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Abstract

My PhD thesis seeks to answer two important questions in a world where the spread of technology from the North to the South has accelerated as never before, and most emerging countries are experiencing large productivity improvements. First, *should advanced countries welcome productivity improvements in their backward trading partners*? And second, *what are the factors that affect a country's capacity to absorb foreign technology*?

Chapters 1 and 2 contain a short outline of the questions motivating my research, and an overview of the existing literature on international technology transfer, welfare and absorptive capacity.

In chapter 3, I investigate the welfare effects that developed countries experience after productivity improvements occur in their backward trading partners. I use a two-country model featuring pro-competitive effects of trade, where one country has better technology than the other. I model the technology advantage of the leading country by assuming that the productivity distribution its firms draw from stochastically dominates that of the laggard country. Calibrated to match aggregate and firm level statistics of the US economy, the model predicts that the country with better technology has a higher productivity cutoff level, higher average productivity and higher welfare. Productivity improvements in the backward country generate selection and raise welfare everywhere, with both the selection effect and the positive welfare effect being stronger in the laggard country. Finally, trade liberalization is associated with more

selection and higher welfare in both the leading and the laggard country.

In chapter 4 (co-authored with Michael Rochlitz), we investigate differences in and determinants of technical efficiency across three groups of OECD, Asian and Latin American countries. As technical efficiency determines the capacity with which countries absorb technology produced abroad, these differences are important to understand differences in growth and productivity across countries, especially for developing countries which depend to a large extend on foreign technology. Using a stochastic frontier framework and data for 22 manufacturing sectors for 1996-2005, we find notable differences in technical efficiency between the three country groups we examine. We then investigate the effect of human capital and domestic R&D, proxied by the stock of patents, on technical efficiency. We find that while human capital has always a strongly positive effect on efficiency, an increase in the stock of patents has positive effects on efficiency in high-tech sectors, but negative effects in low-tech sectors.

Finally, chapter 5 sums up the main results and outlines possible future research directions.

Chapter 1

Introduction

The International Monetary Fund (IMF) defines globalization as *the growing economic interdependence of countries worldwide through increasing volume and variety of cross-border transactions in goods and services, freer international capital flows, and more rapid and widespread diffusion of technology* (IMF, 1997).

Since the 1980s, world trade has expanded rapidly, boosted by trade liberalization reforms in many countries and by decreasing transportation costs. During the 1990s, most countries have started to adopt policy measures to attract foreign direct investment (FDI), which have constantly increased during the last decades, especially in low and medium income countries. The spread of technology from the North to the South has accelerated as never before, with trade and FDI being the main forces driving international technology transfer. Despite increasing international economic integration, however, serious imbalances in the access to technology remain between North and South. New technology originates in the North, where most of research and development (R&D) activities are performed, whereas the South heavily relies on technology imported from the North. Empirical evidence reveals that globalization has boosted productivity growth in emerging countries that have restructured their economies along market oriented lines (e.g. South Korea, Taiwan and more recently China). However, while trade liberalization and the expansion of FDI have opened up channels for technology diffusion, the capabilities of these countries to absorb, diffuse and use effectively imported technologies have been crucial to realize the gains from international technology transfer.

My research focuses on two important questions in a world where the spread of technology from the North to the South has accelerated as never before, and most emerging countries are experiencing large productivity improvements. First, *should advanced countries welcome productivity improvements in their backward trading partners?* And second, *what are the factors that affect a country's capacity to absorb foreign technology?*

Most previous studies have used traditional trade models to investigate the welfare effects that productivity improvements in emerging countries generate in developed countries. Traditional trade models predict that productivity improvements in the South may hurt the North when they occur in sectors where the North has a comparative advantage or when they reduce the relative wage gap. Only a few recent studies have used richer frameworks to answer this question, highlighting new channels through which productivity improvements in developing countries may affect welfare of trading partners (e.g. variety effect and industry productivity effects).

A rich set of studies have investigated the determinants of absorptive capacity and their relative contribution in explaining differences in productivity and income levels across countries, both in developed and developing countries. However, as sectoral data for most developing countries has been made available only recently, there is still a wide scope for empirical investigation.

My dissertation is structured in four chapters. Chapter 2 surveys the literature on international technology transfer, welfare, and absorptive capacity. A first paragraph focuses on the studies which emphasize the role of trade and FDI as channels for international technology transfer. The second paragraph surveys the studies that explore how productivity improvements in emerging countries affect welfare of developed countries. The last paragraph is a review of the studies on absorptive capacity in both developed and developing countries.

In Chapter 3, I investigate the welfare effects that developed countries experience after productivity improvements occur in their backward trading partners. I use a two-country model featuring pro-competitive effects of trade, with a country being technologically more advanced than the other. To my knowledge, this work is the first using an endogenous market structure framework to answer this question. I use an industry model with heterogeneous firms based on that of Impullitti and Licandro (2010), where the response of the market structure is driven by the strategic interaction of firms competing la Cournot. I model the technology advantage of the leading country, assuming that the productivity distribution its firms draw from stochastically dominates that of the laggard country. Using a numerical calibration based on firm-level and aggregate statistics of the US economy, I show that the country with better technology has a higher productivity cutoff level, higher average productivity and higher welfare. Productivity improvements in the backward country generate selection and raise welfare everywhere, with both the selection effect and the positive welfare effect being stronger in the laggard country. Finally, trade liberalization is associated with more selection and higher welfare in both the leading and the laggard country.

Chapter 4, co-authored with Michael Rochlitz (IMT Lucca, Italy), is an empirical investigation of the determinants of absorptive capacity across three groups of OECD, Asian and Latin American countries. We use stochastic frontier analysis (SFA) and sectoral data for 22 manufacturing sectors for 1996-2005, which allows us to treat technical efficiency and technical change as two distinct components of total factor productivity (TFP) in each industry. We investigate the effect of two potential determinants of absorptive capacity, human capital measured by years of schooling, and the domestic R&D, proxied by the stock of patents. The contributions of this paper to the existing literature are twofold. To our knowledge, this paper is the first to use SFA and sectoral data to analyse efficiency levels and determinants of absorptive capacity not only for a group of OECD countries, but also for two groups of developing and newly industrialized economies in a comparative approach. Secondly, instead of R&D expenditure, we use the stock of patents as a proxy for R&D, which to our knowledge has not been done before. We find notable differences in technical efficiency between the three country groups we examine. Human capital has always a strongly positive effect on efficiency, while an increase in the stock of patents has positive effects on efficiency in high-tech sectors, but negative effects in low-tech sectors.

Finally, Chapter 5 concludes with a summary of the main results and an outline of possible future research directions.

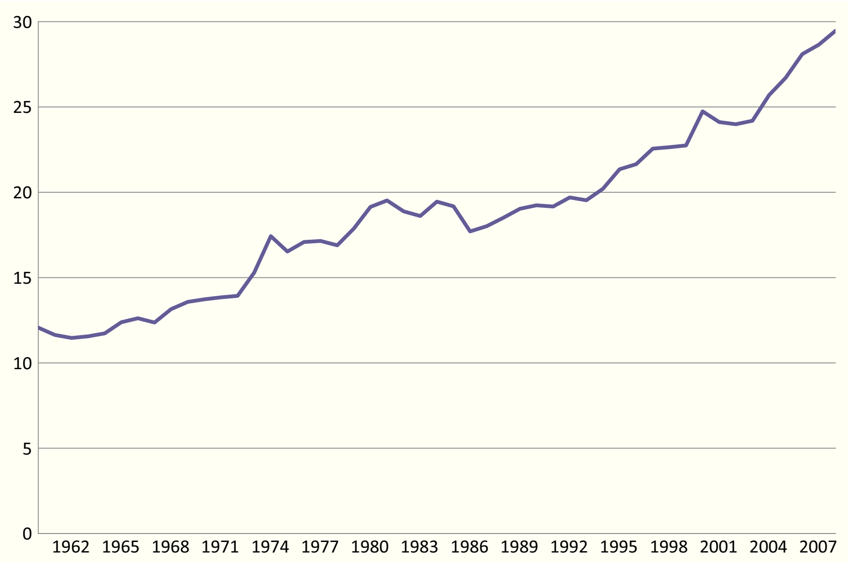
Chapter 2

International Technology Transfer, Welfare and Absorptive Capacity: A Survey

2.1 Introduction

Globalization has drastically increased the spread of technology from developed to developing countries. Increasing international trade and the expansion of FDI have been the main forces driving international technology transfer. Figure 1 plots worldwide exports as a percentage of gross domestic product (GDP) from 1960 to 2008. During this period, the percentage of worldwide exports has increased from approximately 12.1% to 29.5%. Similarly, capital goods exports (%GDP), which are considered to1 be an important vehicle of foreign technology spillovers, have constantly increased over the last decade (Figure 2). Figure 3 plots net FDI inflows as a percentage of GDP for low and middle-income countries for 1975-2008. The share of net FDI inflows over GDP has grown six-fold through the last decades for those countries. The total inward stock of FDI as percentage of GDP has grown from 0.19% to

Figure 1: Worldwide exports as a percentage of GDP (1960-2008, World Bank)



37% between 1990-2007 in transition economies, and from 13% to 30% in developing economies (Table 1).

Despite the emergence of newly industrialized countries and an increasing fragmentation of production, most R&D activities are still carried out in a small number of R&D-intensive countries. Developing countries heavily rely on technology imported from those countries. Figure 4 shows R&D expenditure as a percentage of GDP by country in 2007. Most R&D activities in 2007 were performed in Sweden, United States, Japan, Germany, United Kingdom, Finland and Canada, whereas most countries in Latin America, Asia and Africa have invested less than 1% point of their GDP. As most developing countries still depend to a large extent on foreign technology, international technology transfer offers important opportunities for catch up and development. The empirical evidence reveals that emerging countries that have opened their economies significantly and adopted measures to attract FDI, have experienced large productivity improvements. This is indeed what happened in South Korea, Taiwan or more recently in China, where the capacity to absorb foreign technology has played a crucial role in realizing gains from international technology transfer.

In a world characterized by a more rapid spread of technology from

Figure 2: Global Exports of Capital Goods as a Percentage of Total GDP (1995-2007, UNCTAD)

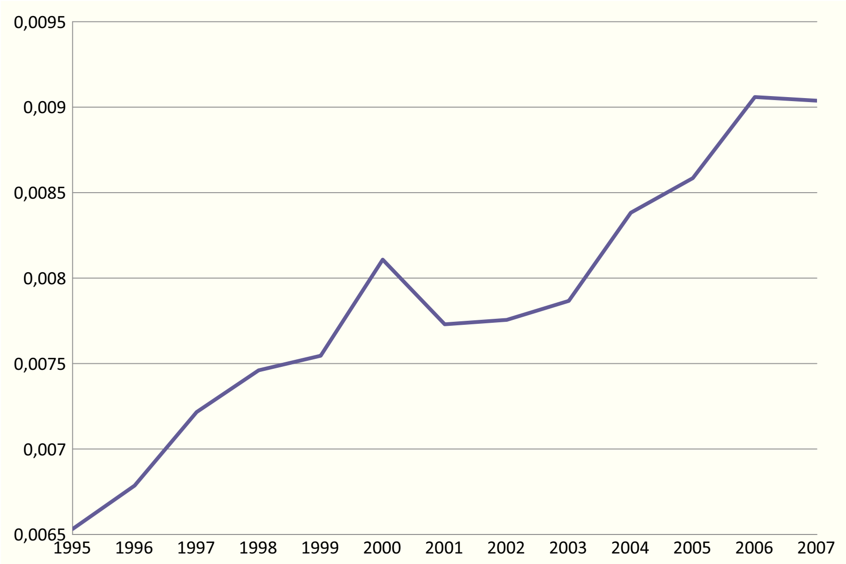


Table 1: Inward stock of FDI as a Percentage of GDP (1988-2007, UNCTAD)

	1990	1995	2000	2005	2007
Developing economies	13.43	14.37	24.82	25.03	29.81
Transition economies	0.19	2.03	15.32	25.19	37.03
Developed economies	8.94	10.81	22.75	25.31	32.62

the North to the South, and by concomitant productivity improvements in many emerging countries, some research questions have become central to international and development economics. Should developed countries welcome productivity improvements in their backward trading partners? What are the factors that affect a country's ability to absorb foreign technology?

Traditional trade models based on comparative advantage analysis predict that productivity improvements in a country benefit its trading partners when they occur in export-oriented industries, whereas they hurt its trading partners otherwise (Hicks, 1953). Product cycle models suggest that uncompensated technology transfer from the North to the South may hurt the North by reducing the wage gap (Saggi, 2002). Recently, a new set of studies have provided richer and more interesting

Figure 3: Net Inflows of FDI over GDP - Low and Middle Income Countries (1975-2008, World Bank)

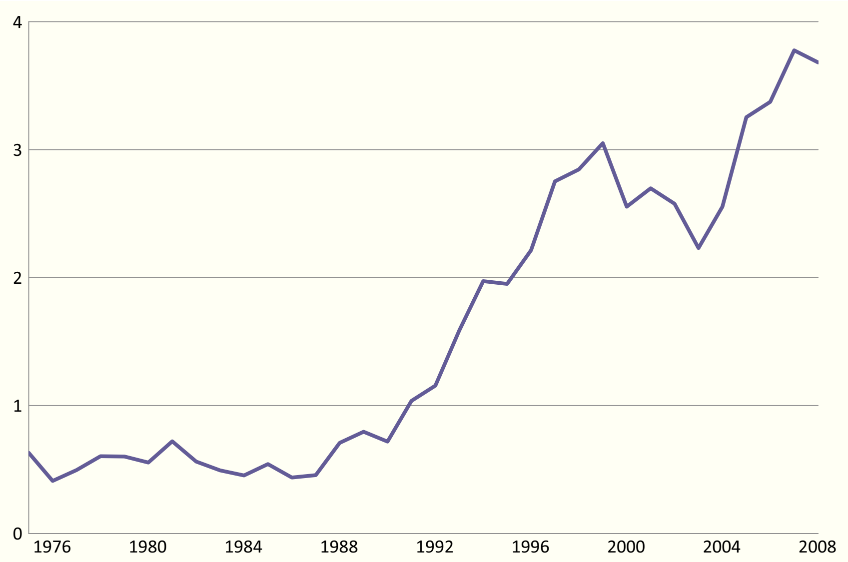


Figure 4: R&D Expenditure as a Percentage of GDP (year 2007, World Bank)

frameworks to answer this question, suggesting a wide scope for empirical investigations. An extensive literature has investigated the factors which affect a country's ability to absorb foreign technology in both developed and developing countries. These studies show that differences in absorptive capacity significantly explain differences in productivity and and income levels across countries. However, as sectoral data for most developing countries has been made available only recently, there is still a lot of scope for future work.

This chapter aims at providing a coherent picture of all these theoretical and empirical findings. The first paragraph surveys the studies on the role of trade and FDI as channels for international technology transfer. In the second paragraph, I review the literature that has explored how productivity improvements in backward countries affect welfare of more advanced countries. Finally, the last section is a review of works which investigate the determinants of absorptive capacity and differences in productivity and income levels in both developed and developing countries.

2.2 International technology transfer: the role of trade and FDI

An extensive literature focuses on the channels through which technology diffuses internationally, highlighting that both trade and FDI play important roles in promoting technology transfer across countries.

A strand of this literature has studied the interaction between trade and technology, focusing on both the static and the dynamic effects of trade. Most of these works share the view that trade affects the allocation of resources in an economy and plays a key role in diffusing technology internationally (Saggi, 2002).

In neoclassical growth models, capital accumulation is the main force driving economic growth, whereas knowledge plays only a marginal role. A key assumption is that capital is subject to diminishing returns, implying that the economy may cease to growth in the long run. Another important assumption is that countries have access to the same knowledge, thereby producing with the same technology and techniques. Parente and Prescott (1994) propose a model in which access to technology has a different cost across countries, depending on their legal, regulatory, political and social system. In such a framework, barriers to technology may retard the adoption of new technologies and therefore explain differences in per capita income across countries. Trade plays therefore an important role, as lowering barriers to technology adoption may encourage the development of an economy. In the new growth theory, R&D-based models clearly emphasize the potential gains of knowledge transfer across countries. These models stress the importance of new sources of growth, such as technological change and the accumulation of human capital (Lucas, 1988). The key assumption of the R&D-based models is that growth results from new knowledge embodied in new or better products. In a first class of R&D-based models, entrepreneurs undertake profitable research activities which lead to the creation of new varieties of products (Grossman and Helpman, 1993). In this model, the creation of new products expands the stock of knowledge and lowers the cost of innovation, thereby generating growth. In the quality ladder model (Aghion and Howitt, 1992; Paul S. Segerstrom and Dinopoulos, 1990), entrepreneurs have an incentive to improve the quality of existing products. A crucial assumption of quality ladder models is that patents do not prevent other firms from using knowledge embodied in the higher quality product, according to the non-rival nature of knowledge (Romer, 1990). An important implication of R&D-based models is that trade in goods might be a crucial vehicle of knowledge.

In the class of endogenous growth models, some focus on trade between identical countries, while others have a North-South structure. The first category includes the works of Grossman and Helpman (1993) and of Rivera-Batiz and Romer (1991). Grossman and Helpman (1993) describe an economy where non-traded intermediate goods are invented to produce two final goods which are internationally traded at exogenous prices. In their setting, trade may affect growth both directly and indirectly. On the one hand, trade encourages the diffusion of knowledge from foreign sources, thereby directly enhancing growth. However, by influencing domestic factor markets, trade has also an indirect effect on growth. Depending on whether the country is an importer of human-capital-intensive goods, trade can ultimately encourages economic growth by reducing the cost of innovation. Rivera-Batiz and Romer (1991) use a R&D-based model where technical progress is driven by the invention of new capital goods. In their framework, economic integration promotes economic growth by increasing world research activities, and by encouraging cross-border technological spillovers.

Endogenous growth models focusing on North-South trade have been particularly useful to understand international technology transfer. These models highlight the product-cycle nature of trade (Vernon, 1966), describing a world economy where new products are first produced and exported by advanced countries. Later, these products are improved (quality ladders model) or imitated (varieties models) by the South, making production in the North unprofitable (Saggi, 2002). A first generation of North-South models includes Krugman (1979), Paul S. Segerstrom and Dinopoulos (1990), Grossman and Helpman (1993), Lai (1998), and Glass and Saggi (2002). In all these models, total factor productivity was assumed to depend positively on the scale of the economy, and to be proportional to R&D employment. Jones (1995a) points out that, despite dramatic population growth in developing countries (e.g. China) and a more than five-fold increase in R&D employment in advanced countries, there is no evidence of an upward trend in the TFP growth rates of advanced countries. A second generation of North-South models was developed in response to the Jones critique. Important contributions include Jones (1995b), Segerstrom (1998), and Howitt (1999), and more recently and Gustafsson and Segerstrom (2010). An interesting feature of most of these models is that they generate a two-way product cycle: when southern firms imitate northern products, production shifts from the North to the South, and when northern firms develop higher quality products, production goes from the South to the North.

