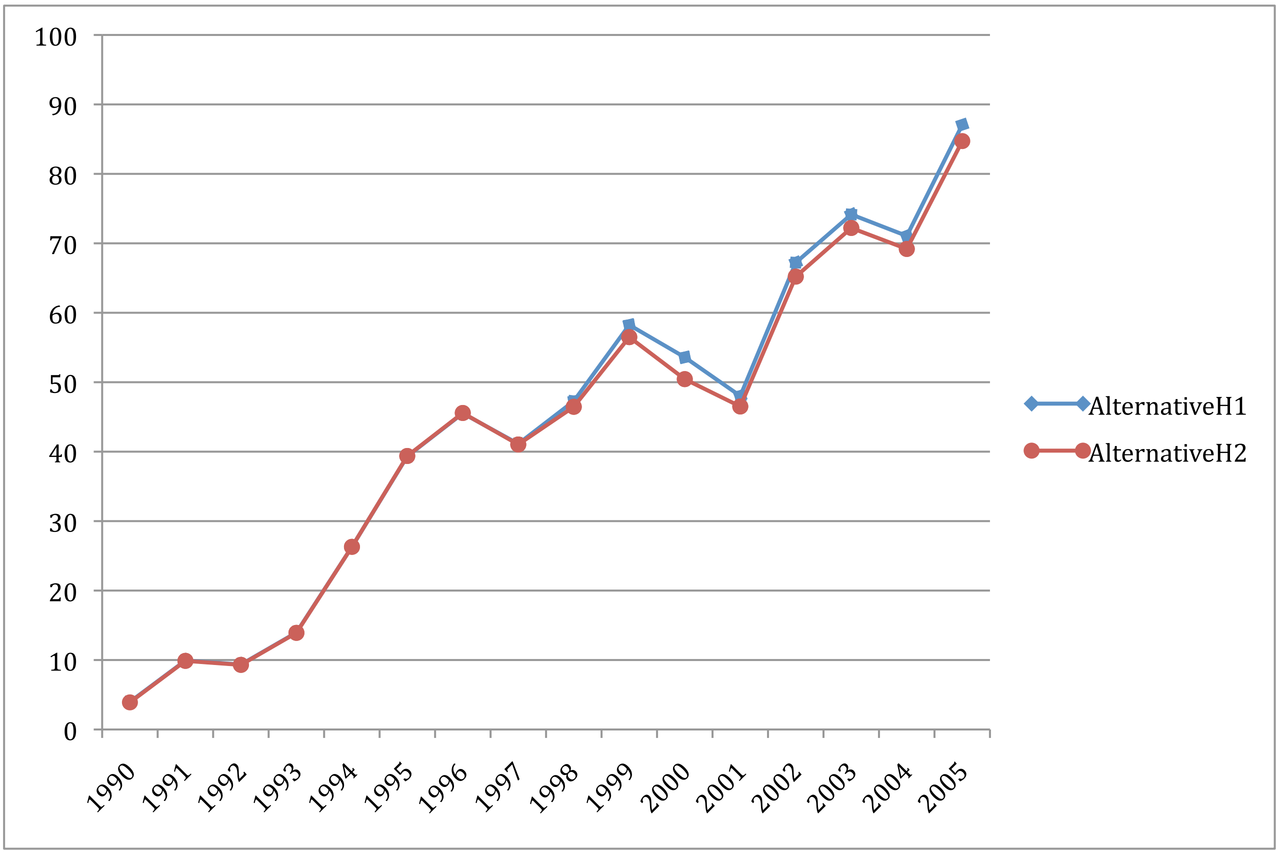


Figure 3.16: Interval for U.S. MNCs' R&D expenditures, technology-exploiting (H1) versus technology-sourcing (H2) FDI: Alternative technologies



3.5 Conclusions

The analysis of the macro data on MNCs' R&D expenditures have been augmented by exploiting micro-evidence on the firms' patenting activity over the 1990–2005 period. Multinationals are differentiated as U.S.-owned and foreign-owned firms to account for different strategies.

From the early 1990s automakers undertook investments aimed at developing alternative technologies to meet the binding environmental standards required by the ZEV program. The traditional ICE faces competition of the alternative electric, hybrid, and fuel cell vehicles. The ongoing competition among different engine technologies increases the competition among firms' technological innovations. Firms continuously develop innovative technologies by their R&D centers, whose output is represented by firms' patenting activity. At the firm level the direction of the firms' patenting activity in new technologies is increasingly important in order to be competitive in the market. Indeed, in the literature patent data are used to investigate firms' innovation activity. Microeconomic results show that the traditional engine still draws the most R&D efforts. Among alternative vehicles, the electric technology was strongly developed until the end of the 1990s. From 2001 onwards HVs and FCVs become the leading alternative engines. Japanese firms are the first movers in electric and hybrid vehicles, while American firms started the development of fuel cell technology.

At macroeconomic level, the firms' R&D expenditure is the main input of their patenting activity (Dodgson and Hinze, 2000). Indeed there is a strong link between R&D and output innovation (Chen and Mohnen, 2009; Aw and Batra, 1998). At the macroeconomic level the firms' R&D expenditures are the only proxy for technological innovation. In this line it is important to analyze the direction of companies' R&D expenditures by technology in order to account for innovation strategies. Accordingly, the present work analyzes for the first time how Research and Development (R&D) expenditures are split among different technologies in the U.S. automotive industry. It is also investigated how technological investments of U.S. MNCs differ among different firms' ownership. The technological specializations of U.S.-based R&D centers have been inferred through interacting micro-level results from previous research on technological patent applications and macro-level data on R&D expenditures by U.S. MNCs. MNCs are differentiated between U.S. Parents and U.S. Affiliates, and the difference in R&D activities due to difference in firms' ownership is investigated.

The micro-level analysis of Oltra and Saint Jean (2009) has been taken as microeconomic reference in order to deepen the macroeconomic research on R&D expenditures by U.S. MNCs. U.S. Parents are taken as investing in the home country following their own technological specialization (Section 3.4.2). Until the end of the 1990s, American firms were mainly focused on traditional technologies. After 2001 their R&D has increasingly been devoted to the development of alternative technologies. Among the traditional technologies, the gasoline engine is the most important for all periods. Among alternative engines, EVs and HVs are the leading technologies, with an important surge in investment in FCVs after 2000. For U.S. Affiliates two possible scenarios have been assumed (Section 3.4.3). First, U.S. Affiliates' R&D expenditures are split by technology following their home-country technological specialization. Under this hypothesis foreign MNCs undertake technology-exploiting FDI in the U.S. (Section

3.4.3.1). Foreign firms' R&D is mainly focused on diesel and alternative engines. Among alternative technologies the EVs are the leaders, immediately followed by hybrid technologies. FCVs have a minor role in foreign companies' R&D for all the period analyzed. The second hypothesis is that U.S. Affiliates invest in R&D according to the U.S. Parents' technological specialization. In this case MNCs invest in U.S. according to technology-sourcing strategies (Section 3.4.3.2). In this case U.S. Affiliates follow exactly the same specialization as for U.S. Parents. By the two hypotheses the U.S. MNCs' R&D expenditures have been decomposed in two extreme ways to find the interval containing the real R&D expenditures of U.S. Affiliates. Obviously the assumptions imply a great level of generalization on the firms R&D investments. In addition, this study reports all the limitations recognized by Oltra and Saint Jean (2009), given that the data used are from their work. Nevertheless, the procedure is very important from an analytical point of view because it allows deepening the analysis of macro data in a qualitative way by exploiting micro level results leading to an innovative, much more integrated perspective. This procedure can well be qualified as a Qualitative Meso-economic Analysis derived from the micro–macro integration.

Finally, the macroeconomic data have been aggregated in order to identify the R&D strategies at country-level by exploiting firm-level results. The data aggregation considered the two hypotheses used to decompose the U.S. Affiliates' R&D activity. In this way U.S. MNCs' total R&D expenditures have been split by technology in the two extreme ways and the real R&D strategy followed by the U.S. firms without ownership distinction has been found (Section 3.4.4). The macro-data integration is the final step of the analysis. This is a very important result because it allows differentiating the car manufacturers' technological specialization in the United States at the country-level in terms of aggregated R&D expenditures by accounting for the real strategy followed at the firm-level.

The decrease in market shares of U.S.-owned car manufacturers is likely to be due to a technological specialization of U.S. firms in the traditional as well as fuel cell vehicles. The traditional technologies are decreasing in popularity because of the current environmental regulations. On the other hand, fuel cell is not feasible in the short-term. Foreign competitors devoted large R&D expenditures to the development of electric and hybrid technologies. HVs are considered by car manufacturers as the most promising technology in the short-term. The great specialization of Japanese firms in hybrid engines is likely to determine the future patterns of the automotive industry, at least in the short and medium term.

Appendix 3

Table A1: Share of patents applied by each car manufacturer in the total applied by the sample of car manufacturers, Linear Trend evolution

ICEV	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	0.34	0.33	0.31	0.30	0.29	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Renault	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.07
Ford	0.01	0.03	0.05	0.06	0.08	0.10	0.10	0.09	0.09	0.09	0.08	0.09	0.09	0.09	0.10	0.10
Nissan	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10	0.10
Honda	0.30	0.27	0.25	0.22	0.20	0.17	0.18	0.18	0.19	0.19	0.20	0.19	0.19	0.18	0.18	0.17
Mitsubishi	0.09	0.10	0.12	0.14	0.15	0.17	0.16	0.15	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09
Hyundai	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GM	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
PSA	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03
Daimler	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.07	0.07	0.08	0.09	0.09	0.09	0.09	0.10	0.10
Volkswage	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05

DE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	0.27	0.28	0.29	0.3	0.32	0.33	0.33	0.33	0.32	0.32	0.3	0.31	0.3	0.29	0.3	0.27
Renault	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.02	0.02	0	0.03
Ford	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0	0.02	0.02	0.03	0	0.03
Nissan	0.28	0.28	0.27	0.26	0.25	0.25	0.25	0.25	0.25	0.24	0.2	0.24	0.23	0.23	0.2	0.22
Honda	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.01
Mitsubishi	0.19	0.21	0.22	0.24	0.25	0.26	0.26	0.25	0.24	0.24	0.2	0.22	0.22	0.21	0.2	0.19
Hyundai	0	0	0	0	0	0.01	0.01	0.02	0.03	0.03	0	0.05	0.07	0.08	0.1	0.11
GM	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0	0.02	0.02	0.02	0	0.02
PSA	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0	0.02	0.02	0.03	0	0.04
Daimler	0.11	0.1	0.09	0.08	0.07	0.06	0.06	0.07	0.07	0.07	0.1	0.07	0.07	0.06	0.1	0.06
Volkswage	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0	0.02	0.03	0.03	0	0.03

FCV	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	1	0.87	0.74	0.61	0.49	0.36	0.34	0.32	0.3	0.29	0.3	0.25	0.24	0.22	0.2	0.19
Renault	0	0	0	0	0	0	0.01	0.01	0.02	0.02	0	0.04	0.05	0.07	0.1	0.09
Ford	0	0	0	0	0	0	0.01	0.01	0.02	0.02	0	0.03	0.03	0.03	0	0.04
Nissan	0	0.01	0.03	0.04	0.06	0.07	0.07	0.07	0.06	0.06	0.1	0.1	0.14	0.18	0.2	0.26
Honda	0	0.01	0.03	0.04	0.06	0.07	0.07	0.07	0.07	0.07	0.1	0.09	0.11	0.13	0.1	0.17
Mitsubishi	0	0.01	0.03	0.04	0.06	0.07	0.07	0.08	0.08	0.09	0.1	0.08	0.06	0.05	0	0.02
Hyundai	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0	0.03
GM	0	0	0	0	0	0	0.01	0.02	0.03	0.04	0	0.05	0.05	0.06	0.1	0.07
PSA	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0.02
Daimler	0	0.09	0.17	0.26	0.34	0.43	0.42	0.41	0.4	0.38	0.4	0.32	0.26	0.2	0.1	0.08
Volkswage	0	0	0	0	0	0	0.01	0.01	0.02	0.02	0	0.03	0.03	0.03	0	0.04

continued

Table A.1contd

HV	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	0	0.06	0.11	0.17	0.23	0.28	0.3	0.31	0.33	0.34	0.4	0.34	0.33	0.32	0.3	0.29
Renault	0	0	0	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0	0.04	0.04	0.04	0	0.04
Ford	0	0.02	0.04	0.07	0.09	0.11	0.09	0.08	0.06	0.04	0	0.04	0.05	0.06	0.1	0.08
Nissan	1	0.82	0.64	0.46	0.28	0.1	0.13	0.15	0.18	0.21	0.2	0.23	0.23	0.22	0.2	0.21
Honda	0	0.01	0.02	0.03	0.03	0.04	0.07	0.09	0.11	0.13	0.2	0.16	0.17	0.18	0.2	0.2
Mitsubishi	0	0.05	0.09	0.14	0.18	0.23	0.2	0.18	0.15	0.12	0.1	0.09	0.09	0.08	0.1	0.07
Hyundai	0	0	0	0	0	0	0	0	0	0.01	0	0.01	0.02	0.02	0	0.03
GM	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0	0.02	0.02	0.02	0	0.02
PSA	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0.01	0	0.02
Daimler	0	0.03	0.06	0.08	0.11	0.14	0.12	0.1	0.08	0.06	0	0.04	0.04	0.04	0	0.03
Volkswage	0	0.01	0.03	0.04	0.05	0.07	0.05	0.04	0.03	0.02	0	0.01	0.01	0.01	0	0.01