Many empirical studies on international technology diffusion have tried to correlate economic growth with increased trade openness. These studies can be classified in two groups (López, 2005): (1) case studies of specific countries (e.g. the Bhagwati–Krueger project for the NBER, carried out during the 1970s; and the Papageorgiou–Michaely–Choksi study conducted for the World Bank during the 1980s); and (2) cross-countries studies (Alcalà and Ciccone, 2004; Dollar, 1992; Dollar and Kraay, 2003; Noguer and Siscart, 2005; Sachs and Warner, 1995). Although using different techniques, the case studies have reached similar conclusions: an outward-oriented strategy is considered more successful in increasing the long-term rate of growth of output than an import substitution strategy. The cross-country literature generally finds a positive correlation between measures of openness and growth. However, Edwards (1993) claims that most of the studies published until the early 1990s suffer from serious problems in terms of endogeneity and measurement errors. Rodriguez and Rodrik (2001) and Hallak and Levinsohn (2004) have also argued that omitted variables may be responsible for a positive correlation between trade and growth. Moreover, when using geography measures (e.g. Rodriguez and Rodrik (2001), Irwin and Terviö (2002)) or proxies for the quality of institutions (e.g. Rodrik et al (2004)) as instruments, the effect of openness on growth either becomes smaller or not significant.

Grossman and Helpman (1995) argue that the effect of trade on growth depends on the geographical scope of knowledge spillovers. When spillovers are international, trade drives economic growth, but when spillovers are national, several scenarios may arise. A number of studies find a weak correlation between R&D activity and productivity growth at the national level and evidence of substantial international spillovers. Eaton and Kortum (1996) for instance find that more than 50% of the growth of OECD countries is stimulated by innovation in the United States, Germany and Japan. They also find that distance hampers knowledge transfer, whereas trade promotes it. Coe and Helpman (1995) and David T. Coe and Hoffmaister (1997) also find evidence of substantial international knowledge spillovers, and argue that trade is an important channel of technology diffusion. On the other hand, performing an analysis similar to the one by Coe and Helpman (1995) and David T. Coe and Hoffmaister (1997), Keller (1998) does not find any evidence of a positive relation between trade and R&D spillovers.

Empirical studies based on industry-level data and which look specifically on trade in capital or high-technology goods, show that foreign knowledge spillovers affect productivity and growth and that trade plays an important role in diffusing technology. Using cross-countries data for 1960-1985, Lee (1995) finds that the ratio of imported to domestically produced capital goods in the composition of investment significantly affects per capita income growth rates, with the effect being stronger for developing countries. Xu and Wang (1999) find that trade in capital goods helps to explain differences in total factor productivity across a group of OECD countries over the period 1983-90, whereas total trade does not. Using industry-level data, Keller (1998, 2000) shows that foreign technology embodied in imports of machinery goods positively affects productivity growth. He also finds that international trade contributes about 20% to the total productivity effect from foreign R&D, indicating that a large component of the benefits from foreign R&D is not related to trade. Connolly (2003) finds that technology embodied in high-tech imports encourages domestic imitation and innovation, especially in developing countries. She also finds that foreign technology spillovers through high-tech imports contribute more to growth than domestic technology. In a recent paper, Amiti and Konings (2007) estimates the productivity gains from reducing tariffs on final goods and from reducing tariffs on intermediate inputs in a sample of Indonesian manufacturing firms from 1991 to 2001. Results show that a 10% decrease in input tariffs leads to a productivity gain of 12% for a firm importing these inputs, which is twice as high as a gain from reducing output tariffs.

The literature identifies three potential channels of knowledge spillovers through FDI. First, domestic firms may acquire new technologies from multinationals through imitation or reverse engineering processes (demonstration effects). Second, workers previously employed by multinationals may transfer information to local employers or start their own firm (labor turnover). Finally, vertical linkages between multinationals and their suppliers of intermediate goods or buyers of their products may also play an important role in encouraging technology diffusion Saggi (2002).

The demonstration effect argument is based on the idea that the introduction of new technologies by multinationals lowers the cost of adoption for local firms. Geographical proximity plays a crucial role in this context, as it facilitates firms' exposure to new technologies, especially in developing countries that are less integrated into the global economy. Das (1987) is the first to develop a model where firms in a country may learn from the subsidiary of a multinational firm that has a dominant position on the market. Wang and Blomström (1992) et up a model where multinationals transfer technology to their subsidiaries, and host country firms learn from the new technologies introduced. Learning takes place through costless technology spillovers, and through a costly investment by local firms. An interesting feature of the model is that learning efforts by local firms increase the rate at which technology is transferred by multinationals. Huizinga (1995) presents a model where a multinational firm that transfers technology to a foreign subsidiary faces the risk of expropriation by the government of the host country. The main result is that the national firm transfers an inferior technology to reduce the benefit of expropriation. Baldwin et al (2005) develop a North-North growth model where FDI activities promote innovation and growth everywhere through learning by doing. A key assumption is that innovators can only partially understand foreign technology, but they become more efficient as they observe more local production processes. However, although the share of varieties transferred abroad affects innovation and growth in both regions, the rate of multinationalization is taken as exogenous in the model. The rate of multinationalization is endogenized in many dynamic North-South models (Glass and Saggi, 2002; Helpman, 1993; Lai, 1998) that focus on the effect of a tighter regulation concerning intellectual property rights (IPRs) protection in the South on the rate of northern innovation and global growth (for a review on IPRs and innovation see He and Maskus (2012)). He and Maskus (2012)) develop a general equilibrium model where northern firms innovate and transfer a share of new products to the South via FDI, and southern firms imitate. In an extended version of the model, southern firms may also innovate, although at a higher costs than northern firms, with the help of FDI spillovers through learning by doing. He and Maskusi also allow for "reverse" spillovers to northern firms and assume that the extent of spillovers depends on the geographic location of production processes, and on the ownership of general knowledge. Due to the difficulty in measuring the role of "imitation" and “learning by doing” as channels for technology spillovers, only a few empirical works have explicitly explored the existence of demonstration effects. An interesting attempt is the study by Anthony Bende-Nabende and Slater (2001). Using a panel of five Asian economies for 1970-96, they show that FDI has stimulated economic growth mainly through human factors and learning by doing.

The second channel through which FDI transfers technology to local firms is labor turnover. Andrea Fosfuri and Ronde (2001) develop a model where a foreign subsidiary can use a superior technology only after training local workers. In their framework, FDI generates two types of spillovers. Technological spillovers arise when workers having previously worked for the multinational are hired by a local firm. Pecuniary spillovers occur when the foreign subsidiary pays higher wages to trained workers to keep them from moving to local firms. Glass and Saggi (2002) argue that the wage premium paid by the multinational to trained workers to restrict technology diffusion may exceed or fall short of the benefit that the local economy would reach if the workers were employed by local firms. Sinani and Meyer (2004) point out that multinationals may use higher wages to attract skilled workers, thereby negatively affecting the efficiency of local firms, while Brian Aitken and Lipsey (1996) claim that, beside the “brain drain” effect, foreign firms may raise wages also for local firms in the labor market. The empirical literature has provided mixed evidence on labor turnover and on wage spillovers. By studying Kenyan industries, Gershenberg (1987) find limited evidence of labor turnover from foreign-owned to local firms. Conversely, UNCTAD (1992) and Pack (1997) document the important role of labor turnover in diffusing technology to local firms in Bangladesh and Taiwan respectively. Brian Aitken and Lipsey (1996) find that higher levels of foreign investments are associated with higher wages in Mexico, Venezuela and United States. They also report evidence of wage spillovers leading to higher wages for domestic firms in Mexico and Venezuela, whereas they find no evidence of wage spillovers in the United States.

The third channel of technology spillovers from FDI consists in the relationships between a multinational and its suppliers (backward linkages), or between a multinational and its customers (forward linkages). Rodriguez-Clare (1996) investigates how multinationals affect underdeveloped hosting regions through the creation of linkages. He shows that the effects of these linkages are favorable when multinationals intensively use intermediate goods, when there are high cost of communication between the headquarter and the production plant, and when the foreign country and the host country are not too different in the variety of intermediate goods they produced. Markusen and Venables (1999) develop a model to assess the impact of FDI on local firms, highlighting two opposite effects. On the one hand, the presence of FDI renders both the product market and the factor market more competitive, lowering profits of local firms. However, by creating linkages with local suppliers, FDI reduces input costs and raises profits. Pack and Saggi (2001) show that downstream buyers in industrial countries may benefit from FDI, as technology diffusion through backward linkages in developing countries increases competition among potential suppliers. Lin and Saggi (2005) show that the entry of a multinational has two conflicting effects on the degree of backward linkages in the local industry. On the one hand, the entry of the multinational raises the demand for intermediate inputs (demand effect), thereby increasing the degree of backward linkages. On the other, such entry costs strength the competition for local producers of final goods (competition effect), thus lowering the output level of local firms, and producing a negative effect on the degree of backward linkages. A rich body of case studies provides evidence of technology transfer through vertical linkages. For instance, Kenny and Florida (1993) and Helper (1997) describe the technology transfer by Japanese automobile producers to US parts suppliers. Other empirical studies provide evidence of a positive impact of FDI through the creation of vertical linkages with local suppliers (e.g. Blalock and Gertler (2003) for the case of Indonesia, Javorcik (2004) for the case of Lithuania).

2.3 Technology transfer, productivity improvements and welfare

A classical question in international economics is whether technological progress in a country hurts its trading partners.

Product cycle models provide an interesting framework to analyze the welfare effects of productivity improvements in backward countries. In these models, northern firms engage in costly innovation and technology transfer to the South through a number of channels (e.g. imitation, FDI, etc.), affecting the size of the North-South wage ratio. Krugman (1979) develops a general-equilibrium model of the product cycle where the rate of product innovation and the rate of technology transfer from the North to the South are exogenous. The innovation process, consisting in the production of new varieties, is undertaken only by the North, while the South engages in imitation activities. The main findings are that technological imitation hurts the North by reducing the wage gap, while it improves the terms of trade for the South. As result, the North must continually innovate not just to grow, but to maintain its real income. Grossman and Helpman (1991) model innovation in the North as an expanding variety process where the rate of innovation and the rate of imitation are endogenized. Both product innovations by the North and product imitation by the South are costly. They find that an increase in the uncompensated technology transfer to the South rises its relative wage with an ambiguous effect on the North, which might lose or not. Using a product cycle model, Glass and Saggi (2001) show that international outsourcing of production to low wage countries reduces the welfare of workers in industrialized countries by negatively affecting their wages. However, as firms in the North have access to the cheaper work force in the South, international outsourcing increases Northern firms'profits and incentives to innovate, thereby creating gains that can offset the losses due to the decline in northern wages.

Traditional trade models based on comparative advantage analysis predict that technological progress in a country benefits its trading partners if productivity improvements occur in export-oriented industries, whereas otherwise trading partners are hurt (Hicks, 1953). Using a Ricardian-Mill model, Samuelson (2004) simulates the effect on real wage rates in the US of a productivity improvement in China, in the sector in which the US previously had a comparative advantage. He finds that an increase in China's labor productivity harms the US by generating a permanent loss in per capita real income. Jones and Ruffin (2008) find that in a two country, multi-commodity Ricardian model, an advanced country may benefit from an uncompensated technology transfer to a less advanced country. Interestingly, this happens in the sector in which the advanced country has its greater comparative advantage. However, this "technology transfer paradox" occurs only when both countries share the same Cobb-Douglas demand conditions, and for a certain range of relative country size. Shachmurove and Spiegel (2009) explore through a Ricardian framework the effects that technological progress in developing countries has on the welfare of developed countries. They show that various scenarios are possible, depending on the sector in which technological improvements occur. However, they conclude that developed countries may benefit from engaging in trade with less developed countries by adopting policies aimed at enhancing their competitiveness.

Recent contributions have emphasized the importance of specific dimensions that have been neglected in traditional trade models. Using a Melitz (2003) framework, Demidova (2008) investigates the role of a "technological potential" effect in trade, which consists in the distribution of productivities that firms in each country draw from, and the impact of this on competitiveness in the market. Demidova shows that if countries have different productivity distributions in terms of hazard rate stochastic dominance (HRSD) and in absence of specialization, then productivity improvements in one country raise welfare there but reduce that of its trading partner. Using a model featuring inter-industry trade, intra-industry trade and firm heterogeneity, Hsieh and Ossa (2011) capture productivity growth externalities through changes in the gains from comparative advantage (terms-of-trade effects), and through changes in the gains from increased variety and increased industry productivity (home market effects).

A promising empirical literature has tested some of the theoretical predictions, focusing mainly on those countries which have shown particularly high productivity growth rates over the last years (e.g. China). Bitzer et al (2008) test empirically the implications of Samuelson's paper, for a panel of 17 OECD and developing countries and the period 1973-2000. They show that knowledge spillovers through exports or FDI, from the home country to less advanced countries, have a negative impact on output in the home country. They also find that this negative effect is particularly strong when knowledge transfer occurs towards China. Hsieh and Ossa (2011) estimate China's productivity growth at the industry level, and quantify the welfare effects for China and the rest of the world induced by an increase in China's productivity. They find that only 3.0% of the worldwide gains of China's productivity growth spill over to other countries. However, differences across countries are quite pronounced: some countries experience positive welfare effects (e.g. Japan and United States), whereas others experience negative effects (e.g. Russia and France). Using a Ricardian-Heckscher-Ohlin model, di Giovanni et al (2011) assess the welfare impact of China's trade integration and technological change for a group of 75 countries. They estimate that the gain of adding China to world trade is about 0.1%, although welfare effects substantially differ across countries. They find that some countries, and especially in East Asia, experience large positive welfare gains (e.g. Malaysia and Taiwan), whereas for other countries, mainly in Latin America, the welfare effects are negative (e.g. Honduras and El Salvador). Finally, they simulate two alternative scenarios, assuming first that the productivity growth rate in each sector is the same (balanced growth scenario), and then that the sectors in which China has a greater comparative disadvantage grow faster (unbalanced growth scenario). In contrast to Samuelson (2004)'s conjecture, their model predicts that in the unbalanced growth scenario mean gains are 40 times larger than in the balanced growth scenario. Furthermore, they show that China gains much more in the balanced growth scenario relative to the unbalanced growth scenario. Using a multi-sector Ricardian model and industry-level data of 75 countries and 5 decades, Levchenko and Zhang (2011) estimate productivity rates of growth at the sector level. Their findings are that comparative advantage has become weaker and global welfare lower relative to 1960s (welfare is 1.9% lower for the median country). They also find that changes in developing countries' comparative advantage have virtually no impact on the OECD, with a median welfare impact of zero and a very narrow range of variation across countries (from -0.2% to +0.6%).

2.4 Productivity and absorptive capacity

Economic theory predicts that developing countries can realize large productivity gains by adopting advanced technology. However, technology diffusion is not automatic and requires the receiving country to have the capacity to absorb and adopt foreign technology (Abramovitz, 1986; Acemoglu et al, 2006; Gerschenkron, 1962). Narula and Marin (2003) define absorptive capacity as "the ability to internalize knowledge created by others and modifying it to fit their own specific applications, processes, and routines" (Narula and Marin (2003), pp. 23). A rich set of studies has focused on the determinants of absorptive capacity and on its relative importance in explaining productivity and income differences across countries. A strand of this literature has used a two-stage approach to investigate the determinants of absorptive capacity. The two-stage approach consists in estimating total factor productivity (TFP) as a residual of a parameterized production function, and then in regressing it against a number of factors which are assumed to affect productivity. In this literature, the idea of absorptive capacity is linked to the concept of distance to frontier. The rationale behind this concept is that the further a country lies behind the technological frontier, the greater is its potential to increase productivity. Using a panel of 83 developed and developing countries and five time spans over the period 1960-1989, Miller and Upadhyay (2000) find that trade openness, measured by the ratio of exports to gross domestic product, and trade orientation, as measured by deviations from purchasing power parity, have a significant, robust and positive effect on total factor productivity. They also find that human capital generally contributes positively to total factor productivity, even though in poor countries human capital has a negative effect until openness exceeds a threshold, where the effect becomes positive. Kneller (2005) explores whether the effect of foreign R&D on domestic productivity changes with respect to the level of absorptive capacity and the physical distance from the source of new ideas, in a group of 12 OECD countries for 1972-92. He finds that absorptive capacity is quantitatively more important in explaining differences in the level of productivity across countries, whereas physical distance plays a major role only at the beginning of the time period and in sectors where trade is local and contains high-technology. Mastromarco and Zago (2009) find evidence of a significant and positive effect of exports, technological investments and spillovers, public infrastructure and banking efficiency on TFP growth for a sample of Italian manufacturing firms in 1998-2003. Using two groups of 23 OECD countries and 32 developing countries over the period 1970 to 2004, Islam (2009) investigates whether differences in research intensity (measured as the ratio between R&D activity and product variety) and absorptive capacity (measured by the interaction between R&D intensity and the distance to frontier, and the interaction between human capital and distance to frontier) explain cross-country differences in productivity growth. He finds that both research intensity and absorptive capacity significantly contribute to explain differences in productivity growth. In a recent paper, Islam (2010) explores the role of human capital composition in a panel of 87 low, medium and high income countries over the period 1970-2004. Results show that skilled human capital is more relevant in explain productivity growth for high and medium income countries, with the growth-enhancing effect becoming stronger as the distance to the technology frontier decreases. Unskilled human capital is found to play a major role for low income countries and for smaller distances to the frontier. Matured workers with tertiary education are more growth enhancing for high and medium income countries, whereas young workers with secondary education contribute more to productivity growth in low income countries.

Although popular, the two-stage approach has been found to suffer from a number of statistical flaws. Gary Koop and Steel (2000); Koop et al (1999) point out that in the first stage the efficiency terms are assumed to be identically and independently distributed, while in the second stage they are a function of variables which might directly enter the production function specification or be correlated with explanatory variables, thereby contradicting the assumption of identically distributed inefficiency terms. Stochastic frontier analysis (SFA) proposed by Aigner et al (1977) and Meeusen and van den Broeck (1977), has been considered more accurate and statistically correct for the study of the determinants of absorptive capacity, as shown by Battese and Coelli (1995). SFA assumes technical inefficiency and random errors of production to be independently but not identically distributed, and simultaneously estimates the stochastic frontier and the inefficiency model. Furthermore, SFA allows to distinguish between technical progress, technical efficiency, and a stochastic component of TFP. In a SFA context, the concept of absorptive capacity is related to that of production frontier, which is the maximum output that can be produced starting from any given input vector (i.e. the upper boundary of the production possibilities set). Using SFA, Kneller and Stevens (2006) study differences in the level of productivity across a group of 12 OECD countries, for nine manufacturing industries, and over the period 1973-91. They find that an increase in human capital reduces technical inefficiency, whereas domestic R&D has only an insignificant effect. Using a panel of 57 developing countries for the period 1970-98, Michael Henry and Milner (2009) find that trade and trade policy significantly and positively affect efficiency. They also find evidence for a significant effect on efficiency of a set of geographical characteristics (e.g. whether a country is tropical or not). However, they do not find any significant effect of agriculture intensity (share of agriculture over GDP). Using a panel of 57 developing countries for the period 1960-2000, Mastromarco (2008) explores the role of FDI, human capital and imported capital goods as channels for increased efficiency. Her findings reveal that both FDI and human capital considerably increase efficiency, whereas imported capital goods have no significant effect. Using the same data, Mastromarco and Ghosh (2009) show that the effect of FDI, imported capital goods (imports of machinery and equipment), and imported R&D on technical efficiency crucially depend on the level of accumulated human capital. They also find that the impact of formal education is more relevant for imported R&D, whereas "learning by doing" is more important for technology transfer through FDI and imported capital. Mastromarco and Ghosh (2010) use SFA also for a panel of 24 OECD countries for the period 1993-2004 to investigate the impact of three forms of cross-border activities: international trade, FDI and migration. They find that both international trade and FDI are important channels for improving efficiency, with the effect being stronger for high levels of human capital. Conversely, they find that migration reduces efficiency in countries with a low stock of human capital, whereas enhances it in countries with a high accumulation of human capital.