EVB	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	0.59	0.53	0.47	0.41	0.35	0.28	0.28	0.27	0.26	0.25	0.2	0.24	0.24	0.24	0.2	0.24
Renault	0	0	0	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0	0.02	0.02	0.02	0	0.02
Ford	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0	0.02	0.02	0.03	0	0.04
Nissan	0.11	0.13	0.14	0.15	0.17	0.18	0.19	0.2	0.22	0.23	0.2	0.24	0.23	0.23	0.2	0.23
Honda	0.11	0.14	0.17	0.19	0.22	0.25	0.24	0.24	0.24	0.24	0.2	0.23	0.23	0.22	0.2	0.22
Mitsubishi	0.11	0.12	0.13	0.13	0.14	0.15	0.15	0.14	0.14	0.14	0.1	0.13	0.13	0.13	0.1	0.12
Hyundai	0	0	0	0	0	0	0.01	0.02	0.02	0.03	0	0.04	0.04	0.05	0.1	0.05
GM	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.02
PSA	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.01
Daimler	0	0.01	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0	0.04	0.04	0.04	0	0.04
Volkswage	0	0	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0	0.01	0.01	0.01	0	0.01

Table A2: Number of patents by technology for each car manufacturer

ICEV	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	41.50	65.72	90.18	112.43	142.70	165.85	198.84	235.03	290.66	339.41	397.50	478.44	559.86	641.76	750.96	854.08
Renault	0.00	1.40	4.02	7.88	14.00	21.42	28.01	35.88	47.83	59.93	75.00	96.48	120.12	145.92	180.32	215.90
Ford	1.21	5.64	13.32	24.23	41.40	61.81	71.78	82.08	98.05	110.42	124.50	154.80	186.90	220.80	266.00	311.15
Nissan	12.71	21.36	31.17	41.40	56.10	69.77	84.90	101.85	127.83	151.47	180.00	209.16	236.04	260.64	293.44	320.68
Honda	35.70	54.12	70.66	83.18	98.70	105.88	131.33	160.48	205.01	247.10	298.50	348.48	395.22	438.72	496.72	546.10
Mitsubishi	10.41	20.64	34.55	51.60	77.40	105.26	120.13	134.75	157.62	173.40	190.50	216.36	238.14	255.84	279.44	295.28
Hyundai	0.00	0.08	0.23	0.45	0.80	1.22	1.62	2.10	2.83	3.57	4.50	5.76	7.14	8.64	10.64	12.70
GM	1.21	2.20	3.44	4.88	7.00	9.18	10.76	12.43	15.00	17.09	19.50	25.56	32.34	39.84	49.84	60.33
PSA	3.51	6.00	8.90	12.00	16.50	20.81	22.85	24.50	27.18	28.05	28.50	37.08	46.62	57.12	71.12	85.73
Daimler	10.41	16.00	21.24	25.50	31.00	34.27	45.84	59.85	81.09	103.02	130.50	160.56	191.94	224.64	268.24	311.15
Volkswage	4.60	7.16	9.64	11.78	14.60	16.52	21.08	26.43	34.57	42.59	52.50	69.48	88.62	109.92	138.32	168.28

DE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	39.90	69.60	116.32	185.86	276.15	360.80	432.75	487.80	566.65	644.80	722.25	768.24	824.45	896.52	919.38	938
Renault	1.20	2.15	3.68	6.01	9.10	12.10	14.58	16.50	19.25	22.00	24.75	35.64	48.95	65.72	81.18	98
Ford	2.40	4.00	6.40	9.81	14.00	17.60	22.26	26.40	32.20	38.40	45.00	54.95	67.10	82.46	95.04	108.5
Nissan	42.30	68.80	107.36	160.36	222.95	272.80	327.28	369.00	428.75	488.00	546.75	590.54	644.05	712.38	743.82	773.5
Honda	4.80	7.00	9.60	12.26	14.00	13.20	15.11	16.20	17.85	19.20	20.25	23.76	28.05	33.48	37.62	42
Mitsubishi	29.10	52.00	88.80	144.67	218.75	290.40	341.32	376.80	428.40	476.80	522.00	553.91	592.90	642.94	657.36	668.5
Hyundai	0.00	0.25	0.80	1.84	3.50	5.50	16.17	29.10	46.55	67.60	92.25	133.16	183.15	246.14	304.26	367.5
GM	4.80	7.35	10.72	14.83	18.90	20.90	24.12	26.10	29.05	31.60	33.75	39.60	46.75	55.80	62.70	70
PSA	2.40	4.00	6.40	9.81	14.00	17.60	21.20	24.00	28.00	32.00	36.00	49.01	64.90	84.94	102.96	122.5
Daimler	15.75	24.10	35.12	48.55	61.78	68.20	84.54	98.40	117.95	138.40	159.75	170.28	183.15	199.64	205.26	210
Volkswage	7.20	10.60	14.72	19.13	22.40	22.00	27.03	31.20	37.10	43.20	49.50	58.41	69.30	83.08	93.72	105

FCV	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	10	8.71	7.43	4.30	4.86	5.00	9.16	8.05	15.21	18.06	20.18	44.28	65.18	88.40	128.13	155.93
Renault	0	0	0	0	0	0	0.162	0.3	0.9	1.512	2.25	7.385	14.96	26.64	49.25	75.075
Ford	0	0	0	0	0	0	0.162	0.3	0.9	1.512	2.25	5.425	8.8	13.2	21.25	28.875
Nissan	0	0.14	0.28	0.30	0.57	0.99	1.86	1.67	3.22	3.92	4.50	17.57	38.72	72.48	138.50	216.15
Honda	0	0.14	0.28	0.30	0.57	0.99	1.94	1.82	3.67	4.67	5.63	16.31	30.64	51.84	92.38	136.95
Mitsubishi	0	0.14	0.28	0.30	0.57	0.99	2.02	1.97	4.12	5.43	6.75	13.44	17.49	20.16	23.25	19.80
Hyundai	0	0	0	0	0	0	0	0	0	0	0	1.02	3.19	6.96	14.50	23.93
GM	0	0	0	0	0	0	0.24	0.45	1.35	2.27	3.38	8.65	14.80	23.28	39.13	55.28
PSA	0	0	0	0	0	0	0	0	0	0	0	0.60	1.87	4.08	8.50	14.03
Daimler	0	0.86	1.72	1.80	3.43	6.01	11.28	10.17	19.77	24.20	27.98	55.16	70.79	79.84	88.63	69.30
Volkswage	0	0	0	0	0	0	0.162	0.3	0.9	1.512	2.25	5.46	8.91	13.44	21.75	29.7