2.5 Conclusion

This chapter has covered the literature on international technology transfer via trade and via FDI, on the welfare effects generated by productivity improvements in emerging countries, and on the determinants of absorptive capacity in both developing and developed countries. This concluding section highlights some of the main results. New growth theory and product cycle models emphasize the role of trade as an important vehicle of knowledge diffusion, with important implications especially for developing countries. Empirical studies based on industry-level data show that technology transfer via trade occurs mainly through capital and high-technology goods, and that foreign knowledge spillovers affect domestic productivity and growth. The literature identifies three channels of knowledge spillovers through FDI: imitation or reverse engineering, labor turnover, and linkages between multinationals and their suppliers or buyers. While a rich body of studies provides evidence for technology transfer through vertical linkages, less and mixed evidence links FDI with imitation and labor turnover. Traditional trade models predict that productivity improvements in the South may hamper the North when they occur in sectors where the North has a comparative advantage, or when they reduce the wage gap. However, recent contributions based on new trade models have emphasized the importance of new dimensions (e.g. the technological potential effect), providing more realistic frameworks to answer this question. The empirical literature has delivered mixed evidence, showing that welfare effects of productivity improvements in emerging economies vary a lot across countries. Finally, absorptive capacity is quantitatively important in explaining differences in the level of productivity across countries. Among other factors, human capital and trade openness play a significant role in enhancing a country's ability to absorb technology, both in developed and developing countries.

Chapter 3

Trade, Productivity Improvements and Welfare: An Endogenous Market Structure Framework

3.1 Introduction

Recently, a new line of research revived a classic debate in international economics about the welfare effects developed countries experience after productivity improvements occur in their backward trading partners. This interest is driven by a series of recent developments in the world economy, such as a decline in trade costs and barriers, and an increase in market accessibility and in the spread of technology from the North to the South. Some of these studies rely on traditional trade models based on comparative advantage. Using a Ricardo-Mill framework, Samuelson (2004) simulates the effect on welfare in the US of a technology improvement in China, induced by imitation in the good in which the US previously had a comparative advantage. Results show that an expansion in China's labor productivity harms the US by causing a permanent loss in per capita real income. Jones and Ruffin (2008) show that under certain demand conditions and for a given range of relative country size, an advanced country benefits from an uncompensated technology transfer to a less advanced country. Paradoxically, this happens in the sector in which the advanced country has its greater comparative advantage. A number of empirical studies based on industry-level data have tested the predictions of such models. Bitzer et al (2008) test the predictions of Samuelson's paper for a group of OECD and developing countries, finding that knowledge spillovers from advanced to less advanced countries have a negative impact on output in the advanced countries. They also find that this negative effect is especially strong when knowledge transfer occurs towards China. Using a Ricardian-Heckscher-Ohlin model, di Giovanni et al (2011) find that the welfare effects generated by a productivity improvement in China substantially change across regions: most Asian countries (e.g. Malaysia and Taiwan) experience large positive welfare effects, whereas for many Latin American countries (e.g. Honduras and El Salvador) the welfare effects are negative. Finally, Levchenko and Zhang (2011) find that changes in developing countries' comparative advantage have virtually no impact on OECD countries, with a median welfare impact of zero and a very narrow range of variation across countries (from -0.2% to +0.6%). Other contributions have emphasized the importance of specific dimensions that have been neglected in traditional trade models. In a recent paper, Demidova (2008) highlights the role of "technological potential" in trade, which consists in the distribution of productivities that firms in each country draw from and the impact of this on competitiveness in the market. Demidova shows that if countries have different productivity distributions in terms of hazard rate stochastic dominance (HRSD) and in absence of specialization, then productivity improvements in one country raise welfare there but reduce that of its trading partner. Using a model featuring inter-industry trade, intra-industry trade and firm heterogeneity, Hsieh and Ossa (2011) capture productivity growth externalities through changes in the gains from comparative advantage (terms-of-trade effects), and through changes in the gains from increased variety and increased industry productivity (home market effects). They estimate China's productivity growth at the industry level, and quantify the welfare effects for China and the rest of the world generated by an increase in China's productivity. They find that only 3% of the worldwide gains of China's productivity growth spills over to other countries. Their analysis also reveals that some countries experience positive welfare effects (e.g. Japan and United States), whereas others experience negative effects (e.g. Russia and France).

This paper fits into this new line of research, proposing a novel framework to answer this classical question. I use an industry model with heterogeneous firms based on that of Impullitti and Licandro (2010), where trade liberalization has pro-competitive effects. Impullitti and Licandro use an oligopolistic framework to obtain an endogenous market structure, following a class of static trade models where the response of the market structure is driven by the strategic interaction of firms (Brander and Krugman, 1983; Neary, 2002, 2009; Venables, 1985). This is a more general framework than that proposed by Melitz and Ottaviano (2008), where the endogenous market structure is obtained by combining a particular form of preferences with a monopolistic competition framework. In Impullitti and Licandro, when an economy moves from autarky to trade, the number of firms operating in each local market doubles, thereby increasing product market competition. In this setting, trade liberalization generates two effects: a reduction in markups with a decrease in the inefficiency of oligopolistic markets, followed by an increase in firm's incentive to innovate (*direct competition effect*), and a selection effect (*selection effect of competition*), since the least productive firms exit the market as result of a greater product market competition. In my paper, there are two main differences with respect to Impullitti and Licandro (2010). First, I use a static version of their model, without innovation and growth. Second, I consider a model with only two countries that differ in their "technological potential". I am using the same definition of "technological potential" as introduced by Demidova, i.e. the productivity distribution firms in each country draw from. In particular, I assume that one of the two countries has a higher technological potential (better productivity distribution in terms of HRSD) than the other. This implies that firms in the country with higher technological potential have a better chance of drawing a higher level of productivity than firms in the other country, for any given level of productivity. Using a static model with endogenous market structure and only two countries having different technology allows me to analyse in a tractable framework the welfare effects of productivity improvements in backward countries, where new interesting mechanisms are at work. Although I use the same definition of "technological potential" as introduced by Demidova, my model is substantially different. Demidova uses a monopolistic competition model with heterogeneous firms based on Melitz (2003) to identify a technological potential effect. In this paper, I explore instead the properties of a new model where trade liberalization has also pro-competitive effects, and where welfare is affected through different channels.

The paper starts with the description of the closed economy case. I show that in equilibrium a better technology leads to a higher productivity cutoff level and higher average productivity. By means of a simple calibration based on firm-level and aggregate statistics of the US economy, I also show that welfare is lower in the backward country and decreasing in the technology gap. The second step consists in deriving the open economy equilibrium in a world with two countries having different technologies. I assume that one of the two countries (home) has a higher technological potential (better productivity distribution) than the other (foreign). The two countries engage in costly trade (iceberg type) with no entry costs in the export market. By means of a numerical simulation, I find that the advanced country has a higher productivity cutoff level, higher average productivity and higher welfare. Productivity improvements in the backward country generate a selection effect and raise welfare everywhere. However, both the selection effect and the positive welfare effect are stronger in the laggard country than in the leading country. Finally, I simulate trade liberalization scenarios for a given productivity gap, finding that a reduction in trade costs leads to more selection and increases consumers' welfare in both the leading and the laggard country.

3.2 The model

3.2.1 Preferences

In the economy there is a continuum of consumers of measure one. Two types of goods are produced: a homogeneous good, taken as the numeraire, and a composite good produced with a continuum of varieties. Each consumer inelastically supplies one unit of labor and has the following utility function:

$$U = lnX + \beta lnY \tag{3.1}$$

Y is the homogeneous good produced under constant returns to scale: a unit of labor can be transformed one-to-one into the homogeneous good.

The differentiated good X is produced with a continuum of varieties of endogenous mass $M \in [0, 1]$ according to

$$X = (\int_0^M x_j^\alpha dj)^{\frac{1}{\alpha}} \tag{3.2}$$

where $\frac{1}{(1-\alpha)}$ is the elasticity of substitution across varieties, with $\alpha \in (0, 1)$

Each variety is produced by n identical firms according to the following production technology (I omit index j and identify the variety with its productivity)

$$\tilde{z}^{-1}q + \lambda = y \tag{3.3}$$

where y represent inputs, $\lambda > 0$ is a fixed production cost and $\tilde{z}^{-1}q$ is the variable cost of the firm producing variety j with productivity $\tilde{z}$.

The representative household maximizes utility subject to its budget constraint. The corresponding first order conditions are:

$$Y = \beta E \tag{3.4}$$

$$p_j = \frac{E}{X^\alpha} x_j^{\alpha-1} \tag{3.5}$$

where p is the price of variety j and $E = \int_0^M p_j x_j dj$ is the total household expenditure on the composite good X. Log preferences imply the total expenditure on the homogenous good to be β times total spending in the composite good. Equation (3.5) corresponds to the inverse demand function of variety $j \in [0, 1]$.

3.2.2 Production

Firms producing the same variety compete à la Cournot and maximize their profits, taking as given the production of their competitors $\hat{x}$. Firm *m* producing variety *j* solves the following problem:

$$\pi_{mj} = [(p_{mj} - \tilde{z}_{mj}^{-1}) q_{mj} - \lambda] \tag{3.6}$$

st.

$$p_{mj} = \frac{E}{X^\alpha} x_{mj}^{\alpha-1}$$

$$x = \hat{x} + q$$

The corresponding first order condition is (let us suppress indexes m and j to simplify notation):

$$\tilde{z}^{-1} = \theta \frac{E}{X^\alpha} x^{\alpha-1} \tag{3.7}$$

where $\theta \equiv \frac{(n-1+\alpha)}{n}$ is the inverse of the markup that firms charged over the marginal cost. Firms producing the same variety are symmetric, implying $x = nq$. The demand for variable inputs is obtained substituting (3.7) into (3.2) (See Appendix 3.6 for the derivations):

$$\tilde{z}^{-1} q = \theta e \frac{z}{\bar{z}} \tag{3.8}$$

where

$$\bar{z} = \frac{1}{M}\int_{0}^{M} z dj \tag{3.9}$$

is the average productivity, $e = E/(nM)$ is expenditure per firm and $z = \tilde{z}^{\frac{\alpha}{1-\alpha}}$.

3.2.3 Equilibrium in a closed economy

Profits can be written as a linear function of the relative productivity:

$$\pi(\frac{z}{\bar{z}}) = (1-\theta)e\frac{z}{\bar{z}} - \lambda \tag{3.10}$$

Let z^*be the cutoff productivity making firms' profits equal to zero. Solving for e , I derive the exit condition (EC) which denotes a negative relation between e and z^*:

$$e = \lambda\frac{1}{1-\theta}\frac{\bar{z}}{z^*} \tag{3.11}$$

Let us assume that there is a mass of unit measure of potential varieties of which $M \in [0, 1]$ are operative. Non operative varieties draw their productivities from a common distribution $\Gamma(z)$, which is assumed to be continuous in (z_{min}, ∞), with $0 \leq z_{min} \leq \infty$. Since any entering firm drawing a level of productivity below z^* will immediately exit, the equilibrium density distribution $\mu(z)$ is given by:

$$\mu(z) = \begin{cases} \frac{f(z)}{(1-\Gamma(z^*))} & if z \geq z^* \\ 0 & otherwise \end{cases}$$

The average productivity can now be written as a function of the productivity cutoff z^*:

$$\bar{z}(z^*) = \frac{1}{1-\Gamma(z^*)}\int_{z^*}^{\infty} zf(z)dz \tag{3.12}$$

Irrespective of their productivity, varieties exit the market at rate δ. In a stationary equilibrium, in any period, the mass of new successful entrants should exactly replace the firms who face the bad shock and exit, hence:

$$(1 - M)(1 - \Gamma(z^*)) = \delta M \tag{3.13}$$

From (3.13) the mass of operative varieties is:

$$M(z^*) = \frac{1 - \Gamma(z^*)}{1 + \delta - \Gamma(z^*)} \tag{3.14}$$

The market clearing condition (MC) for the homogeneous good is:

$$n \int_0^M y_j dj + Y = n \int_0^M (\tilde{z}^{-1} q + \lambda) dj + \beta E = 1 \tag{3.15}$$

After changing the integration domain from sector $j \in [0, 1]$ to productivities $z \in [z*, \infty]$, the market clearing condition becomes:

$$\int_{z^*}^{\infty} [\theta e \frac{z}{\bar{z}} + \lambda] \mu(z) dz + \beta e = \frac{1}{nM} \tag{3.16}$$

Since $\int_{z^*}^{\infty} \mu(z) dz = \int_{z^*}^{\infty} \frac{z}{\bar{z}} \mu(z) dz = 1$, after integrating over all sectors I obtain:

$$e = \frac{\frac{1}{nM(z^*)} - \lambda}{(\theta + \beta)} \tag{3.17}$$

Equation (3.17) denotes a positive relation between e and z^*. Assumption (1) guarantees the existence of a stationary equilibrium.

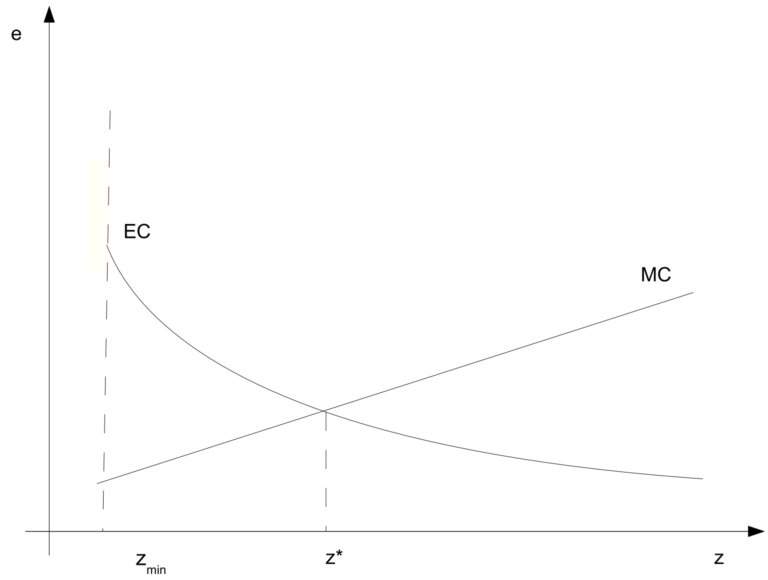
Assumption 1 *The entry distribution verifies, for all z,*

$$\frac{\bar{z}(z) - z}{\bar{z}(z)} \leq \frac{1 - \Gamma(z)}{z f(z)}$$

Assumption 1 makes $z^*/\bar{z}(z^*)$ increasing in z^* and therefore the (EC) curve decreasing in z^*.

Figure 5 provides a graphical representation of the equilibrium. An increase in the degree of competition (a reduction in the markup $1/\theta$), produced either by an increase in the substitutability parameter α or

Figure 5: Equilibrium in closed economy



in the number of firms n, shifts both the (EC) and the (MC) curves to the right. Consequently z^* increases, therefore reducing the number of varieties $M(z^*)$, whereas the effect on e is ambiguous. In fact, depending on the relative strengths of the shift of the two curves, e can increase or decrease.

Using (3.1), (3.2), (3.4), and (3.7), I derive the indirect utility function as a measure of consumers' welfare

$$U = ln(\theta E(M\bar{z})^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E) \tag{3.18}$$

with $\alpha \in (0, 1)$

Welfare in each country depends on the inverse of the markup θ, on the number of active varieties M, on the average productivity $\bar{z}$ and on the total expenditure in the composite good E.

3.2.4 The effect of a better productivity distribution

In this section, I analyse the effect of a better productivity distribution on the equilibrium, without making any specific distributional assumption. Two closed economies are compared, assuming that one of them (home) has a better technology than the other (foreign).

Assumption 2: *The productivity distribution in the home country, $\Gamma_H(z)$, dominates the productivity distribution in the foreign country, $\Gamma_F(z)$, in terms of hazard rate stochastic dominance (HRSD), $\Gamma_H(.) \succ_{hr} \Gamma_F(.)$, if for any given level of productivity z*

$$\frac{f_H(z)}{1-\Gamma_H(z)} < \frac{f_F(z)}{1-\Gamma_F(z)}$$

Assumption 2 implies that for any given level of productivity z, firms in the home country have a better chance of drawing a level of productivity above this level than firms in the foreign country.

Proposition 1 *Under Assumption 2, for any given level of z, $EC_H > EC_F$ and $MC_H < MC_F$, thereby implying $z^*_H > z^*_F$.*

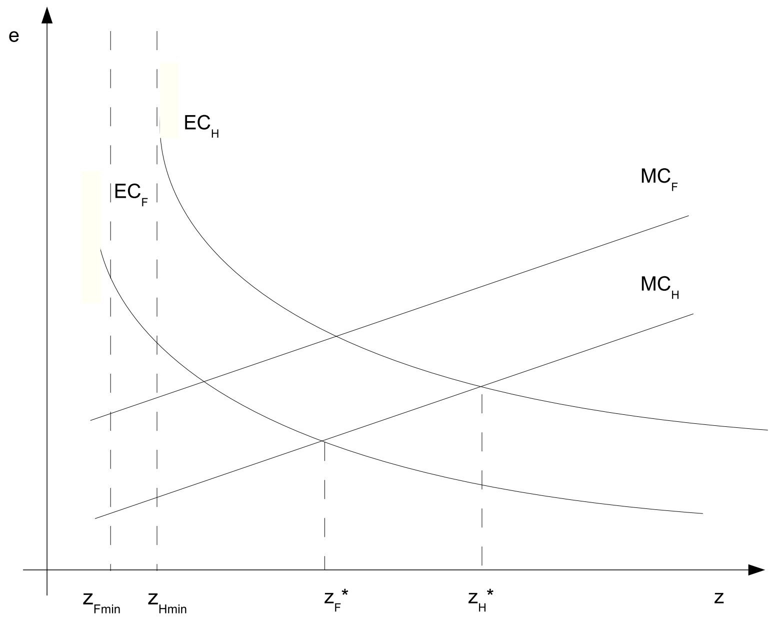
Proof See Appendix 3.6.

Figure 6 provides a graphical representation of the equilibrium with the home country having a higher technological potential than the foreign country. In Section 3.4, I show through a numerical calibration that welfare is higher in the home country. I also show that welfare in the foreign country falls as the productivity gap increases (see Figure 7). Intuitively, firms in the home country are on average more productive and, in absence of trade, they face the same markup than firms in the foreign country (See equation 3.18).

3.3 Open Economy

Consider a world economy with two countries that have the same preferences and endowments as described in the previous section, but with different technologies. The home country has a superior technology,

Figure 6: The effect of a better productivity distribution



modeled in the form of a better productivity distribution its firms draw from in terms of HRSD. Trade costs are symmetric and of the standard iceberg type: $\tau > 1$ units shipped result in 1 unit arriving. As in the baseline model of Impullitti and Licandro (2010), there are no entry costs in the export market, so that all firms operate both in the domestic and the foreign market

3.3.1 Equilibrium characterization

Assumption 2 implies that firms producing the same variety, but located in different countries, have different marginal costs. As a consequence, there is no perfect overlap between the varieties produced in the two economies, as in Impullitti and Licandro (2010), because firms in sector j in country i might decide, given their draw, to exit, while their rivals in the other country might stay and produce in the same sector. Firms in sector j in country i face two possible scenarios: (i) they might be the only ones producing variety j, therefore serving both the domestic and the foreign market; (ii) they might produce variety j in competition with firms located in the other country, sharing with them both the domestic and the foreign market.

First scenario: varity j is produced only in the home (foreign) country

Let us consider the case in which variety j is produced only by firms in the home country. Let q_{HH} and q_{HF} be the quantities of variety j produced for the domestic and the foreign markets respectively. Each firm in the home country solves a problem which leads to the following first order conditions[1]

$$[(\alpha-1)\frac{q_{HH}}{x_H}+1]p_H=\frac{1}{\tilde{z}_H} \tag{3.19}$$

$$[(\alpha-1)\frac{q_{HF}}{x_F}+1]p_F=\frac{\tau}{\tilde{z}_H} \tag{3.20}$$

Variables x_H and x_F represent the total output offered and $p_H = \frac{E_H}{X_H^\alpha}x_H^{\alpha-1}$ and $p_F = \frac{E_F}{X_F^\alpha}x_F^{\alpha-1}$ are prices of variety j in the domestic and in the foreign market respectively. Firms in the home country entirely satisfy both the domestic and the foreign demand, implying $x_H = nq_{HH}$ and $x_F = nq_{HF}$. The resulting demand for variable inputs is

$$\frac{q_{HH}+\tau q_{HF}}{z_H}=\psi e\frac{z_H}{\bar{z_H}} \tag{3.21}$$

where $\psi = \left[\frac{\alpha-1+n}{n}(1+\tau)\right]$ is the inverse of the average markup faced by a firm in the home country in both the domestic and the foreign market. Not surprisingly, the average markup corresponds to the markup faced by firms in the closed economy times $(1+\tau)$, which takes into account the transportation costs for the quantities sold into the foreign market. Profits of a firm in sector j in the home country are

$$\pi_H(\frac{z_H}{\bar{z}_H})=(1+\tau-\psi)e\frac{z_H}{\bar{z}_H}-\lambda \tag{3.22}$$

[1]Appendix 3.6 provides details of derivations.

The specular case is when variety j is produced only in the foreign country. In this case, profits of a firm in the foreign country producing variety j are

$$\pi_F(\frac{z_F}{\bar{z}_F}) = (1 + \tau - \psi)e\frac{z_F}{\bar{z}_F} - \lambda \tag{3.23}$$

Second scenario: variety j is produced in both countries

The second scenario occurs when variety j is produced in both countries. In this case, firms in sector j in country i share the market with their rivals in the other country, and their profits are a function of the relative productivity gap γ_j in that sector. The relative productivity gap is defined as

$$\gamma_j = \frac{z_{jF}}{z_{jH}}$$

$0 < \gamma_j < \infty$, $\gamma_j = \tilde{\gamma_j}^{\frac{\alpha}{1-\alpha}}$

with cumulative distribution $G(\gamma)$ and a density $g(\gamma)$ (I keep on omitting index j, however each variety is now associated with two levels of productivity, one in the home country and one in the foreign country). Let q_{HH} and q_{HF} be the quantities of variety j produced for the domestic and for the foreign market by firms in the home country, and q_{FF}, and q_{FH} the quantities produced for the domestic and the foreign market by firms in the foreign market.

A firm in the home country producing variety j solves a problem which leads to the following first order conditions[2]

$$[(\alpha - 1)\frac{q_{HH}}{x_H} + 1]p_H = \frac{1}{\tilde{z}_H} \tag{3.24}$$

$$[(\alpha - 1)\frac{q_{HF}}{x_F} + 1]p_F = \frac{\tau}{\tilde{z}_H} \tag{3.25}$$

the corresponding first order conditions for a firm in the foreign country are

[2] Appendix 3.6 provides details of derivations.

$$[(\alpha - 1)\frac{q_{FF}}{x_F} + 1]p_F = \frac{1}{\tilde{z}_F} \quad (3.26)$$

$$[(\alpha - 1)\frac{q_{FH}}{x_H} + 1]p_H = \frac{\tau}{\tilde{z}_F} \quad (3.27)$$

Using $\tilde{z}_F = \tilde{\gamma}\tilde{z}_H$ and the first order conditions, the domestic and the foreign markups can be expressed in both countries as a function of the relative technology gap $\tilde{\gamma}$

$$\theta_{HH} = \frac{\alpha - 1 + 2n}{n}(\frac{\tilde{\gamma}}{\tilde{\gamma} + \tau}) \quad (3.28)$$

$$\theta_{HF} = \frac{\alpha - 1 + 2n}{n}(\frac{\tilde{\gamma}\tau}{1 + \tilde{\gamma}\tau}) \quad (3.29)$$

$$\theta_{FF} = \frac{\alpha - 1 + 2n}{n}(\frac{1}{1 + \tilde{\gamma}\tau}) \quad (3.30)$$

$$\theta_{FH} = \frac{\alpha - 1 + 2n}{n}(\frac{\tau}{\tilde{\gamma} + \tau}) \quad (3.31)$$

Since firms in the home country and firms in the foreign country have different marginal costs, they face different markups both in the domestic and in the foreign market. Furthermore, as in Impullitti and Licandro (2010), because of trade costs, firms located in the same country face different markups for the domestic and the foreign market. For any given level of productivity gap, the following inequalities hold: $\theta_{HH} < \theta_{HF}$ and $\theta_{FF} < \theta_{FH}$.

The demands for variable inputs in the home country and in the foreign country are

$$\frac{q_{HH} + \tau q_{HF}}{z_H} = \chi_H e \frac{z}{\bar{z_H}} \quad (3.32)$$

$$\frac{q_{FF} + \tau q_{FH}}{z_F} = \chi_F e \frac{z}{\bar{z_F}} \quad (3.33)$$

where:

$$\chi_H = \left\{ \frac{\alpha-1+2n}{n} \frac{1}{(\alpha-1)} \frac{\tilde{\gamma}}{(\tilde{\gamma}+\tau)} \left[\frac{\tilde{\gamma}(\alpha-1+n)-\tau n}{\tilde{\gamma}+\tau} + \frac{\tilde{\gamma}\tau(\alpha-1+n)-n}{1+\tau\tilde{\gamma}} \tau \right] \right\}$$
$$\chi_F = \left\{ \frac{\alpha-1+2n}{n} \frac{1}{(\alpha-1)} \frac{1}{(1+\tau\tilde{\gamma})} \left[\frac{\alpha-1+n-\tau\tilde{\gamma}n}{1+\tau\tilde{\gamma}} + \frac{\alpha-1+n-n\tilde{\gamma}}{\tilde{\gamma}+\tau} \tau \right] \right\}$$

Differently from Impullitti and Licandro (2010), χ_H and χ_F do not coincide with the inverse of the average markups as, due to asymmetry, total supply in country i, $x_i = n(q_{ii} + q_{li})$, does not correspond to total quantity produced there, $Q_i = n(q_{ii} + q_{il})$, with $i \neq l$.

The inverse of the average markup faced by firms in the home country and in the foreign country is a weighted sum of the domestic and of the foreign markup, where the weights are given by the relative quantities produced for the domestic and for the foreign market respectively[3]

$$\theta_{\tau H} = \left[\frac{q_{HH}}{q_{HH} + q_{HF}} \frac{\alpha - 1 + 2n}{n} (\frac{\tilde{\gamma}}{\tilde{\gamma} + \tau}) + \frac{\tau q_{HF}}{q_{HH} + q_{HF}} \frac{\alpha - 1 + 2n}{n} (\frac{\tilde{\gamma}\tau}{1 + \tilde{\gamma}\tau}) \right] \tag{3.34}$$

$$\theta_{\tau F} = \left[\frac{q_{FF}}{q_{FF} + q_{FH}} \frac{\alpha - 1 + 2n}{n} (\frac{1}{1 + \tilde{\gamma}\tau}) + \frac{\tau q_{FH}}{q_{FF} + q_{FH}} \frac{\alpha - 1 + 2n}{n} (\frac{\tau}{\tilde{\gamma} + \tau}) \right] \tag{3.35}$$

Profits for a firm in the home country and for a firm in the foreign country are

$$\pi_H(\frac{z}{\bar{z}}) = (A - \chi_H) e \frac{z}{\bar{z}_H} - \lambda \tag{3.36}$$

$$\pi_F(\frac{z}{\bar{z}}) = (B - \chi_F) e \frac{z}{\bar{z}_F} - \lambda \tag{3.37}$$

where

$$A = \frac{1}{(\alpha-1)} \frac{1}{\tilde{\gamma}+\tau} \left[(1+\tau) \left((\alpha - 1 + n)\tilde{\gamma} - n \right) \right]$$
$$B = \frac{1}{(\alpha-1)} \frac{1}{1+\tau\tilde{\gamma}} \left[(1+\tau) \left((\alpha - 1 + n) - \tilde{\gamma} n \right) \right]$$

[3]When $\tilde{\gamma} = 1$, that is countries are symmetric, $\theta_{\tau H}$ and $\theta_{\tau F}$ collapse into $\theta_\tau = \frac{2n-1+\alpha}{n(1+\tau)^2(1-\alpha)}[\tau^2(1-n-\alpha) + n(2\tau - 1) + (1-\alpha)]$, the average markup in Impullitti and Licandro (2010).

The equilibrium conditions

Firms in the home country and in the foreign country face these two events with different probabilities. Therefore, the profit function of a firm in sector j in country i is a weighted sum of the profits obtained in these two events, where the weights are given by the probability that sector j is active, $1-\Gamma_l(z_l^*)$, or not active, $\Gamma_l(z_l^*)$, in the other country with $l \neq i$. Profits when sector j is active in both countries are also weighted by the density function of the productivity gap $g(\gamma)$

$$\pi_H(\tfrac{z_H}{\bar{z}_H}) = \left[e\tfrac{z_H}{\bar{z}_H}(1+\tau-\psi)-\lambda\right]\Gamma_F(z_F^*) + \\ + \left[e\tfrac{z_H}{\bar{z}_H}\int_o^\infty (A-\chi_H)g(\gamma)d\gamma - \lambda\right](1-\Gamma_F(z_F^*)) \tag{3.38}$$

$$\pi_F(\tfrac{z_F}{\bar{z}_F}) = \left[e\tfrac{z_F}{\bar{z}_F}(1+\tau-\psi)-\lambda\right]\Gamma_H(z_H^*) + \\ + \left[e\tfrac{z_F}{\bar{z}_F}\int_o^\infty (B-\chi_F)g(\gamma)d\gamma - \lambda\right](1-\Gamma_H(z_H^*)) \tag{3.39}$$

Assumption 2 implies $\int_o^\infty (A-\chi_H)g(\gamma)d\gamma > \int_o^\infty (B-\chi_F)g(\gamma)d\gamma$ as for every z the home country has a better chance of drawing a higher level of productivity. As in the closed economy, we derive the productivity cutoff in the two countries by the exit conditions which are

$$e_H = \frac{\lambda}{[(1+\tau-\psi)]\,\Gamma_F(z_F^*) + \left[\int_o^\infty (A-\chi_H)g(\gamma)d\gamma\right](1-\Gamma_F(z_F^*))}\frac{\bar{z}_H}{z_H^*} \tag{3.40}$$

$$e_F = \frac{\lambda}{[(1+\tau-\psi)]\,\Gamma_H(z_H^*) + \left[\int_o^\infty (B-\chi_F)g(\gamma)d\gamma\right](1-\Gamma_H(z_H^*))}\frac{\bar{z}_F}{z_F^*} \tag{3.41}$$

The market clearing conditions become

$$e_H = \frac{\frac{1}{M(z_H^*)} - \lambda}{\psi\Gamma_F(z_F^*) + \left[\int_o^\infty \chi_H g(\gamma)d\gamma\right](1 - \Gamma_F(z_F^*)) + \beta} \tag{3.42}$$

$$e_F = \frac{\frac{1}{M(z_F^*)} - \lambda}{\psi\Gamma_H(z_H^*) + \left[\int_o^\infty \chi_F g(\gamma)d\gamma\right](1 - \Gamma_H(z_H^*)) + \beta} \tag{3.43}$$

The equilibrium allocations for the home country and the foreign country are obtained by solving this system of four equations (3.40), (3.41), (3.42), and (3.43) and four unkowns: $z_H^*, z_F^*, e_H^*, e_F^*$. Since the equilibrium system is fairly complex, its properties are explored numerically in Section (3.4)

In the open economy, welfare for consumers in the home country and in the foreign country becomes

$$W_H = [ln(E_H\theta(M_H\bar{z}_H)^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E_H)][\Gamma_F(z^*)]+$$

$$+ [ln(E_H(\int\limits_0^\infty \Phi_H g(\gamma)d\gamma)(M\bar{z})^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E_H)][1 - \Gamma_F(z^*)] \tag{3.44}$$

and

$$W_F = [ln(E_F\theta(M_F\bar{z}_F)^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E_F)][\Gamma_H(z^*)]+]$$

$$+ [ln(E_F(\int\limits_0^\infty \Phi_F g(\gamma)d\gamma)(M\bar{z})^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E_F)][1 - \Gamma_H(z^*) \tag{3.45}$$

where

$\Phi_H = [\frac{\alpha-1+2n}{n}]\frac{\tilde{\gamma_i}}{\tilde{\gamma_i}+\tau}\frac{1}{1+\tilde{\gamma_i}}$
$\Phi_F = [\frac{\alpha-1+2n}{n}]\frac{\tilde{\gamma_i}}{1+\tilde{\gamma_i}\tau}\frac{1}{1+\tilde{\gamma_i}}$

$\theta_{HH} = \theta_{FF} = \theta = \frac{\alpha - 1 + n}{n}$

Welfare in the open economy in each country depends not only on domestic average productivity and on the number of varieties produced by local firms, but also on the total aggregate productivity $\bar{z}$ of the two economies and on the total number of varieties M produced by domestic and foreign firms.

3.4 Quantitative analysis

In this section I calibrate the model to match aggregate and firm level statistics of the US economy. First, I study the welfare effects of a productivity improvement in the backward country both in the closed and in the open economy. Then, I simulate the selection effect induced by trade liberalization for a given level of technology gap, and I study how a reduction in trade costs affects welfare in the two economies. I assume that in both countries the entry distribution is Pareto. The choice of this specific productivity distribution is consistent with the empirical findings on firm size distribution (e.g. Axtell (2001) and Luttmer (2007)). In this section, I relax the assumption of HRSD to the usual (first order) stochastic dominance (USD).[4] This implies that in the two countries, the productivity distributions have a common shape parameter $k_H = k_F = k$ but different scale $z_H min \geq z_F min$. Using the fact that γ is defined by the ratio of two Pareto independent random variables, I can compute $g(\gamma)$ applying formula (4) in M. Masoom Ali and Woo (2010).[5]

I calibrate nine parameters: α, τ, δ, β, λ, n, k, $z_H min$, $z_F min$. For the trade costs, I take the sum of tariff (5%) and non-tariff (8%) barriers for industrialized countries summarized by Anderson and van Wincoop (2004), and I set $\tau = 1.13$. Following Impullitti and Licandro (2010), I set $n = 6$ and $\alpha = 0.309$ getting an elasticity of substitution across varieties of 1.44, which is in the range of the estimates provided by the

[4]Note that HRSD implies USD, but the reverse is not true.

[5]Formula (4) in M. Masoom Ali and Woo (2010) is valid for $\gamma > z_F/z_H$ .When $\gamma < z_F/z_H$ we use a transformation of γ, that is $\rho = 1/\gamma$.

Table 2: Summary of calibration

Parameter	Value	Moment	Source
α	0.309	Elasticity of sub/markup	Ruhl (2008)
τ	1.13	Trade cost	Anderson and van Wincoop (2004)
δ	0.09	Enterprise death rate	US Census (2004)
β	0.5	Share non differentiated	Rauch (1999)
λ	1.507	Aver.firm size	Axtell (2001)
n	6	Elasticity of sub/markup	Basu and Fernald (1994)
k	3	Std. firm productivity	Demidova (2008)
$z_{\mathrm{H}}min$	0.1	Min productivity Home	free
$z_{\mathrm{F}}min$	0.1- 0.01	Min productivity Foreign	free

international business cycle literature (e.g. Heathcote and Perri (2002) and Ruhl (2008)). Impullitti and Licandro set $1/\theta_\tau = 1.13$ to match a 13% markup, which is in the range of estimation of Basu and Fernald (1994). Then, setting $n = 6$ they obtain $\alpha = 0.309$. I use the value obtained by Impullitti and Licandro also for the fixed operating costs $\lambda = 1.507$.[6]

I set $\delta = 0.09$ to match the average enterprise death rate in manufacturing in the period 1998-2004 (Census 2004). Following Rauch (1999), who finds that the differentiated goods represent a percentage between 64.4 and 67.1 of total US manufactures, we set the share of differentiated goods $1 - \beta = 0.66$. Finally, I calibrate $k = 3$ and $z_H min = 0.1$, while letting $z_F min$ vary between 0.1 and 0.01. The calibration of the shape parameter as well as of the scale parameters does not affect qualitatively our results.

Table 2 summarizes the calibration. Table 3 shows the results of the calibration in the closed economy when the foreign country is exactly half as productive as the home country.