HV	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	0	0.57	1.13	4.25	16.98	28.30	48.28	74.18	114.80	197.23	290.70	37.82	461.44	551.95	632.52	703.15
Renault	0	0.02	0.04	0.17	0.66	1.10	2.82	5.64	10.57	21.05	34.92	4.60	56.84	68.95	80.22	90.65
Ford	0	0.22	0.44	1.64	6.54	10.90	14.97	17.96	20.72	24.50	21.11	4.05	66.64	102.20	145.32	196.00
Nissan	10	8.20	6.39	11.47	20.88	9.80	20.41	36.50	63.70	120.75	193.26	25.65	319.76	391.30	459.48	524.30
Honda	0	0.09	0.17	0.65	2.58	4.30	10.56	20.71	38.36	75.79	125.05	17.84	238.56	312.55	392.28	477.75
Mitsubishi	0	0.46	0.91	3.42	13.68	22.80	32.72	41.71	52.50	71.30	79.58	10.12	120.40	140.00	155.40	166.60
Hyundai	0	0	0	0	0	0	0.259	0.758	1.68	3.68	6.496	1.43	25.2	40.25	58.8	80.85
GM	0	0.02	0.04	0.17	0.66	1.10	1.94	3.08	4.90	8.63	12.99	1.94	26.88	36.40	47.04	58.80
PSA	0	0.02	0.04	0.17	0.66	1.10	1.52	1.85	2.17	2.65	2.44	0.73	14.28	24.15	36.54	51.45
Daimler	0	0.28	0.56	2.12	8.46	14.10	19.73	24.32	29.19	36.92	36.54	4.64	55.16	64.05	70.98	75.95
Volkswage	0	0.13	0.26	0.98	3.90	6.50	8.85	10.48	11.83	13.46	10.56	1.36	16.52	19.60	22.26	24.50

EV	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	14.83	39.84	40.84	61.14	77.81	106.50	143.31	176.89	207.04	237.88	272.25	302.50	338.80	363.00	417.45	444.55
Renault	0	0.17	0.38	0.99	1.98	4.13	6.97	10.46	14.56	19.57	25.88	28.75	32.20	34.50	39.68	42.25
Ford	0.93	2.67	2.98	4.92	7.07	11.25	13.94	15.62	16.32	16.34	15.75	23.50	33.04	42.60	57.27	69.81
Nissan	2.78	9.38	12.09	22.95	37.58	67.88	100.26	135.45	173.12	216.79	270.00	296.25	327.60	346.50	393.30	413.33
Honda	2.78	10.35	14.36	28.80	49.28	92.25	126.88	160.20	192.00	226.10	265.50	289.75	318.64	335.10	378.12	394.96
Mitsubishi	2.78	8.90	10.98	20.07	31.82	55.88	75.82	94.40	111.52	129.39	149.63	163.75	180.60	190.50	215.63	225.95
Hyundai	0	0.05	0.10	0.27	0.54	1.13	4.89	10.46	17.76	27.17	39.38	48.50	59.64	69.60	86.60	99.20
GM	0.93	2.39	2.31	3.21	3.65	4.13	5.62	7.02	8.32	9.69	11.25	13.75	16.80	19.50	24.15	27.56
PSA	0	0.21	0.49	1.26	2.52	5.25	6.76	7.94	8.80	9.50	10.13	12.00	14.28	16.20	19.67	22.04
Daimler	0	0.74	1.71	4.41	8.82	18.38	24.96	31.11	36.80	42.75	49.50	53.75	58.80	61.50	69.00	71.64
Volkswage	0	0.36	0.84	2.16	4.32	9.00	11.54	13.50	14.88	15.96	16.88	18.25	19.88	20.70	23.12	23.88

Table A3: Total number of patents applied by each car manufacturer

Total	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Toyota	106.23	184.44	255.89	367.97	518.49	666.45	832.34	981.94	1194.36	1437.37	1702.87	1631.27	2249.73	2541.63	2848.44	3095.70
Renault	1.2	3.74	8.12	15.04	25.74	38.75	52.53	68.78	93.11	124.05	162.79	172.85	273.07	341.73	430.65	521.88
Ford	4.54	12.53	23.13	40.59	69.01	101.56	123.11	142.36	168.19	191.16	208.61	242.72	362.48	461.26	584.88	714.33
Nissan	67.78	107.87	157.30	236.48	338.07	421.24	534.70	644.46	796.62	980.93	1194.51	1139.17	1566.17	1783.30	2028.54	2247.95
Honda	43.27	71.70	95.07	125.18	165.12	216.62	285.82	359.41	456.89	572.85	714.92	696.14	1011.11	1171.69	1397.12	1597.76
Mitsubishi	42.28	82.13	135.53	220.06	342.21	475.33	572.01	649.63	754.16	856.32	948.45	957.58	1149.53	1249.44	1331.08	1376.13
Hyundai	0	0.38	1.13	2.56	4.84	7.85	22.93	42.42	68.82	102.02	142.62	189.86	278.32	371.59	474.80	584.17
GM	6.94	11.96	16.52	23.08	30.21	35.31	42.68	49.07	58.62	69.27	80.87	89.49	137.57	174.82	222.86	271.96
PSA	5.91	10.23	15.83	23.23	33.68	44.76	52.33	58.29	66.15	72.20	77.06	99.41	141.95	186.49	238.79	295.74
Daimler	26.16	41.98	60.34	82.38	113.49	140.95	186.35	223.85	284.80	345.29	404.27	444.39	559.84	629.67	702.11	738.04
Volkswage	11.80	18.25	25.46	34.04	45.22	54.02	68.66	81.91	99.28	116.71	131.68	152.96	203.23	246.74	299.17	351.36

Figure A1: Growth rates of R&D expenditures: US Parents and US Affiliates – technology-exploiting (H1) and technology-sourcing (H2) hypotheses: Traditional technologies

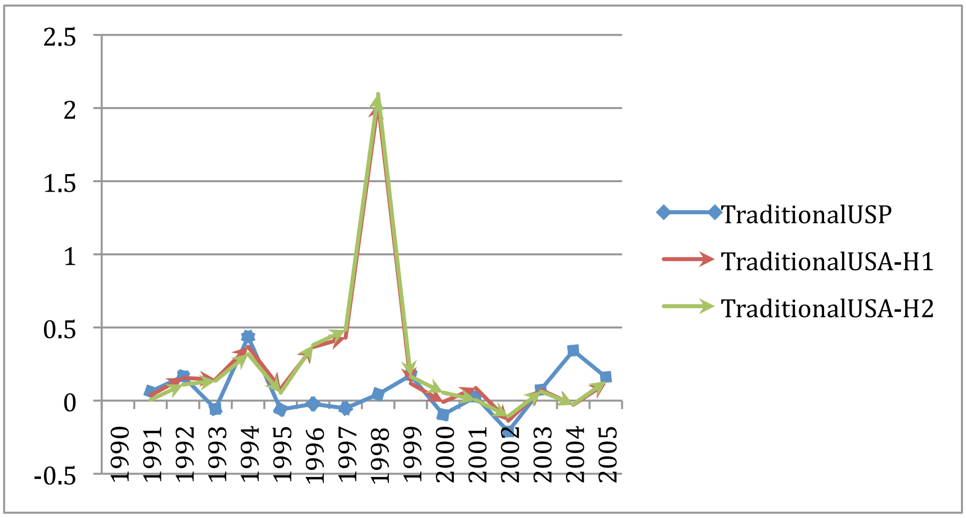


Figure A2: Growth rates of R&D expenditures: US Parents and US Affiliates – technology-exploiting (H1) and technology-sourcing (H2) hypotheses: Alternative technologies

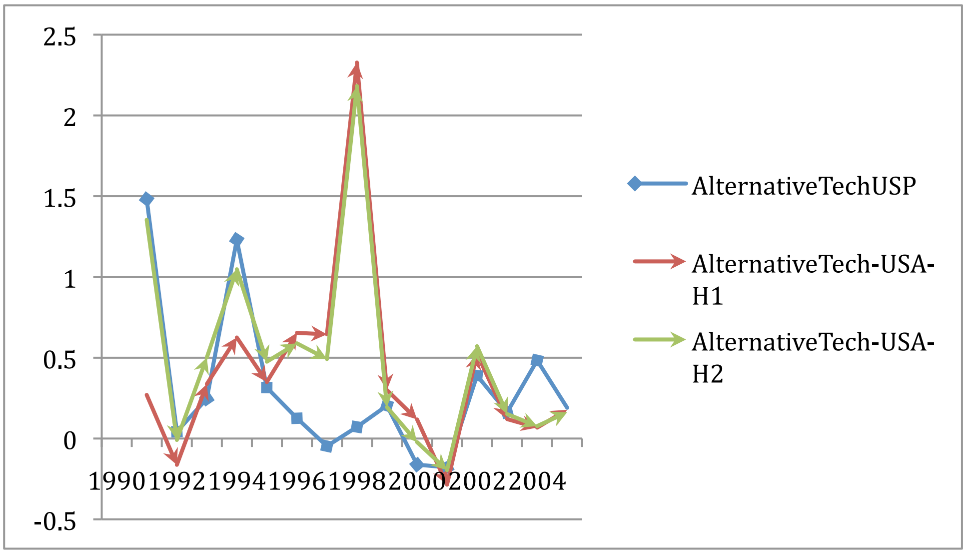


Figure A3: Growth rates of R&D expenditures (moving average): US Parents and US Affiliates – technology-exploiting (H1) and technology-sourcing (H2) hypotheses: Traditional technologies

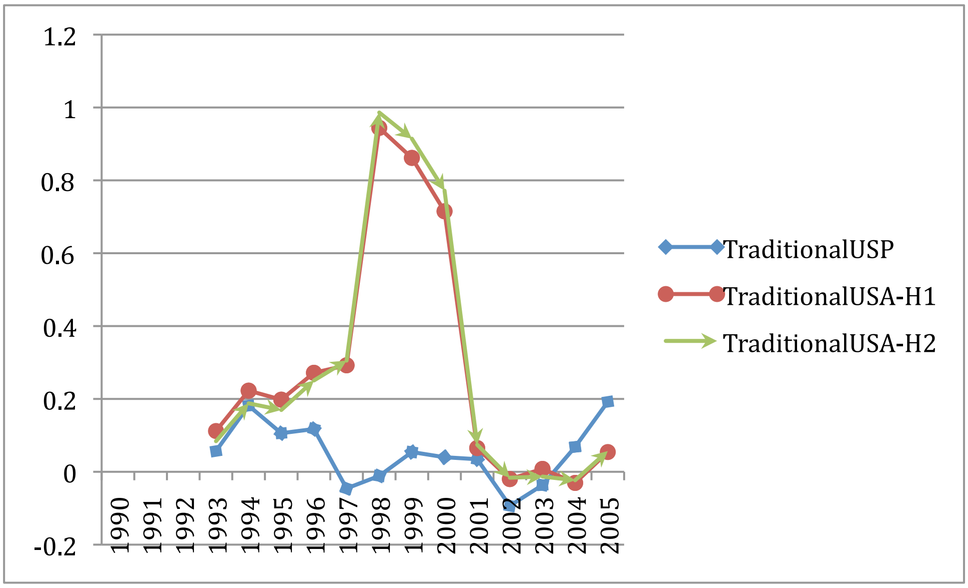
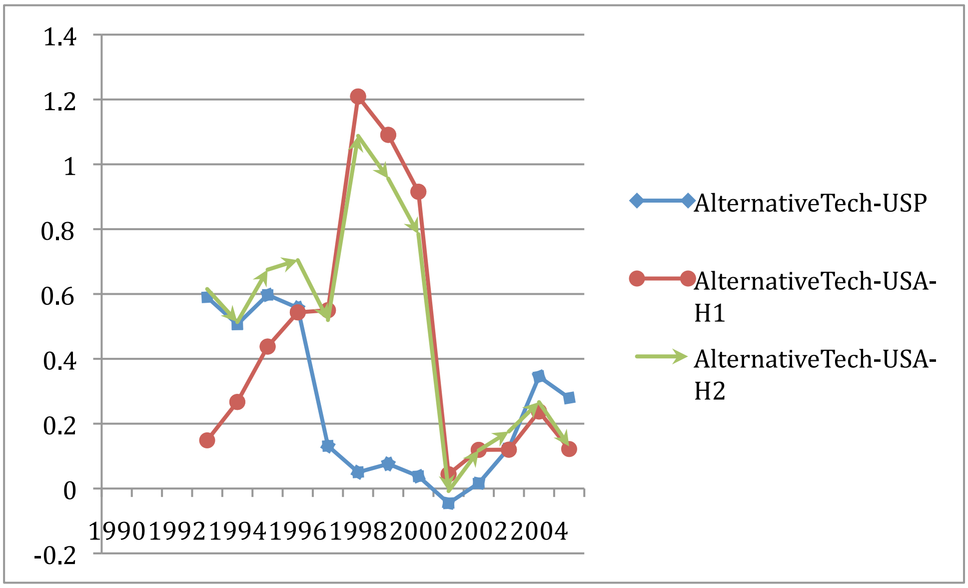