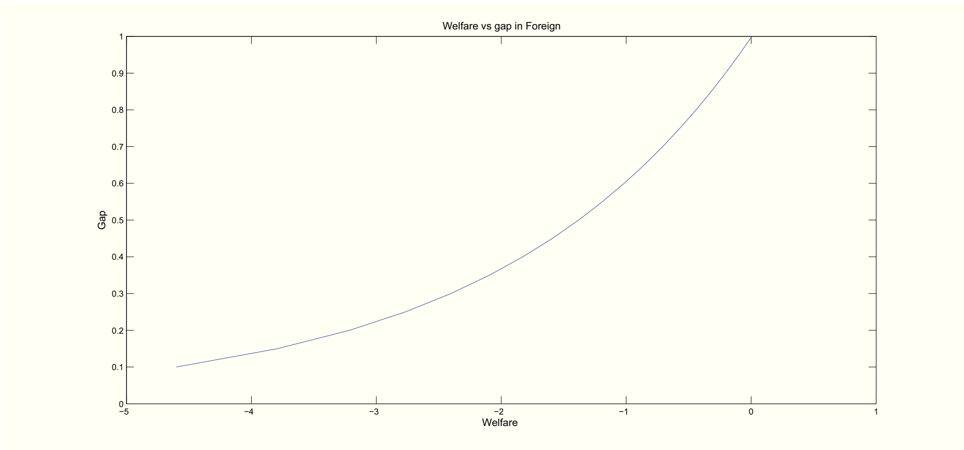
As expected, the home country has a higher productivity cutoff level and higher average productivity than the foreign country. Despite the technology gap, the home country and the foreign country produce the same number of varieties. This last finding depends on the specific form of the productivity distribution I am using, the Pareto distribution, and on the assumption of usual (first order) stochastic dominance. Consumers in the home country are better off than consumer in the

[6]Impullitti and Licandro use the average firm size of 21.8 workers found in Axtell (2001) for US firms in 1997 having at least one employee.

Table 3: Closed economy

Parameter	Foreign	Home
$z_i min$	0.05	0.1
z_i^*	0.3418	0.6837
W_i	-1.3811	0.0054
$\bar{z}_i$	0.5127	1.0255
M_i	0.0336	0.0336
$1/\theta$	1.1250	1.1250

Figure 7: Welfare in closed economy



foreign country, as firms in the advanced country are on average more productive (see Equation 3.18). Figure 7 shows a negative relation between welfare and the productivity gap in the foreign country: in the closed economy, productivity improvements in the backward country render its firms more productive and raise the welfare of its consumers.[7]

Table 4 shows the results of the calibration in open economy. In the open economy, the home country still has a higher productivity cutoff level and higher average productivity than the foreign country for any level of the productivity gap.

Productivity improvements in the backward country generate a selection effect (an increase in the productivity cutoff level and a fall in the number of varieties) in both countries (see Figure 8). However, the selection effect is stronger in the foreign country, where both the productivity cutoff level and the average productivity dramatically

[7]The technology gap is defined as $\gamma = \frac{Z_{Fmin}}{Z_{Hmin}}$.

Table 4: Open economy ($z_H min = 0.1$)

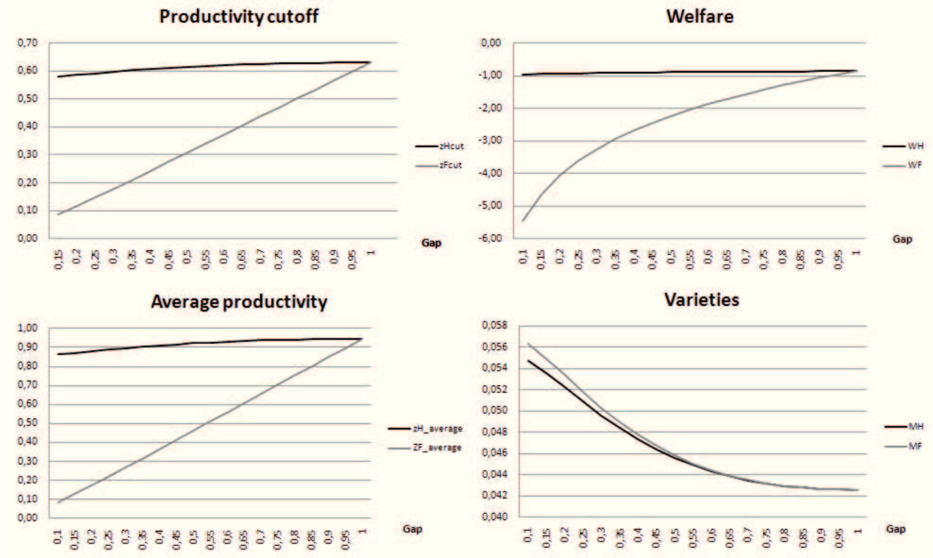
$z_F min$	z_H^*	z_F^*	M_H	M_F	$\bar{z}_H$	$\bar{z}_F$	W_H	W_F
0.01	0.5769	0.0571	0.0547	0.0563	0.8653	0.0856	-0.9636	-5.4494
0.02	0.5864	0.1164	0.0522	0.0534	0.8796	0.1746	-0.9436	-4.0631
0.03	0.5971	0.1782	0.0496	0.0503	0.8957	0.2673	-0.9256	-3.2525
0.04	0.6069	0.2420	0.0473	0.0478	0.9104	0.3630	-0.9101	-2.6780
0.05	0.6149	0.3070	0.0456	0.0458	0.9224	0.4604	-0.8972	-2.2333
0.06	0.6210	0.3723	0.0443	0.0444	0.9314	0.5585	-0.8867	-1.8708
0.07	0.6252	0.4375	0.0436	0.0435	0.9378	0.6563	-0.8783	-1.5652
0.08	0.6279	0.5023	0.0430	0.0430	0.9418	0.7534	-0.8717	-1.3012
0.09	0.6293	0.5664	0.0427	0.0427	0.9439	0.8496	-0.8663	-1.0692
0.1	0.6297	0.6297	0.0426	0.0426	0.9446	0.9446	-0.8621	-0.8621

rise. The interpretation of this result is that when the backward country faces the productivity improvement, firms there have a better chance of receiving a high productivity draw. Therefore, firms with a low productivity which before were able to survive, exit, and the productivity cutoff rises. In the home country, instead, the selection effect is due to a more severe competition in the foreign market which forces the least productive firms to exit.

Consumers in the home country are better off than consumers in the foreign country for any level of the gap. Productivity improvements in the foreign country increase welfare in both countries, but considerably more in the backward country than in the advanced country. In both economies the positive effect on welfare is the sum of a direct effect of a reduction in the productivity gap (an increase in γ) and of an indirect effect of an increase in the average firm productivity. The sum of these two positive effects overcomes the negative effect on welfare generated by a reduction in the number of varieties (see Equations 3.44 and 3.45). Furthermore, the welfare effect is much stronger in the backward country as the average productivity there grows considerably more than the average productivity in the advanced country.

Part of my results are in line with those of Demidova (2008). She finds that the country with greater technological potential (stochastically better productivity distribution) has higher welfare per worker than the laggard country. However, she obtains partly different predictions on the welfare effects generated by productivity improvements in the

Figure 8: Technology catch up



backward country. Demidova shows that productivity improvements in the backward country raise the domestic productivity cutoff level there, while reducing it in the advanced country.[8] As welfare in each country is an increasing function of the domestic cutoff, consumers in the laggard country gain, whereas consumers in the leading country loose.[9]

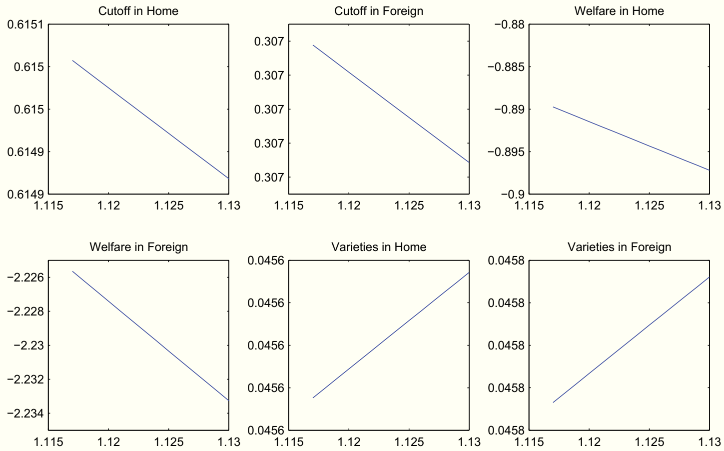
The difference in the effect that productivity improvements in the backward country generate on the productivity cutoff level and on welfare in the advanced country crucially depends on the features of the models we are using.

Demidova uses a Melitz (2003) framework where the domestic and the export cutoff are derived through a *free entry condition*. In her model, productivity improvements in the backward country lower the present discount value of the expected profits of firms in the advanced country. Thus, in the advanced country fewer firms enter the market and the domestic cutoff level, as well as welfare, falls. (See Demidova (2008), pp. 1454). In my model the productivity cutoff is derived through an

[8] In the advanced country the export cutoff rises, whereas in the backward country falls (See Demidova (2008) pp. 1454.

[9] Welfare per worker in Demidova (2008) is determined by the indirect utility function $W_i = (1-\beta)^{1-\beta}\beta^{\beta}\left(\frac{\beta L}{\sigma f}\right)^{\frac{\beta}{(\sigma-1)}}\left(\rho\varphi_i^*\right)^{\beta}$, where φ_i^* is the productivity cutoff for domestic producers there.

Figure 9: Trade liberalization for $\gamma = 0.5$



exit condition. Here, productivity improvements in the backward country force the least productive firms in the advanced country to exit because of increased competition in the foreign market. As the least productive firms exit, the average productivity increases generating a positive effect on welfare. In my model, welfare is also affected directly by variations in the productivity gap (γ): in both countries, as the gap decreases (γ increases), consumers are better off.

Figure 9 shows the effects of a reduction in τ from its benchmark value of 1.13 for a given level of productivity gap ($\gamma = 0.5$). In both countries, trade liberalization generates a selection effect, thereby increasing the productivity cutoff level and lowering the number of varieties as in the baseline model of Impullitti and Licandro (2010). Finally, in both economies, a reduction in trade costs has a direct and an indirect (through increased average firm productivity) positive effect on welfare.

3.5 Conclusion

This paper uses a two-country model with endogenous market structure to investigate the welfare effects that productivity improvements in emerging countries generate in their developed trading partners. To my knowledge, this is the first work using an endogenous market structure framework to answer this classical question. The response of the market structure to trade liberalization (pro-competitive effect of trade) is driven by the strategic interaction of firms competing à la Cournot. Firms in the leading country draw from a stochastically better productivity distribution, thereby having a better change of receiving higher levels of productivity than firms in the laggard country. Calibrated to match firm-level and aggregate statistics of the US economy, the model predicts that the developed country has a greater productivity cutoff level, greater average productivity and greater welfare in both closed and open economy. Productivity improvements in the backward country generate more selection and positive welfare effects in both countries, with both effects being stronger in the backward country. Finally, trade liberalization, for a given level of the technology gap, leads to more selection and increases welfare everywhere. There are two general directions to extend the work presented in this paper. First, assuming differences in preferences (e.g. assuming a different elasticity of substitution across varieties in the two countries) would be more realistic in a world where countries differ in technology. Second, it would be interesting to see whether the basic results still hold in a richer environment, where only the most productive firms serve the foreign market (e.g. with fixed export costs), and where the response of the market structure to trade liberalization endogenously determines the number of firms in each industry (e.g. with an entry condition).

3.6 Appendix

3.6.1 Derivation of equation (3.8)

Equation (3.7) can be written as $x_j = \left[\tilde{z}\frac{\theta E}{X^\alpha}\right]^{\frac{1}{1-\alpha}}$. Substituting it into (3.2) yields

$$X^\alpha = \left(\int_0^M \tilde{z}^{\frac{1}{1-\alpha}} dj\right)^{1-\alpha} (\theta E)^\alpha$$

Combining this with the equation of x_j, I obtain

$$x = \frac{\theta E \tilde{z}^{\frac{1}{1-\alpha}}}{\left[\int_0^M \tilde{z}^{\frac{\alpha}{1-\alpha}} dj\right]^{1-\alpha}}$$

Now, substituting this into (3.7), using $x = nq$ and $\tilde{z} = z^{\frac{1-\alpha}{\alpha}}$, I get

$$\tilde{z}^{-1}q = \frac{(\theta E)^{1-\alpha}q^\alpha}{(M\bar{z}n)^{1-\alpha}} = \theta e\frac{z}{\bar{z}}$$

where $e = \frac{E}{(nM)}$ and $\bar{z} \equiv \frac{1}{M}\int_0^M z_j dj$

3.6.2 Proof of proposition 1

HRSD allows to rank expectations over an increasing function above some cutoff level, that is if $y(x)$ is increasing in x and $\Gamma_H(.) \succ_{hr} \Gamma_F(.)$, then for any given level z, $E_H[y(x) \mid x > z] > E_F[y(x) \mid x > z]$.

Using (3.12), I can write the EC as

$$e = \lambda\frac{1}{1-\theta}\left[\frac{1}{1-\Gamma_i(z^*)}\int_{z^*}^{\infty} zf_i(z)dz\right]\frac{1}{z^*} = \lambda\frac{1}{1-\theta}E_i\left[\frac{z}{z^*} \mid z > z^*\right], i = H, F$$

thus, since $\Gamma_H(.) \succ_{hr} \Gamma_F(.)$, given that $\frac{z}{z*}$is increasing in z and $E_i[(\frac{z}{z*} \mid z > z*] > 1, i = H, F$, it follows that

$$E_H\left[\frac{z}{z^*} \mid z > z^*\right] > E_F\left[\frac{z}{z^*} \mid z > z^*\right]$$

Therefore, for any level of z, $EC_H > EC_F$.

The proof for the MC is based on (3.14). Since $\Gamma_H(z^*) < \Gamma_F(z^*)$, then $M_H(z^*) > M_F(z^*)$. Consequently, for any level of z, $MC_H < MC_F$.

3.6.3 Firm problem in the open economy

First scenario: Varity j is produced only in the home (foreign) country

Let us consider the case in which variety j is produced only in the home country. Each firm there solves the following problem

$$\Pi_H = \max_{\{q_{HH}, q_{HF}\}} \left[\left(p_H - \frac{1}{\tilde{z}_H} \right) q_{HH} + \left(p_F - \frac{\tau}{\tilde{z}_H} \right) q_{HF} - \lambda \right]$$

s.t.

$$p_H = \frac{E_H}{X_H^{\alpha}} x_H^{\alpha-1}$$

$$p_F = \frac{E_F}{X_F^{\alpha}} x_F^{\alpha-1}$$

$$x_H = n q_{HH}$$

$$x_F = n q_{HF}$$

The first order conditions are

$$\left[(\alpha - 1) \frac{q_{HH}}{x_H} + 1 \right] p_H = \frac{1}{\tilde{z}_H}$$

$$\left[(\alpha - 1) \frac{q_{HF}}{x_F} + 1 \right] p_F = \frac{\tau}{\tilde{z}_H}$$

Using $x_H = n q_{HH}$ and $x_F = n q_{HF}$, multiplying the above equations by q_{HH} and q_{HF} respectively, and summing up, I obtain:

$$\frac{q_{HH} + \tau q_{HF}}{\tilde{z_H}} = q_{HH}\left[\frac{\alpha - 1 + n}{n}\right] p_H + q_{HF}\left[\frac{\alpha - 1 + n}{n}\right] p_F \qquad (3.46)$$

Using $p_H = p_F\tau$, and $\left(\frac{x}{X}\right)^{\alpha} = \frac{z}{M\bar{z}}$, I derive the demand for variable inputs

$$\frac{q_{HH} + \tau q_{HF}}{\tilde{z}} = \psi e \frac{z_H}{\bar{z}_H} \qquad (3.47)$$

where $\psi = \left[\frac{\alpha-1+n}{n}\right](1+\tau)$ corresponds to the inverse of the markup.

Finally, using $p_H = p_F\tau$, the first order conditions and the demand for variable inputs, I derive firms' profits

$$\pi_H\left(\frac{z_H}{\bar{z}_H}\right) = e\frac{z_H}{\bar{z}_H}\left[(1+\tau) - \psi_H\right] - \lambda$$

The specular case is when sector j is active only in the foreign country.

Second scenario: Varity j is active in both countries

Each firm in the home country solves the following problem

$$\Pi_H = \max_{\{q_{HH}, q_{HF}\}}\left[\left(p_H - \frac{1}{\tilde{z}_H}\right) q_{HH} + \left(p_F - \frac{\tau}{\tilde{z}_H}\right) q_{HF} - \lambda\right]$$

s.t.

$$p_H = \frac{E_H}{X_H^{\alpha}} x_H^{\alpha-1}$$

$$p_F = \frac{E_F}{X_F^{\alpha}} x_F^{\alpha-1}$$

$$x_H = n(q_{HH} + q_{FH})$$

$$x_F = n(q_{HF} + q_{HF})$$

The first order conditions are

$$\left[(\alpha - 1)\frac{q_{HH}}{x_H} + 1\right] p_H = \frac{1}{\tilde{z}_H} \tag{3.48}$$

$$\left[(\alpha - 1)\frac{q_{HF}}{x_F} + 1\right] p_F = \frac{\tau}{\tilde{z}_H} \tag{3.49}$$

A firm at the foreign country solves a similar problem which leads to the following first order conditions

$$\left[(\alpha - 1)\frac{q_{FF}}{x_F} + 1\right] p_F = \frac{1}{\tilde{z}_F} \tag{3.50}$$

$$\left[(\alpha - 1)\frac{q_{FH}}{x_H} + 1\right] p_H = \frac{\tau}{\tilde{z}_F} \tag{3.51}$$

Using (3.48), (3.49), (3.50), (3.51) and $\gamma = \frac{z_{jF}}{z_{jH}}$, I can express the markups for the domestic and the foreign market as function of the relative technology gap

$$\theta_{HH} = \frac{\alpha - 1 + 2n}{n}\left(\frac{\tilde{\gamma}}{\tilde{\gamma} + \tau}\right) \tag{3.52}$$

$$\theta_{HF} = \frac{\alpha - 1 + 2n}{n}\left(\frac{\tilde{\gamma}\tau}{1 + \tilde{\gamma}\tau}\right) \tag{3.53}$$

$$\theta_{FF} = \frac{\alpha - 1 + 2n}{n}\left(\frac{1}{1 + \tilde{\gamma}\tau}\right) \tag{3.54}$$

$$\theta_{FH} = \frac{\alpha - 1 + 2n}{n}\left(\frac{\tau}{\tilde{\gamma} + \tau}\right) \tag{3.55}$$

The market shares can be computed using the first order conditions and equations (3.52), (3.53), (3.54) and (3.55)

$$\frac{q_{HH}}{x_H} = \frac{\tilde{\gamma}(\alpha - 1 + n) - n\tau}{n(\tilde{\gamma} + \tau)(\alpha - 1)}$$

$$\frac{q_{HF}}{x_F} = \frac{\tilde{\gamma}\tau(\alpha - 1 + n) - n}{n(\tilde{\gamma} + \tau)(\alpha - 1)}$$

$$\frac{q_{FF}}{x_F} = \frac{\alpha - 1 + n - \tau\tilde{\gamma}n}{n(1 + \tau\tilde{\gamma})(\alpha - 1)}$$

$$\frac{q_{FH}}{x_H} = \frac{\tau(\alpha - 1 + n) - \tilde{\gamma}n}{n(1 + \tau\tilde{\gamma})(\alpha - 1)}$$

Using $p_F = p_H \frac{(1+\tau\tilde{\gamma})}{\tilde{\gamma}+\tau}$ and the equations of the market shares, I can derive the demand for variable inputs for a firm in the home country and for a firm in the foreign country.

Multiplying equations (3.48), (3.49), (3.50) and (3.51) by q_{HH}, q_{HF}, q_{FF} and q_{FH} respectively and summing up, I obtain

$$\frac{q_{HH}+\tau q_{HF}}{\tilde{z}_H} = \\ = \left\{ \frac{\alpha-1+2n}{n} \frac{1}{(\alpha-1)} \frac{\tilde{\gamma}}{(\tilde{\gamma}+\tau)} \left[\frac{\tilde{\gamma}(\alpha-1+n)-\tau n}{\tilde{\gamma}+\tau} + \frac{\tilde{\gamma}\tau(\alpha-1+n)-n}{1+\tau\tilde{\gamma}}\tau \right] \right\} e \frac{z}{\bar{z_H}} \quad (3.56)$$

$$\frac{q_{FF}+\tau q_{FH}}{\tilde{z}_F} = \\ \left\{ \frac{\alpha-1+2n}{n} \frac{1}{(\alpha-1)} \frac{1}{(1+\tau\tilde{\gamma})} \left[\frac{\alpha-1+n-\tau\tilde{\gamma}n}{1+\tau\tilde{\gamma}} + \frac{\alpha-1+n-n\tilde{\gamma}}{\tilde{\gamma}+\tau}\tau \right] \right\} e \frac{z}{\bar{z_F}} \quad (3.57)$$

Using $p_F = p_H \frac{(1+\tau\tilde{\gamma})}{\tilde{\gamma}+\tau}$, the first order conditions and the demand for variable inputs, I can now derive firms' profits in each country

$$\pi_H(\frac{z}{\bar{z}}) = (\frac{1}{(\alpha-1)} \frac{1}{\tilde{\gamma}+\tau} \left[(1+\tau)\left((\alpha-1+n)\tilde{\gamma} - n \right) \right] - \chi_H) e \frac{z}{\bar{z}_H} - \lambda \quad (3.58)$$

$$\pi_F(\frac{z}{\bar{z}}) = (\frac{1}{(\alpha-1)} \frac{1}{1+\tau\tilde{\gamma}} \left[(1+\tau)\left((\alpha-1+n) - \tilde{\gamma}n \right) \right] - \chi_F) e \frac{z}{\bar{z}_F} - \lambda \quad (3.59)$$

3.6.4 Market clearing condition in the open economy

To derive the market clearing condition in country i, I must take into account the two possible scenarios and weigh each event by the probability that sector j is active, $1 - \Gamma_l(z_l^*)$, or not active in the other country $\Gamma_l(z_l^*)$ with $l \neq i$.

$$\left[\int_{z_H^*}^{\infty} (e\frac{z}{\bar{z}_H}\psi + \lambda)\mu_H(z)dz_H + \beta e\right]\Gamma_F(z_F*)+$$

$$\left[\int_{z_H^*}^{\infty} (e\frac{z}{\bar{z}_H}\int_{o}^{\infty} \chi_H g(\gamma)d\gamma_H + \lambda)\mu_H(z)dz_H + \beta e\right](1 - \Gamma_F(z_F*)) = \frac{1}{M(z_H^*)}$$

$$\left[\int_{z_F^*}^{\infty} (e\frac{z}{\bar{z}_F}\psi + \lambda)\mu_F(z)dz_F + \beta e\right]\Gamma_H(z_H*)+$$

$$\left[\int_{z_F^*}^{\infty} (e\frac{z}{\bar{z}_F}\int_{o}^{\infty} \chi_F g(\gamma)d\gamma_F + \lambda)\mu_F(z)dz_F + \beta e\right](1 - \Gamma_H(z_H*)) = \frac{1}{M(z_F^*)}$$

Solving for e I obtain

$$e_H = \frac{\frac{1}{M(z_H^*)} - \lambda}{\psi\Gamma_F(z_F^*) + \left[\int_o^{\infty} \chi_H g(\gamma)d\gamma\right](1 - \Gamma_F(z_F^*)) + \beta}$$

$$e_F = \frac{\frac{1}{M(z_F^*)} - \lambda}{\psi\Gamma_H(z_H^*) + \left[\int_o^{\infty} \chi_F g(\gamma)d\gamma\right](1 - \Gamma_H(z_H^*)) + \beta}$$

3.6.5 Welfare in the open economy

First scenario: Varity j is produced only in the home (foreign) country

When sector j is active only in the home country, the total quantity offered in the domestic market is $x_{jH} = n(q_{HH})$. Using $P_H = \frac{E_H}{X_H^\alpha} x_H^{\alpha-1}$ and (3.19), I can write

$$x_H = \left(\frac{X^\alpha}{E_H \theta_{HH} \tilde{z}_H}\right)^{\frac{1}{1-\alpha}}$$

Substituting it into $X_H = (\int_0^M x_{jH}^\alpha dj)^{\frac{1}{\alpha}}$ yields

$$X_H = E_H \theta (M_H \overline{z}_H)^{\frac{1-\alpha}{\alpha}}$$

where $\theta = \theta_{HH} = \frac{\alpha-1+n}{n}$.

Specularly, for the foreign country I get

$$X_F = E_F \theta (M_F \overline{z}_F)^{\frac{1-\alpha}{\alpha}}$$

where $\theta = \theta_{FF} = \frac{\alpha-1+n}{n}$.

Second scenario: Varity j is active in both countries

When variety j is produced in both countries, the total quantity offered in the home country is $x_{jH} = n(q_{HH} + q_{FH})$. Using $P_H = \frac{E_H}{X_H^\alpha} x_H^{\alpha-1}$, equations (3.24) and (3.27), and defining $\tilde{z} = \tilde{z}_H + \tilde{z}_F$, I obtain

$$x_H = \left[\frac{X^\alpha}{E_H} \frac{1}{\tilde{z}} \left(\frac{\theta_{FH} + \tau\theta_{HH}}{\theta_{HH}\theta_{FH}}\right)\right]^{\frac{1}{\alpha-1}}$$

Then, substituting it into $X_H = (\int_0^M x_{jH}^\alpha dj)^{\frac{1}{\alpha}}$ yields

$$X_H = E_H (\int_0^\infty \Phi_H g(\gamma) d\gamma)(M\bar{z})^{\frac{1-\alpha}{\alpha}}$$

where $\Phi_H = [\frac{\theta_{HH}\theta_{FH}}{\theta_{FH}+\tau\theta_{HH}}] = [\frac{\alpha-1+2n}{n}] \frac{\tilde{\gamma_i}}{\tilde{\gamma_i}+\tau} \frac{1}{1+\tilde{\gamma_i}}$, M is the total number of varieties and $\bar{z}$ is total average productivity.

From the representative household problem, the homogeneous good in the home country is $Y_H = \beta E_H$.

The total quantity offered in the foreign country is $x_{jF} = n(q_{FF} + q_{HF})$. Using $P_F = \frac{E_F}{X_F^\alpha} x_F^{\alpha-1}$, (3.25) and (3.26) I get

$$x_F = \left[\frac{X^\alpha}{E_F}\frac{1}{\tilde{z}}\left(\frac{\tau\theta_{FF} + \theta_{HF}}{\theta_{HF}\theta_{FHF}}\right)\right]^{\frac{1}{\alpha-1}}$$

where $\tilde{z} = \tilde{z}_H + \tilde{z}_F$. Then, substituting it into $X_F = (\int_0^M x_{jF}^\alpha dj)^{\frac{1}{\alpha}}$ yields

$$X_F = E_F(\int\limits_0^\infty \Phi_F g(\gamma)d\gamma)(M\bar{z})^{\frac{1-\alpha}{\alpha}}$$

where $\Phi_F = [\frac{\theta_{FF}\theta_{HF}}{\theta_{HF}+\tau\theta_{FF}}] = [\frac{\alpha-1+2n}{n}]\frac{\tilde{\gamma_i}}{1+\tilde{\gamma_i}\tau}\frac{1}{1+\tilde{\gamma_i}}$, M is the total number of varieties and$\bar{z}$ is total average productivity.

From the representative household problem, the homogeneous good in the foreign country is $Y_H = \beta E_H$.

Finally, using (3.1) and taking into account the two possible scenarios, I derive welfare for consumers in the home country and for consumers in the foreign country.

$$W_H = [ln(E_H\theta(M_H\bar{z}_H)^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E_H)][\Gamma_F(z^*)]+$$

$$+[ln(E_H(\int\limits_0^\infty \Phi_H g(\gamma)d\gamma)(M\bar{z})^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E_H)][1 - \Gamma_F(z^*)]$$

$$W_F = [ln(E_F\theta(M_F\bar{z}_F)^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E_F)][\Gamma_H(z^*)]+$$

$$+[ln(E_F(\int\limits_0^\infty \Phi_F g(\gamma)d\gamma)(M\bar{z})^{\frac{1-\alpha}{\alpha}}) + \beta ln(\beta E_F)][1 - \Gamma_H(z^*)]$$

Chapter 4

Absorptive Capacity and Efficiency: A Comparative Stochastic Frontier Approach Using Sectoral Data

4.1 Introduction[1]

Despite the emergence of newly industrialized economies and an increasing fragmentation of global production, most innovations are still carried out in a small number of R&D-intensive countries (Caselli and Wilson, 2004; Eaton and Kortum, 2001). The large majority of developing and newly industrialized countries import technology from these countries (Mastromarco, 2008). Gerschenkron (1962) and Abramovitz (1986) have argued that developing countries have a higher growth potential than advanced countries, as they can realize larger productivity gains in adopting advanced technologies. In a theoretical

[1]This chapter is a joint work with Michael Rochlitz (IMT Lucca, Italy).

paper, Acemoglu et al (2006) formalized the idea that developing countries should focus on adopting foreign technology before starting to innovate themselves. According to the case study literature, this is indeed what happened in newly industrialized countries such as South Korea, Taiwan or more recently China (Amsden, 1989, 2001; Breznitz and Murphree, 2011; Wade, 1990). In all these economies, the capacity to successfully absorb foreign technology has played a crucial role in sustaining high growth rates. Understanding differences in absorptive capacity is thus key to understand the large differences in productivity and income across countries (Prescott, 1998). While the technological distance from R&D-intensive countries determines the scale of potential benefits from importing technology, and trade liberalization opens up channels of technology transfer, the ability of a country to absorb imported technology is crucial to realize the potential gains from catching-up and trade.

The aim of this paper is to examine levels of technical efficiency and determinants of absorptive capacity for two groups of industrialized and emerging economies in Asia and Latin America, and a group of European OECD countries that also includes the US. While this last group is composed of countries that have been leading industrialized nations for a long time, the Asian and Latin American countries in our sample, with the exception of Japan, are mostly developing and newly industrialized economies. Comparing these three country groups permits us to investigate if efficiency levels and determinants of absorptive capacity systematically differ across regions that are at different levels of economic development, and share different political and historical contexts.

We use stochastic frontier analysis (SFA) and sectoral data, which permits us to treat technical efficiency and technical change as two distinct components of total factor productivity (TFP) in each industry. SFA allows us to simultaneously estimate levels and determinants of technical efficiency, with technical efficiency being a close approximation of the concept of absorptive capacity we have in mind. Instead of using SFA, most previous studies in the absorptive capacity literature have employed a two-stage modelling strategy (Madsen et al, 2010; Miller and Upadhyay, 2000; Senhadji, 2000), which however suffers from a number of flaws (that we discuss in section 4.2). The few studies using SFA have either focused on OECD countries (Griffith et al, 2003, 2004; Kneller and Stevens, 2006), or have used aggregate data (Mastromarco, 2008; Michael Henry and Milner, 2009), and do not have data for recent years. Using sectoral instead of aggregate data permits us to get more precise results, and to distinguish between effects on low-tech and high-tech sectors. As sectoral data has become available only recently for many developing countries, this paper is the first one, to our knowledge, that combines SFA with the use of sectoral data for both developed and developing countries. We investigate the effect of two potential determinants of absorptive capacity, namely human capital measured by years of schooling, and the effectiveness of domestic R&D, proxied by the stock of patents filed by a country. While most previous studies have either examined the effects of human capital (Benhabib and Spiegel, 1994; Benhabib and Spiegel., 2005; Cohen and Levinthal, 1989; Nelson R., 1966) or R&D expenditure (Aghion and Howitt, 2005; Fagerberg, 1994; Verspagen, 1991) on absorptive capacity, we follow more recent studies that look on both determinants (Kneller and Stevens, 2006). However, instead of R&D expenditure we use stock of patents as a proxy for R&D, which to our knowledge has not been done before in this context. The contributions of this paper to the literature are thus twofold. To our knowledge, this paper is the first using SFA and sectoral data to comparatively analyse efficiency levels and determinants of absorptive capacity across three groups of developed and developing countries. Secondly, instead of R&D expenditure, we introduce the use of stock of patents as a proxy for R&D to the absorptive capacity literature.

We find that levels of technical efficiency slightly increase over the time span covered in our study, with the exception of Latin America, where efficiency in high-tech sectors experiences a sharp drop after 1999. A temporary drop in high-tech efficiency, albeit less pronounced, is also noticeable for Asia and OECD countries after 1999. While in Europe low-tech sectors are on average more efficienct than high-tech sectors, the opposite is the case for Asia and the US, with Latin America showing mixed results. Looking on the *determinants* of technical efficiency, we find that human capital has always a strongly positive effect on efficiency, especially in low-tech sectors. An increase in the stock of patents has positive effects on efficiency in high-tech sectors, but negative effects in low-tech sectors, especially for Asia and Latin America. In the following, section 4.2 will discuss our empirical strategy, and section 4.3 presents the data. Section 4.4 shows the results for our frontier estimation, the efficiency levels and for determinants of technical efficiency, and section 4.5 concludes.

4.2 Empirical strategy

We use stochastic frontier analysis (SFA), as it provides an ideal framework to estimate technical inefficiency. SFA is prefered to the more popular two-stage modelling approach used in most of the previous literature, since it is statistically more accurate and matches more closely the idea of absorptive capacity we want to capture. The two-stage approach consists in estimating TFP as residual of a parameterized production function, and then regressing it against a number of factors which are considered to be linked to changes in productivity (Madden et al, 2001; Madsen et al, 2010; Miller and Upadhyay, 2000; Okabe, 2002; Senhadji, 2000; Wang, 2007). However, Kumbhakar et al (1991); Reifschneider and Stevenson (1991) point out that while in the first stage of this approach the efficiency terms are assumed to be identically and independently distributed, in the second stage they are a function of a number of variables which might directly enter the production function specification (or be correlated with explanatory variables), thereby contradicting the assumption of identically distributed inefficiency terms (Battese and Coelli (1995), pp. 326). SFA overcomes this problem by assuming that technical inefficiency effects of production are *independently* but *not identically* distributed, and then by simultaneously estimating the stochastic frontier and the inefficiency model. Another important feature of SFA is that it allows us to distinguish between technical progress, technical efficiency, and a stochastic component of TFP. This distinction is omitted in the two-stage approach, where TFP is used as a measure of technical inefficiency. A third criticism concerns the use of the country with the highest TFP as the numeraire in a measure of relative productivity, to account for the distance to the technical frontier (Griffith et al, 2004; Kneller, 2005). This approach is based on two unrealistic assumptions. First, it assumes that the country with the highest TFP is at the frontier, which might not be true. Secondly, it assumes that a unique technology frontier exists for all countries. In the SFA approach, the concept of absorptive capacity is instead related to that of production frontier, which represents the maximum output that can be produced starting from any given input vector (i.e. the upper boundary of the production possibilities set). Our emprical strategy is based on that of Battese and Coelli (1995). Following their formulation, the stochastic production frontier can be expressed as

$$Y_{ijt} = exp(x_{ijt}\beta + V_{ijt} - U_{ijt}) \tag{4.1}$$

where Y_{ijt} is output, x_{ijt} is a vector of inputs of production, β is a vector of parameters to be estimated, V_{ijt} are random errors which capture the stochastic nature of the frontier, and U_{ijt} are non-negative random variables which denote technical inefficiency of production and are obtained by a truncation at zero of the normal distribution with mean $z_{it}\delta$ and variance σ^2(see Battese and Coelli (1995)).

The technical inefficiency effect is specified by the following equation

$$U_{ijt} = z_{it}\delta + W_{ijt} \tag{4.2}$$

where z_{it} is a vector of explanatory variables associated with technical inefficiency of production, δ is a vector of unknown coefficients, and W_{ijt} is a random variable defined by the truncation of a normal distribution with zero mean and variance σ^2. The requirement that $U_{ijt} \geq 0$ is ensured by truncating W_{ijt} such that $W_{ijt} \geq -z_{ijt}\delta$.

The parameters of equations (4.1) and (4.2) are estimated simultaneously by the method of maximum likelihood.[2] The likelihood function is expressed in terms of the variance parameters $\sigma_S^2 \equiv \sigma_V^2 + \sigma^2$ and $\gamma \equiv \sigma^2/\sigma_S^2$.[3] The technical efficiency of production of sector *j* in country *i* at time *t* is

$$TE_{ijt} = exp(-U_{ijt}) = exp(-z_{it}\delta - W_{ijt}) \tag{4.3}$$

The prediction of the technical efficiency terms is based on their conditional distribution $U_{ijt}|E_{ijt}$ where $E_{ijt} = V_{ijt} - U_{ijt}$, given the model assumptions (See Battese and Coelli (1993)).

To estimate equation (4.1), we assume a semi-translog specification (i.e. translog in k and l, as proposed by Kneller and Stevens 2003), which provides a less restrictive functional form for a production function

$$y_{ijt} = \beta_{0j} + \beta_1 k_{ijt} + \beta_2 l_{ijt} + \beta_3 k_{ijt}^2 + \beta_4 l_{ijt}^2 + \beta_5 k_{ijt} l_{ijt}$$

$$+ \beta_6 p_{it} + \beta_7 r_{it} + \beta_8 year^2 + \beta_9 c_i + \beta_{10} s_j - u_{ijt} + v_{ijt} \tag{4.4}$$

where all lower case letters represent logarithms

Y_{ijt} is value added, $K_{ijt}$is physical capital, $L_{ijt}$is labour supply, P_{ijt} is domestic knowledge measured by local R&D and R_{it} represents foreign knowledge spillovers, which are assumed to be a function of the stock of R&D in the five countries that contribute most to the global stock of R&D. We make the simplifying assumption that technology is factor-neutral, implying that output is separable in the production function and technology, so that we can separate technological change p_{it} from efficiency u_{ijt} in TFP. A quadratic time trend, $year^2$, is also included to measure technical progress not captured by local and foreign R&D.[4] Finally, a set of country fixed effects c_i and a set of sector fixed effects

[2]The parameters of the model defined by (4.1) and (4.2) are estimated simultaneously using Frontier 4.1 which is a package for SFA developed by Battese and Coelli. Frontier 4.1 provides maximum-likelihood estimates of the parameters and predicts technical efficiencies.