Figure A4: Growth rates of R&D expenditures (Moving Average): US Parents and US Affiliates – technology-exploiting (H1) and technology-sourcing (H2) hypotheses: Alternative technologies



Conclusions

With the increase of the globalization process in the last three decades, the analysis of the activity of multinational corporations (MNCs) is a key economic issue. Foreign Direct Investment (FDI) is the most important channel through which MNCs organise their activity and their production across countries because FDI is strictly related to control and management activities. The United States have historically been the most attractive destination for FDI. In 2005 it was surpassed by China, but in 2006 it regained the leading role in receiving foreign investments. Inside U.S., the automotive industry is one of the sectors most involved in FDI activity. From 1982, foreign automakers started creating U.S. production transplants strengthening the competition in the U.S. market. The strong foreign competition made the American Big Three lose their market power continuously until present.

This thesis addresses the analysis of MNCs' activity through three empirical chapters sharing a focus on the U.S. auto industry. Each chapter focuses on a specific topic in order to investigate U.S. automotive MNCs from different perspectives. The first two sections develop a quantitative analysis of the companies' behaviour through the use of econometric techniques. The last chapter focuses on a qualitative perspective. The analyses carried out in the three chapters use a unique dataset of the U.S. Bureau of Economic Analysis (BEA). "BEA is one of the world's leading statistical agencies" (www.bea.gov). It collects data on the U.S. economy at national, international, regional, and industry level. On MNCs, it provides useful information on companies' total assets, total employment, compensation to employees, export and import of goods, net income, total sales, capital expenditures, and research and development (R&D) expenditures. MNCs are distinguished by ownership in order to investigate differences between domestic firms, that is U.S. Parents, and foreign-owned companies, that is U.S. Affiliates. The period analyzed is 1983–2007 according to the availability of data.

In Chapter 1 it was investigated whether domestic and foreign-owned companies are characterized by different economic behaviours. U.S. automakers lost their market shares against their foreign competitors from the early 1960s. Foreign competitors entered the U.S. market by importing small and compact cars, while U.S. Big Three focused on the production of big-size cars. A great decrease in U.S. companies' market shares started in the early 1980s following the two oil shocks. In the same period the U.S. Government passed the Fair Practices for Automotive Product Act requiring foreign automakers to start a U.S. based production in order to retain their current levels of U.S. sales. The government regulation was intended to facilitate a recovery in Big Three's competitiveness, but U.S. automakers continued losing market power. In the meantime foreign producers entered the U.S. with productive transplant further strengthening their competitive pressure (Section 1.2). A first glance at data reveals the continuous loss in the market power of U.S. Parents from 1983 to 2007. U.S. Affiliates' sales per employee are higher than their American counterparts, while U.S. Parents have an R&D per employee greater than U.S. Affiliates. Also the average labour compensation of U.S. Parents is greater than that of U.S. Affiliates, in contrast to the main FDI literature, where "it is rare to find a study of FDI and wages in any host country that does not find that foreign owned firms pay higher wages, on average, than a least privately owned local firms" (Lipsey, 2002) (Section 1.3). To analyze the dataset, homogeneous time series spanning the 1983–2007 period have been constructed. Indeed until 1997 data were collected according to the Standard Industrial Classification (SIC) system, while from 1997 onwards data are collected according to the North America Industrial Classification System (NAICS). The two coding systems differ in the methodology of counting establishments. Homogeneous time series have been constructed according to the "bridge tables between SIC and NAICS" provided by the U.S. Census Bureau. The data pertain to total assets, employees' compensation, total employment, export, import, capital expenditures, net income, R&D expenditures, and total sales for both U.S. Parents and U.S. Affiliates. In the spirit of LSE approach two simultaneous equations systems have been elaborated, one for each type of MNC. The use of the system deals with endogeneity problems, un-observable bias, and simultaneous correlation bias. In order to take into account the financial troubles occurred in the time span investigated, many financial variables are included in the estimations. By this procedure it is possible to solve the bias avoiding the use of dummy variables, which will reduce the generality of the models and their degree of freedom (Section 1.4). As expected, Three Stages Least Squares (3SLS) results show that U.S. Parents and U.S. Affiliates follow very different behaviour in all the variables analyzed, while they strongly influence each other (Section 1.5). In particular, U.S. Parents' total sales are positively and significantly affected by the foreigners' total sales lagged one period. Given that foreign automakers are focused on small cars production, the effect of U.S. Affiliates' total sales stands for the fact that the U.S. demand of small cars is increasing and so positively affecting the share of U.S. firms producing such cars. The R&D expenditures of the American firms are negatively related to the rational expectations on U.S. Affiliates' R&D one-period forward. It is likely that U.S. firms improve in foreign-based facilities the innovative products to compete with foreign-owned companies, given the difference in products supplied by American and foreign car producers. The U.S. Parents' employee compensation specification does not present inter-relationship with U.S. Affiliates' activity in contrast with many studies on FDI spillovers. The capital expenditures carried out by American firms are negatively influenced by the lagged levels of capital expenditures and total sales of foreign-owned companies. It is likely that U.S. Parents do not react to a foreign expansion. Given the focus of U.S. Affiliates on small cars, their total sales can be taken as proxy for market demand in the small and compact vehicles sector. The positive influence of foreigners' total sales on U.S. Parents' capital expenditures suggests that American firms try to increase their production facilities to start local production of small and compact cars. That is in order to regain competitiveness on the American market, whereas consumers' preferences have changed after the two oil shocks of the 1970s and early 1980s. As expected, U.S. Parents' total employment is negatively related to U.S. Affiliates' total sales lagged one-period. Indeed the greater the foreign sales, the greater their market shares, the lower the U.S. Parents' market shares, the lower their production and employment level. Total assets of American companies are negatively related to rational expectations on U.S. Affiliates' local expansion, proxied here by the total assets variable one-period forward. It is likely that U.S. Parents react to U.S. Affiliates' expected expansion through captive import from abroad, as suggested by Eden and Molot (1996). U.S. Parents' total import is negatively influenced by the foreigners' sales level as expected. American companies' total export is negatively affected by the lag of U.S. Affiliates' capital expenditures (Section 1.5.1).