[3]For the derivation of the likelihood function and its partial derivatives with respect to the parameters of the model see Battese and Coelli (1993).

[4]A similar assumption is made by Michael Henry and Milner (2009).

s_j are included to control for country and sector specific characteristics. Following Griliches and Lichtenberg (1984), knowledge is assumed to be an input in the production function. As Kneller and Stevens (2006), we assume that knowledge evolves with the local stock of R&D and with foreign knowledge spillovers, capturing technical change. To measure foreign R&D spillovers to the domestic economy, we follow Coe and Helpman (1995) and Michael Henry and Milner (2009). They use a bilateral-imports-share weighted sum of R&D capital stocks of trade partners. Using the same logic, we weight the stock of R&D of the five countries that contribute most to the total stock of R&D by the share of imported machinery and equipment from these countries. This is motivated by the evidence that most of the world's R&D is produced in a small number of R&D-intensive countries and imported through R&D-intensive inputs (Caselli and Wilson, 2004; Eaton and Kortum, 2001). Finally, we assume that knowledge transfer is partial, depending on the degree of economic integration across countries. Barriers to knowledge transfer are captured by weighting the stock of R&D by the distance to the source.

$$R_{it} = \sum_{n=5} \left(\frac{P_{nt} * m_{int}}{D_{in}} \right)$$

where n is an index for the five top countries, $P_{nt}$is the stock of R&D in country n, m_{in} is the share of machinery and equipment imported by country i from country n, and D_{in} is the distance between country i to country n.

Technical inefficiency is defined by

$$u_{ijt} = \delta_{oj} + \delta_1 z_{it} + \delta_2 lowtech * z_{it} + \delta_3 h_{it} + \delta_4 lowtech * h_{it} + \delta_5 s_i + W_{ijt} \quad (4.5)$$

where, as before, all lower case letters represent logarithms.

z_{it} is stock of patents, $h_{it}$is human capital, $lowtech$ is a dummy variable taking value 1 when the sector is low-tech and 0 otherwise, s_i are sector fixed effects, and W_{it} has been defined after equation (4.2). The impact of knowledge on inefficiency is captured by the stock of patents. To our knowledge, the use of stock of patents is new in the empirical literature on absorptive capacity. Kneller and Stevens (2006) use spending on R&D in the industry to measure the effect of knowledge on inefficiency. In our analysis, we prefer to use stock of patents as a measure of knowledge for two reasons: first we believe that stock of patents is a more reliable indicator of effective knowledge production in a country, and second we find stock of patents to be more robust to multicollinearity problems, given the high correlation between spending in R&D and years of schooling that we found ($\rho = 0.77$). We use average years of schooling in country i as proxy for human capital. The effect of both stock of patents and years of schooling is allowed to vary between high-tech and low-tech sectors. Finally, a set of sector fixed effects are added to control for sector specific characteristics. If the stock of knowledge and human capital positively affect absorptive capacity in the high-tech sectors, we should expect δ_1 and δ_3 to have a negative sign. In the low-tech sectors, we should expect the sum of the coefficients for both the stock of patents and years of schooling to be negative (e.i. $\delta_1 + \delta_2 < 0$ and $\delta_3 + \delta_4 < 0$).

4.3 Data

The model is estimated for a sample of 10 European and North-American OECD countries (United Kingdom, United States, France, Germany, Italy, Belgium, Norway, Sweden, Netherlands, Denmark), 7 Asian countries (China, India, Indonesia, Japan, Philippines, Singapore, South Korea), 5 Latin American countries (Bolivia, Chile, Colombia, Mexico, Uruguay) and for twenty-two manufacturing industries over the period 1996-2005.[5] We divide the 22 manufacturing sectors into high-tech and low-tech sectors, following the standard OECD sector classification.[6]

While the first group of 10 OECD countries is included as a benchmark, we have chosen the other two country groups from regions

[5]Stock of R&D, years of schooling and number of patents are available only at the country level.

[6]See Table 10 in Appendix 4.6.

that are characterized by different historical and political pre-conditions, i.e. Asia and Latin America. Whereas the countries in the first group have been among the world's leading industrialized nations for a long time, most countries in the two other groups are developing and newly industrialized economies that are still at a much lower level of economic development. Many of them share a recent history of successful economic catch-up, which makes them especially interesting for an analysis of absorptive capacity. Our choice of countries was limited by the availability of sectoral data. Sectoral data is not yet available for many developing countries, and has only recently been made available for most of the non-OECD countries in our sample. As of now, our sample is thus the largest possible considering issues of data availability. Furthermore, we have exluded developing countries from Africa, as data availability was very limited and technology absorption has arguably played only a marginal role in these countries until recently (Lall and Pietrobelli, 2002). Data for valued added, gross fixed capital formation and number of employees are taken from the UNIDO ISDB (3-4 digit level). Data are comparable across years, having been deflated to 2000 prices and converted using measures of purchaising power parity (PPP) to US$. Both the GDP deflator and the PPP conversion factor are taken from World Bank. The perpetual inventory method (PIM) is used to construct the capital stock.

$$K_{ijt+1} = K_{ijt} + I_{ijt+1} - \delta K_{ijt} \tag{4.6}$$

$$K_{ij0} = \frac{I_{ij0}}{g_i^K + \delta^K} \tag{4.7}$$

where K_{ij} is capital stock of sector j in country i , I_{ij} is capital formation/investment, δ^K is the depreciation rate set at 4% (Liao et al. 2009), and g_i^K is the average growth in the first five years of investment series. Human capital is measured by average years of schooling in the population in country i, and is taken from Barro and Lee (2010). The PIM is also used to compute stock of R&D using total R&D expenditure in country i deflated to 2000 prices, and converted using measures of PPP to US$.

$$P_{it+1} = P_{it} + R_{it+1} - \delta P_{it} \tag{4.8}$$

$$P_{i0} = \frac{R_{i0}}{g_i^R + \delta^p} \tag{4.9}$$

where P_i is the stock of R&D in country i, R_i is the expenditure in R&D, $g_i^R$is the average annual growth rate of R&D and $\delta^R$is the rate of depreciation of R&D stock that we set at 15% (Griliches, 1984). Data on patents are obtained from OECD. We use the triadic patent families which are a set of patents filed at the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO), and the Japan Patent Office (JPO), for the same invention, by the same applicant. The PIM is used to compute the stock of patents:

$$Z_{it+1} = Z_{it} + TPF_{it+1} - \delta Z_{it} \tag{4.10}$$

$$Z_{i0} = \frac{TPF_{i0}}{g_i^Z + \delta^Z} \tag{4.11}$$

where Z_{it} is the stock of patents in country i, TPF_i is the number of triadic patent families, g_i^Z is the average annual growth rate of patents, and $\delta^Z$is the depretiation rate set at 15% (Hall and MacGarvie, 2010). Foreign R&D spillovers are computed using the stock of R&D of the United States, Japan, Germany, France and the United Kingdom, which are the countries which contributed most to the stock of total R&D over the period 1996-2005. The share of imported machinery and equipment is calculated by using data on total imports and imported machinery and equipment from UN Comtrade, deflated to 2000 prices and converted using measures of PPP to US$. Distance between capital cities in kilometers is taken from Gleditsch (2003). For about 50% of our observations we have a balanced panel, while for more than 63% we have 9 out of 10 years, and for almost 70% 8 out of 10 years.[7] Table 5 shows the basic descriptive statistics for all the variables of our analysis.

[7]Table 11 in Appendix 4.6 summarizes the number of available sectors by country and

Table 5: Descriptive statistics

	Q1	Median	Q2	Mean	St. Dev.
Total					
y	6.57	7.98	9.20	7.80	2.06
k	7.18	8.852	10.28	8.68	2.19
l	9.43	10.78	12.15	10.69	1.98
p	27.65	29.17	30.34	28.84	2.08
r	26.55	27.30	27.81	27.16	0.70
z	3.40	7.22	8.83	6.38	3.42
h	2.07	2.23	2.38	2.17	0.31
OECD					
	Q1	Median	Q2	Mean	St. Dev.
y	7.01	8.23	9.32	8.17	1.86
k	8.00	9.24	10.31	9.08	1.85
l	9.79	11.08	12.17	10.89	1.80
p	28.81	29.64	30.60	29.79	1.37
r	27.50	27.80	27.92	27.61	0.59
z	7.34	8.45	9.38	8.56	1.46
h	2.23	2.35	2.44	2.35	0.13
Asia					
	Q1	Median	Q2	Mean	St. Dev.
y	7.36	8.53	9.65	8.36	1.83
k	8.11	9.89	10.88	9.51	1.93
l	10.35	11.71	12.66	11.45	1.82
p	27.49	29.45	30.20	29.01	1.94
r	26.25	26.63	27.26	26.67	0.54
z	3.59	5.43	8.19	5.86	3.39
h	1.63	2.08	2.36	1.97	0.43
Latin America					
	Q1	Median	Q2	Mean	St. Dev.
y	4.63	6.36	7.43	6.07	1.96
k	5.28	6.50	7.66	6.46	1.87
l	7.82	9.23	10.29	9.08	1.73
p	24.50	26.58	26.90	26.21	1.39
r	26.46	26.65	26.99	26.73	0.32
z	0.32	1.73	2.41	1.69	1.20
h	1.96	2.02	2.08	2.03	0.11

by year.

4.4 Results

4.4.1 Frontier estimates

We report the results of our frontier estimation in Tables 6 and 4.4.1, with Table 6 showing frontier estimates, and Table 4.4.1 output elasticities. Estimated elasticities are within the range of what is found elsewhere in the literature, although we find slightly higher values for the elasticity of value added with respect to labour than studies using data for earlier periods (Kneller and Stevens, 2006; Liao et al, 2009). For the full sample, the elasticity of value added with respect to physical capital is 0.201, and that with respect to labour 0.802. While we find evidence for mildly increasing returns to scale for physical capital and labour concerning OECD countries and Latin America (1.025 and 1.081), returns to scale are slightly decreasing for Asia (0.938). The estimated effect of the stock of local R&D on output is strongly positive and significant at the 1% level for OECD countries (0.233), but only weakly positive and not significant for Asia (0.038). For Latin America, stock of R&D has a negative effect on output (-0.426), significant at the 10% level. Our results for OECD countries are similar to those found by earlier studies. Kneller and Stevens (2006) obtain slightly lower coefficients for a group of twelve OECD countries during the period 1973-1990 (0.03-0.09, pp.10). Coe and Helpman (1995) find that for the seven most adavanced OECD countries between 1971 and 1990, the estimated elasticity of TFP with respect to domestic R&D varies between 0.22 and 0.23, while for the remaining group of fifteen less advanced OECD countries, the elasticity lies between 0.6 and 1 (pp. 869). Kneller (2005) finds much lower coefficients for a group of twelve OECD countries over the same period (0.02-0.04, pp. 10), while Griffith et al (2004) obtain larger coefficients for the same panel of OECD countries (0.4-0.6, pp. 889). However, they use TFP growth instead of TFP as dependent variable, and assess the rate of return to R&D. We thus find that local stock of R&D directly affects production in our sample of OECD countries. For Asia, the weaker and not significant effect suggests that local R&D plays mainly a role in facilitating the absorption of foreign technology, instead of affecting output directly. For Latin America, although a negative effect of the stock of local R&D on output seems to be counterintuitive at first sight, our results confirm findings by earlier studies. In a study of 16 Latin American countries between 1996 and 2006, Castillo et al (2012) find a negative contribution of R&D expenditure to productivity, which they attribute to recent changes in the pattern of specialization in the region in favour of industries with low-value added content that rely less and less on domestic R&D. Cimoli and Katz (2003) make the same argument, outlining that "dramatic changes in the sources of technical change" have occured in Latin America in the 1990s, with "a rapidly increasing share of external sources emerging at the expense of domestic ones" (Cimoli and Katz (2003), pp. 390). While import substitution policies until the 1980s had focused on the building of domestic knowledge creation, they maintain that today those industries still relying on domestic R&D are inefficient and lagging behind. Efficient industries are clustered within the natural resource sectors or are performing assembly operations of imported parts ('maquiladoras'), relying almost exclusively on foreign R&D and cheap labour. It thus seems that our results for Latin America reflect recent structural changes on the continent, and capture the decreasing importance of local R&D. The estimated effect of foreign R&D spillovers on output is slightly lower than what is found elsewhere in the literature (for example, Coe and Helpman (1995) find an elasticity of TFP with respect to foreign R&D spillovers of 0.06-0.092, and Kneller and Stevens (2006) an elasticity of output with respect to foreign R&D of 0.084-0.091). However, for our sample effects are not significant. This could mean that foreign R&D spillovers through machinery and equipment imports have only a weak or indirect effect on domestic production. As we are only capturing foreign knowledge embodied in R&D-intensive inputs, we leave out other potential channels through which foreign R&D might affect domestic output directly, such as FDI, licensing, etc.

Table 6: Results - frontier

	Total	OECD	Asia	Latin America
k	0.354***	0.375***	0.360***	-0.142*
	(0.024)	(0.023)	(0.079)	(0.085)
l	0.705***	0.503***	0.962***	1.525***
	(0.035)	(0.029)	(0.112)	(0.129)
k^2	0.003	0.048***	0.003	0.045***
	(0.003)	(0.005)	(0.006)	(0.009)
l^2	0.013***	0.063***	0.0002	-0.030***
	(0.003)	(0.003)	(0.009)	(0.012)
lk	-0.020***	-0.105***	-0.021*	-0.022
	(0.005)	(0.007)	(0.012)	(0.018)
p	-0.068	0.233***	0.038	-0.426*
	(0.045)	(0.064)	(0.076)	(0.070)
r	0.026	0.045	0.030	0.012
	(0.051)	(0.058)	(0.093)	(0.073)
$year^2$	0.0006***	0.0001	0.0009	-0.0002
	(0.0002)	(0.0002)	(0.0005)	(0.0005)
const	-1.150	-9.568***	-6.300***	4.965***
	(0.990)	(1.122)	(1.010)	(1.034)
log-likelihood	-858.355	694.804	-260.021	-106.590
N	3904	1968	1148	788

The level of significance is shown with the following notation: *** 1%, ** 5%, and * 10%

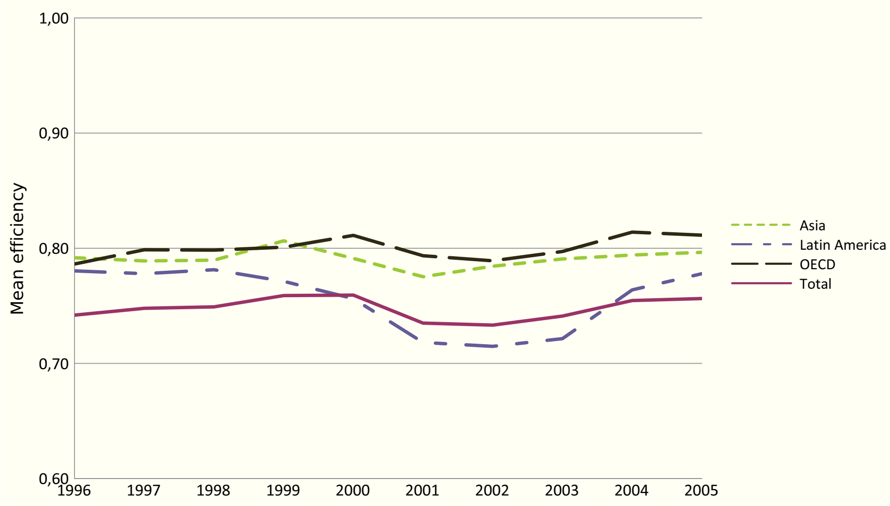
Table 7: Elasticity of value added w.r.t. (at the sample mean)

	Labour	Physical capital
Total	0.802	0.201
OECD	0.924	0.101
Asia	0.763	0.175
Latin America	0.845	0.236

4.4.2 Efficiency levels

Table 8 presents efficiency scores for low-tech and high-tech sectors in each country group. In general, efficiency scores slightly increase over the time span covered in our study, with the exception of Latin America, where efficiency in high-tech sectors experiences a sharp drop after 1999. A temporary drop in high-tech efficiency, albeit less pronounced, is also noticeable for Asia and OECD countries after 1999. Possibly, the Asian and Russian financial crises and the burst of the dot-com bubble are responsible for this drop in high-tech efficiency around the turn of the millenium, with the effect in Latin America being amplyfied by

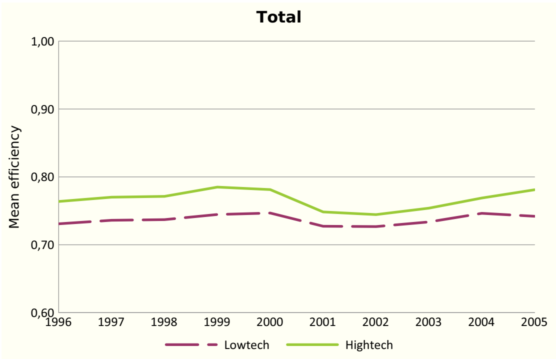
Figure 10: Mean efficiency by country group



the aftermath of recent structural adjustment programs that made the region more vulnerable to economic shocks. For the full sample, mean efficiency in low-tech sectors is slightly lower than mean efficiency in high-tech sectors (Figure 11). However, regional differences are quite pronounced. While from 1996 to 2000 mean efficiency for low-tech and high-tech sectors is almost the same in OECD countries, in 2001 efficiency drops notably in high-tech sectors, which then remain consistently less efficient than low-tech sectors. In Latin America, high-tech sectors are more efficienct than low-tech sectors until 2000, and then experience a similar, albeit much stronger drop. Finally, in Asia high-tech sectors are consistently more efficient than low-tech sectors.