About U.S. Affiliates, surprisingly only the capital expenditures and the import regressions show a link with U.S. Parents' activity. Indeed foreign capital expenditures and total imports are negatively related to U.S. Parents' lagged levels of capital expenditures and import respectively. On the other hand, U.S. Affiliates' total sales, R&D expenditures, employees' compensation, total employment, total assets, and total export are not significantly related to U.S. Parents' behaviour. This pattern is likely due to the fact that U.S. Affiliates are mere production facilities ruled from the foreign headquarters and they are not reflecting strategic influences (Section 1.5.2).

Chapter 2 dealt with the automakers' productivity issue. In particular it investigated whether results on productivity in the U.S. auto industry discussed in recent microeconomic literature can be confirmed when macroeconomic data are used. In addition, the productivity analysis is carried out maintaining the distinction between U.S. Affiliates and U.S. Parents. By this procedure differences in productivity among local and foreign-owned firms is also investigated. The plant-level study of Van Biesebroeck (2007) on the North American auto industry is taken as reference point to develop the macroeconomic perspective. The analysis of auto industry's productivity is a key issue in the recent development of the automotive industry. Indeed from the early seventies the different models of cars and light trucks supplied on the market rose continuously in number. In addition, the number of productive plants did not change as much. Then the average number of models produced in a single plant increased enormously (Van Biesebroeck, 2007). The production of different models in the same assembly plant implies several changes in the organization of the production process. From Van Biesebroeck (2007), firms adopt flexible technology in order to produce efficiently a greater variety of vehicles per assembly line. In addition, American automakers' in-source intermediate activities in order to maintain their competitiveness on the market (Section 2.2.1).

Given the general framework, Van Biesebroeck uses plant-level data to further investigate firms' productivity with respect to the phenomena of increasing Variety, Flexibility, and In-sourcing (Section 2.2.2). In particular, the author investigated whether the joint adoption of the three single activities and their interactions have influence on productivity (Section 2.2.3). Van Biesebroeck's results show that the adoption of the three single activities negatively influences productivity, while their interactions have positive effects on productivity. In addition, the author shows that the productivity penalty due to the production of increased variety is more than offset by the positive effects of the interactions between the three activities under analysis (Section 2.2.4).

As in Chapter 1, the industry-level dataset from the U.S. BEA has been used. In this case the novelty has been the estimation of a model very close to the one elaborated in the microeconomic reference with a macroeconomic dataset. As earlier, the time period spans from 1983 to 2007, and homogeneous time series have been created by using the Bridge Tables between NAICS and SIC provided by the U.S. Census Bureau. Another novelty is the distinction between local firms, that is U.S. Parents, and U.S. Affiliates in the productivity analysis. As resulted from Chapter 1, the two types of MNCs are very different to each other in their economic activity. So the distinction is a key issue also in the productivity context (Section 2.3.1). Given the difference in the aggregation levels among the dataset used by Van Biesebroeck (2007) and the BEA dataset, different proxies for the three investigated activities have been constructed (Section 2.3.2).

In the spirit of the LSE approach (Sargan, 2001; Hendry, 2003), for both U.S. Parents and U.S. Affiliates a model very close to that used at the plant-level has been constructed and estimated first through Ordinary Least Squares (OLS). Surprisingly, using exactly the same specification, the productivity of both U.S. Parents and U.S. Affiliates is explained up to over 97 percent. This is very surprising given that U.S. Parents and U.S. Affiliates are structurally very different. Indeed U.S. Parents are “headquarters companies” while U.S. Affiliates are productive transplants ruled from abroad. In the two estimated models the U.S. Gross Domestic Product (GDP) has been included to account for exogenous factors. In addition, possible inter-relationships between U.S. Parents’ and U.S. Affiliates’ productivity have been investigated through a Granger-causality test. Surprisingly the test failed in assessing the relationship between the productivity of the two types of MNCs. It is likely that domestic and foreign-owned companies producing different cars adopt different production techniques (Section 2.4.1).

In order to deal with endogeneity of adoption decisions on the three investigated activities and with serial correlation problems, two simultaneous equations systems have been developed. The systems have been constructed by treating as endogenous the three activities of Variety, Flexibility, and In-sourcing. The 3SLS results show that in the U.S. Parents’ case, Variety and the Flexibility index enter the productivity specification with a positive sign, in contrast with the plant-level work. The In-sourcing proxy has been dropped from the specification because it was not significant at all. The interaction terms between Variety and Flexibility and between Variety and In-sourcing had the expected positive signs, while that between Flexibility and In-sourcing registers a negative sign, even if with a very small magnitude. The U.S. GDP enters the specification positively. As discussed earlier the U.S. Affiliates' activity does not at all influence U.S. Parents' productivity. On the other hand, U.S. Affiliates strongly influence the proxies for the three investigated activities (Section 2.4.2).

As regards U.S. Affiliates, Variety still enters the productivity regression with a non-expected positive sign. On the other hand, both Flexibility and In-sourcing have a statistically significant negative sign as predicted by the microeconomic literature. The interaction term between Variety and In-sourcing has a negative sign, in contrast with Van Biesebroeck (2007), while the interaction term between Flexibility and In-sourcing register a positive sign as expected. The interaction between Variety and Flexibility has been dropped from the estimation because it was not significant at all. As in the U.S. Parents' case, U.S. GDP enters the productivity specification with a positive and statistically significant sign. As in the previous case, the U.S. Parents' economic activity strongly influences the proxies for U.S. Affiliates' Variety, Flexibility, and In-sourcing (Section 2.4.3). This analysis represents an important novelty in the MNCs' literature by replicating a plant-level analysis at macroeconomic level. In addition, this Chapter innovates the analysis carried out at microeconomic level by taking into account the differences between domestic and foreign-owned companies.

Chapter 3 of this thesis gives a qualitative point of view on the MNCs' effort aimed at developing innovative engine technologies. The technological innovation of alternative fuel vehicles is indeed another key issue of the automotive industry, dealing with the scarcity of natural resources and environmental problems. Indeed from the early 1990s stringent environmental regulations induced car manufacturers to develop alternative fuel vehicles. In 1990, the California Air Resources Board approved the Zero Emissions Vehicles (ZEV) program. For the fist time private transportation was directly involved in the regulation aimed at limiting fuel consumption and pollution. Current macro data related to U.S. Parents and U.S. Affiliates do not distinguish how firms split their R&D expenditures by technologies. The microeconomic evidence on firms' patenting activity from Oltra and Saint Jean (2009) is exploited to decompose by technology the macroeconomic dataset from BEA. The procedure followed here represents a novelty, since it is likely to be the first attempt in exploiting micro results to improve the macro perspective on firms' innovation activity in the U.S. auto industry. The chapter leads to an innovative and much more integrated analytical level, which can be qualified as Qualitative Meso-economics perspective.

Innovations on engine technologies are the main output of firms' patenting activity, while R&D expenditures represent the innovation input (Dodgson and Hinze, 2000). At the macroeconomic level, the firms' R&D expenditures are the only proxy for technological innovation. Accordingly, the present work analyzed for the first time how R&D expenditures are split among the different technologies in the U.S. automotive industry. In addition, it is investigated how technological investments of U.S. MNCs differ among different firms' ownership, that is between U.S. Parents and U.S. Affiliates.

Automakers have been encouraged to shift from the traditional internal combustion engine vehicles (ICEVs) fuelled with gasoline or diesel (DE) to alternative low emissions vehicles (LEVs), such as battery electric vehicles (EVs), hybrid vehicles (HVs), and fuel cell vehicles (FCVs) powered by hydrogen. Section 3.2 introduces the main characteristics of the different technologies, and the ongoing new competition involving both cars and infrastructure. Competition among different car models is related to technical issues, while that related to infrastructure concerns the organizational complexity of the innovation, that is required network change. Changes in technical complexity are divided among incremental and radical innovations. Organizational innovations are divided into modular and system innovations.

The microeconomic analysis of the firms' patenting activity from Oltra and Saint Jean (2009) is taken as reference point in order to deepen the macroeconomic perspective. The authors collected data on patents applications by the 11 major car manufacturers from 1990 to 2005 (Section 3.3). At the technology level, Oltra and Saint Jean (2009) show that traditional engines follow an increasing trend in the firms' patenting activity for the whole period considered still attracting the principal innovation effort of automakers. Among alternative technologies EVs and HVs are those most developed by American car manufacturers, while the fuel cell design registers the lowest innovation effort for the whole period (Section 3.3.1). At firm level, Toyota and Honda are the leading companies in patenting activity. Toyota is the first mover in the development of traditional, electric and hybrid technologies, while Honda focuses its innovation efforts mainly on diesel, fuel cell, and hybrid engines. General Motors and Renault are relatively specialized in fuel cell technology, while Hyundai, Mitsubishi, and PSA direct their innovation effort mostly towards traditional diesel engine. Traditional gasoline is strongly supported by Volkswagen, Daimler-Chrysler, Renault and Ford, while Japanese firms are likely to be the most involved in electric and hybrid vehicles, with the exception of Nissan that strongly supports the fuel cell engine also (Section 3.3.2).

Micro and macro analyses are matched and R&D expenditures are qualitatively differentiated by technology between U.S. Parents and U.S. Affiliates. By this procedure the comparative advantages in innovative technologies have been highlighted. The innovation advantages are a fundamental key issue in the new competition among different car manufacturers (Section 3.4). The data on patents applications are taken from Oltra and Saint Jean (2009) while that on U.S. MNCs' R&D expenditures are from BEA (Section 3.4.1). The main assumption under the analysis is that firms are "skilled" in the most advanced technology in the home country and the most applied to goods traded in the home market. MNCs will develop the most improved technology in the home country and the most promising one for the nearest markets in the home R&D centers, leaving foreign R&D centers for the most developed and applied technology in the foreign country/market. Then U.S. Parents' R&D expenditures are split according to the technological specialization of Ford, General Motors, and Daimler-Chrysler. For all the 1990s, American firms were focused in developing traditional technologies, with particular attention to the gasoline engine. From 2001, investments in alternative designs register a sharp increase until it caught up with the expenditures on the traditional gasoline design. Among alternative vehicles, the electric design was the dominant technology during the 1990s. From the new decade, hybrid technologies become the dominant alternative designs, even if investments in FCVs increase sharply after 2000 (Section 3.4.2). For U.S. Affiliates two alternative scenarios will be assumed in order to construct an interval to include the real values of MNCs' R&D expenditures in the U.S. First in the technology-exploiting FDI hypothesis, U.S. Affiliates' R&D expenditures are split by technology according to the technological specialization of non-American car manufacturers. Here, U.S. Affiliates will perform R&D activities to refine the technology the most developed in the home country. The R&D effort will be aimed at fitting foreign consumer preferences and meeting the regulations of the target country. In the second hypothesis U.S. Affiliates will invest in the most developed technology in the country where they are located (i.e. technology-seeking FDI [Barba Navaretti and Venables, 2004]). U.S. Affiliates' R&D expenditures are split by technology according to the U.S. Parents' technological specialization. By the two hypotheses the R&D expenditures of U.S. Affiliate companies are divided in two extreme ways in order to find an interval including the real FDI strategy. This procedure represents a novelty here. Indeed it allows deepening the analysis of macro data in a qualitative way by exploiting micro level results, leading to an innovative, much more integrated perspective. It can well be qualified as a Qualitative Meso-economic Analysis deriving from the micro-macro integration (Section 3.4.3). In the technology exploiting case, U.S. Affiliates were mainly focused in the diesel technology until 2001. From 2002 onwards they direct the major efforts toward alternative engines. The leading alternative technology for the non-American firms is EV, immediately followed by HV (Section 3.4.3.1). In the technology-sourcing FDI hypothesis, U.S. Affiliates' R&D expenditures are split by technology as in the U.S. Parents' case (Section 3.4.3.2). By interacting the results of the two hypotheses the interval including the real FDI strategy in the U.S. auto industry is found. Until 1998 U.S. Affiliates follow the same technological specialization under the two hypotheses. After 1998 in the technology-sourcing hypothesis U.S. Affiliates are more focused in traditional engines than in the technology-exploiting case. Regarding alternative fuel vehicles, the two hypotheses show the same pattern of technological specialization until 1996, while from 1997 onward U.S. Affiliates exploiting the foreign specialization are more focused in developing alternative engines than in the technology-sourcing case (Section 3.4.3.3). At this point it has been possible to split the U.S. R&D expenditures by technology at country-level. The technological composition of the aggregate figure results by combining the R&D expenditures of U.S. Parents and U.S. Affiliates split as before. Also the total U.S. R&D expenditures is split by technology in two extreme ways in order to find the real R&D strategy followed by U.S.-based firms with no ownership distinction. The macro-data integration is the final and most important result of the analysis. The difference in the country-level R&D expenditures by technology under the two hypotheses is very small. This is mainly due to the fact that here it is dealing with country-level data, in which the impact of U.S. Affiliates' R&D expenditures is minor with respect to the U.S. Parents' expenditures. Indeed until 1997 U.S. Affiliates' R&D expenditures were very low. Only after 1998, R&D performed by foreign-owned firms accounted for around 20 percent of the U.S. Parents' R&D expenditures (Section 3.4.4).

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