Figures 12, 13 and 14 look on the performance of individual countries within our three regional groups. For OECD countries, a marked drop in high-tech efficiency for France, the Netherlands, Sweden and Italy is notable from 2000 onwards, with Italy remaining stuck at a level of high-tech efficiency that is the lowest of all 22 countries in our sample. On the other hand, the United States, Denmark and Norway significantly improve their efficiency during the second half of the period observed, while efficiency levels for the UK, Germany and Belgium remain roughly the same from 1996 to 2005. What we capture here is probably the divergence in productivity between the US and some Scandinavian

Figure 11: Mean efficiency by country group, low-tech, and high-tech sectors



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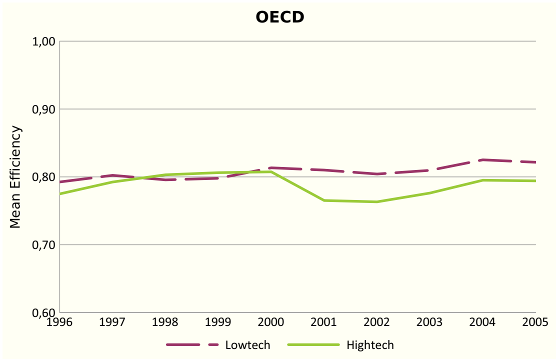

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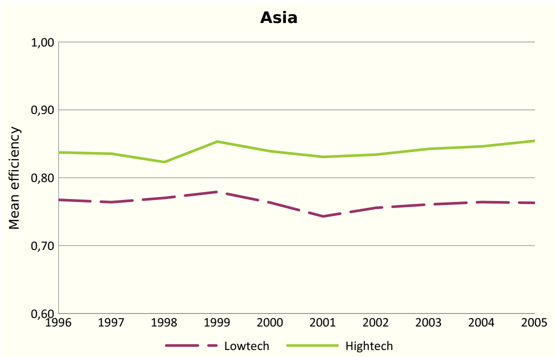

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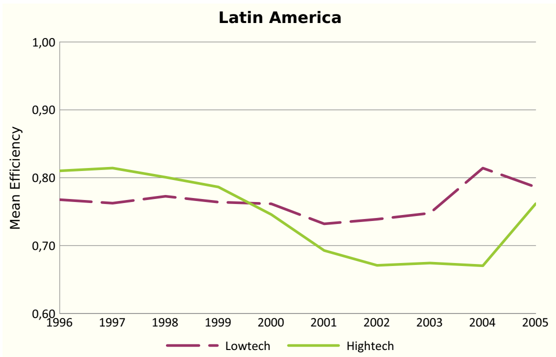


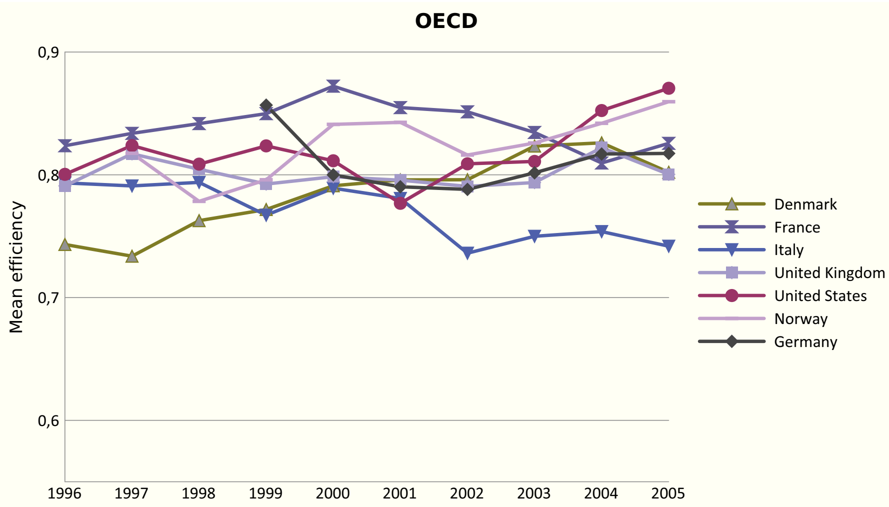
(d)

countries on the one hand, and most European OECD countries on the other hand, which became notable since the late 1990s and is most often attributed to the better exploitation of ICT-induced productivity gains by the US (Van Ark B., 2003). Less flexible and more regulated labour markets in Europe might also play a role in this respect (Bassanini et al, 2009). In Asia, a group of high performers includes South Korea, Japan, Singapore and the Philippines, while Indonesia remains at a lower level of technical efficiency. India and China lie in between, and seem to be fast catching up to the group of high-performers. India significantly increased its efficiency between 1997 and 2005, especially in high-tech sectors, where it has become the most efficient of all 22 countries in our sample by 2005. However, despite a 0.1 increase between 1997 and 2005, low-tech sectors are still very inefficient in the country, so that, with the exception of Mexico, they remain the most inefficient of all countries in our sample in 2005. With respect to the debate about the relative importance of technical efficiency improvements to growth in India (Bhaumik and Kumbhakar, 2010; Kim and M., 2012), our paper thus finds evidence for an increase in technical efficiency, especially in high-tech sectors. The marked divide that we find between efficiency in low- and high-tech sectors also confirms conclusions by earlier studies (D'Costa, 2003), which suggest that the Indian economy is driven forward by some efficient high-tech industries, especially in the ICT sector, while low-tech industries are still lagging behind. With respect to China, even though we only have data for 2003-2005, it looks as if China has successfully managed, within a short time-span, to leave the group of low performers and join the group of high-efficiency countries. For Latin America, a sharp drop in efficiency for high-tech sectors in Chile, Mexico, Colombia and Uruguay is notable between 1999 and 2001, followed by a slight recovery afterwards. After 2000, high-tech sectors are consistently much less efficient in Latin America than in OECD countries and Asia. This drop in efficiency might be a consequence of the series of financial crises that hit the continent around the year 2000. Colombia was hit by a crisis in 1998, Brazil in 1999, and Argentina, Ecuador and Uruguay in 2001, and most countries suffered from a recession for some of the years between 1999 and 2003 (Rojas-Suarez, 2010). For Colombia and Uruguay, the year of their respective financial crisis coincides with the drop in efficiency we notice (Figure 18 in Appendix 4.6). Although Chile and Mexico were not directly affected, their drop in efficiency might be related to close links with the crisis countries. For all four countries, the drop in efficiency is closely related to negative rates of GDP growth. Chile experienced negative GDP growth in 1999, preceeding the 0.23 drop in high-tech efficiency we notice for 2000-2001 (Figure 18). Mexico had a short recession in 2001 and low GDP growth rates for 2002 and 2003, corresponding with a 0.15 drop in high-tech efficiency for 2000-2002 (Figure 18). In Uruguay, GDP per capita decreased in four consecutive years between 1999 and 2002, and high-tech efficiency by 0.13 points

Table 8: Mean efficiency by country, low-tech and high-tech sectors

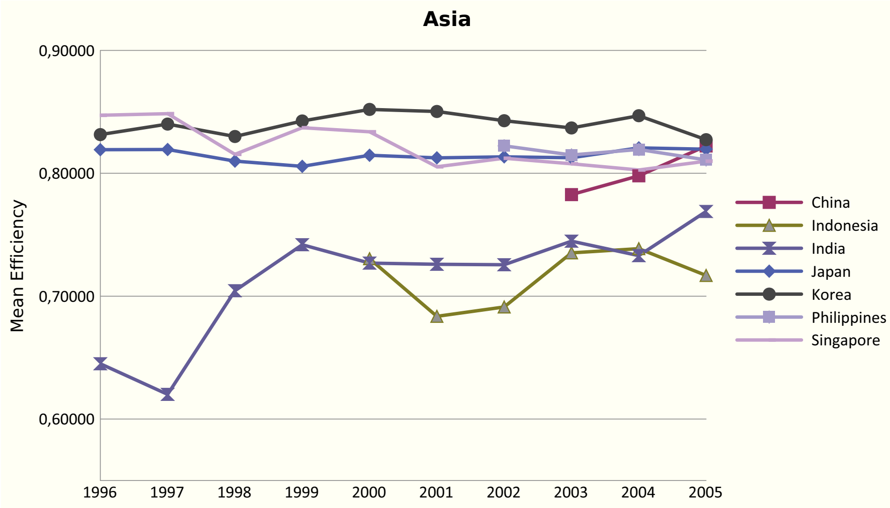
	Total		OECD		Asia		Latin America	
Year	l.tech	h.tech	l.tech	h.tech	l.tech	h.tech	l.tech	h.tech
1996	0.731	0.764	0.793	0.775	0.767	0.837	0.768	0.810
1997	0.736	0.770	0.802	0.792	0.764	0.835	0.763	0.814
1998	0.737	0.771	0.796	0.803	0.770	0.823	0.773	0.801
1999	0.745	0.785	0.798	0.806	0.779	0.853	0.764	0.786
2000	0.747	0.781	0.813	0.807	0.763	0.839	0.762	0.746
2001	0.727	0.748	0.810	0.765	0.743	0.831	0.732	0.693
2002	0.727	0.744	0.804	0.763	0.756	0.834	0.739	0.671
2003	0.734	0.754	0.810	0.776	0.761	0.843	0.748	0.674
2004	0.746	0.769	0.825	0.795	0.764	0.846	0.814	0.670
2005	0.742	0.781	0.822	0.794	0.763	0.854	0.786	0.762

Figure 12: Mean efficiency - OECD



between 2001 and 2004. Finally, Colombia's GDP decreased by -4.2% in 1999, and high-tech efficiency by 0.22 points from 1999 to 2000. The fact that efficiency in high-tech sectors decreased notably during this period of economic turbulence, while low-tech sectors remained remarkably stable, could indicate that high-tech sectors in Latin America are more internationally integrated but also more vulnerable to economic perturbations than low-tech sectors.

Figure 13: Mean efficiency - Asia

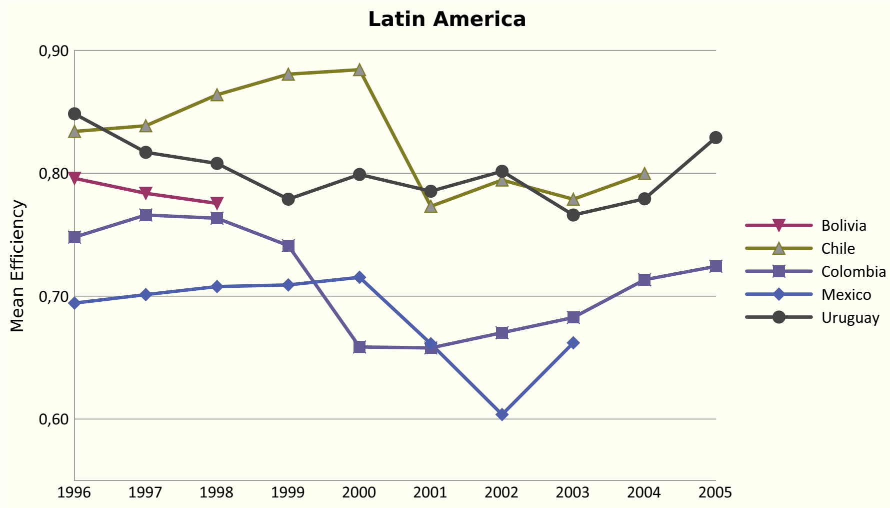


4.4.3 Determinants of technical efficiency

Stock of patents

Table 9 reports the results of our efficiency estimation. We find that an increase in the stock of patents has a negative and significant effect on technical inefficiency in high-tech sectors across all country groups. A 1% increase in the stock of patents decreases inefficiency in high-tech sectors in OECD countries by 0.219%, by 0.14% in Asia and by 0.119% in Latin America. Interestingly, this effect changes once we look on low-tech industries. Here, we consistently find that an increase in the stock of patents *increases* technical inefficiency. While the effect is very low for OECD countries, with a 1% increase in the stock of patents leading to a 0.013% increase in inefficiency, in Asia inefficiency increases by 0.177%, and in Latin America by 0.351% in low-tech sectors for a 1% increase in the stock of patents. Our findings differ from those of Kneller and Stevens (2006), who find that R&D "has only an insignificant effect on inefficiency" (Kneller and Stevens (2006), pp. 19). Using stock of patents instead of R&D expenditure as a proxy for the effectiveness of domestic R&D in a stochastic frontier framework reveals a significant effect of domestic R&D on efficiency, which however fundamentally differs between high-tech and low-tech sectors. Large parts of the more

Figure 14: Mean efficiency - Latin America



general literature on the effects of R&D on productivity also find such a difference between high-tech and low-tech sectors (see Kumbhakar et al (2011) for a literature review). While domestic R&D has generally a strong and positive impact on productivity in high-tech sectors, the impact is low or not significant for low-tech sectors. For instance, using a dataset of top European R&D investors over the period 2000–2005, Kumbhakar et al (2011) find that R&D in low-tech sectors "has a minor effect in explaining productivity", whereas in high-tech sectors the effect of R&D on productivity is found to be strong and positive. By analyzing a sample of 156 large Taiwanese firms for the period 1994-2000, Tsai and Wang (2004) find a positive but very low effect of R&D on productivity for low-tech sectors, whereas the effect was positive and strong for high-tech sectors. Our findings are coherent with previous studies in that we also find a substantial difference between high-tech and low-tech sectors. However, the difference we find is even larger, since for our sample an increase in the stock of domestic knowledge has a positive effect on inefficiency for low-tech sectors. This effect is much stronger in developing countries than in our group of OECD countries. A possible explanation might be that we use patents as a proxy for effectiveness of R&D. As patenting activity is higher in high-tech sectors (Brouwer and Kleinknecht, 1999; Lotti and Schivardi, 2005), and resources for R&D

are scarce, a crowding-out effect might occur that diverts resources from R&D in low-tech to R&D in high-tech sectors, due to expected greater returns to R&D in high-tech sectors. As we have only aggregate data for patents, it is possible that we capture this effect in our regression. An increase in patenting activity in an environment where resources for R&D are relatively scarce could thus lead to the negative effect on efficiency in low-tech sectors that we find. If this interpretation comes close to what is actually happening, it would suggest that the crowding-out effect is stronger for Latin America than for Asia.

Human capital

The second determinant of technical efficiency we examine is human capital, measured by years of schooling (Barro and Lee 2010). We find that an increase in years of schooling has almost always a strong and significant negative effect on technical inefficiency, with the effect being stronger for low-tech sectors. For high-tech sectors, increasing years of schooling by 1% decreases inefficiency by 0.843% in OECD countries, by 1.876% in Asia and by 0.363% in Latin America, although results for Latin America are not significant. In low-tech sectors, a 1% increase in years of schooling decreases inefficiency by 1.39% in OECD countries, by 2.56% in Asia and by 4.07% in Latin America. Our results are in line with those of previous studies. For a group of twelve OECD countries, Kneller and Stevens (2006) find that a 1% increase in human capital decreases inefficiency by 1.86%. Their coefficient is slightly higher than ours. As they look on an earlier period (1973-1990), this could be a sign for marginal decreasing returns of human capital over time in OECD countries. To our knowledge, there are no previous studies that use a stochastic frontier framework and specifically look at the effect of human capital on inefficiency in Asia and Latin America. However, looking at a group of 57 developing countries for the period 1960-2000, Mastromarco (2008) finds that increasing human capital by 1% decreases inefficiency by 2.33%. We find that an increase in human capital reduces technical inefficiency more in low-tech than in high tech-sectors. This could mean that the type of human capital captured by the years of schooling data

Table 9: Results - efficiency determinants

	Total	OECD	Asia	Latin America
z	-0.187***	-0.219***	-0.140***	-0.119*
	(0.013)	(0.021)	(0.019)	(0.071)
Low-tech × z	0.361***	0.232***	0.317***	0.470***
	(0.020)	(0.021)	(0.020)	(0.074)
h	0.660***	-0.843***	-1.876***	-0.363
	(0.136)	(0.168)	(0.198)	(0.437)
Low-tech × h	-2.992***	-0.548***	-0.685***	-3.705***
	(0.157)	(0.174)	(0.208)	(0.3402)
const	0.838***	1.722***	1.654***	4.066
	(0.211)	(0.354)	(0.413)	(0.935)
sigma	0.658***	0.291***	0.558***	0.377***
squared	(0.022)	(0.007)	(0.029)	(0.022)
gamma	0.943***	0.974***	0.912***	0.911***
	(0.004)	(0.003)	(0.009)	(0.012)
N	3904	1968	1148	788

The level of significance is shown with the following notation: *** 1%, ** 5%, and * 10%

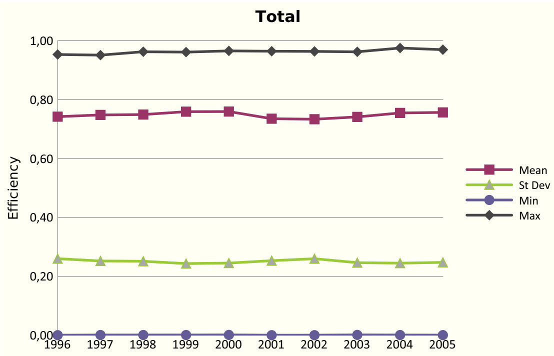
provided by Barro and Lee (2010) is more relevant in low-tech than in high-tech sectors. While an additional year of schooling has a strong impact on efficiency in low-tech activities, efficiency improvements in high-tech sectors are mainly induced by increases in "highly qualified" human capital (e.g. education at a post-graduate and doctoral level, specialist qualifications, etc.), which are not captured by Barro and Lee's data on years of schooling. Comparing OECD countries and Asia to Latin America reveals further interesting results. Whereas in the former the effect of schooling on low-tech sectors is only slightly higher than the effect on high-tech sectors, for Latin America the effect of schooling on efficiency in low-tech sectors is exceptionally strong, whereas the effect on high-tech sectors is relatively small and insignificant. This suggests that the quality of human capital in low-tech sectors is still very low in Latin America.

4.5 Conclusion

Using a stochastic frontier framework and data for 22 manufacturing sectors, we found notable differences in technical efficiency between a group of 10 OECD countries, 7 Asian countries and 5 Latin American countries. As the efficiency with which countries use frontier technology determines their capacity to absorb technology produced abroad, these differences are important to understand differences in growth and productivity, especially for developing countries which depend to a large extend on foreign technology. We examine the effect of two potential determinants of a country's absorptive capacity: human capital measured by years of schooling, and the effectiveness of domestic R&D, proxied by the stock of patents. We find that years of schooling always has a strongly positive effect on efficiency, especially in low-tech sectors and for developing countries. The stock of patents positively affects efficiency in high-tech sectors, but has a consistently negative effect on efficiency in low-tech sectors, especially for Asia and Latin America. To our knowledge, this is the first study using a stochastic frontier approach and sectoral data not only for OECD countries, but also for two groups of emerging economies. Using sectoral data permits us to disaggregate the efficiency effect of schooling and stock of patents between low-tech and high-tech sectors. However, as in many developing countries sectoral data has only been made available recently, and is not yet available to a sufficient extend for human capital, stock of R&D and patents, there is a lot of scope for future work once better data becomes available.

4.6 Appendix

Figure 15: Efficiency



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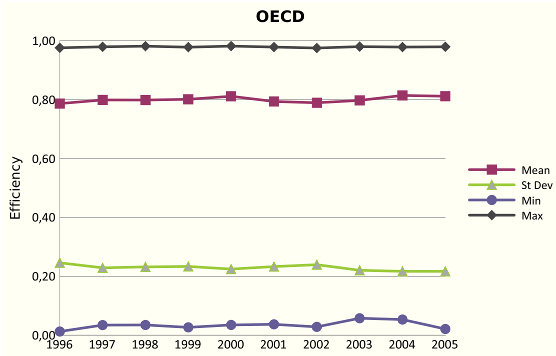

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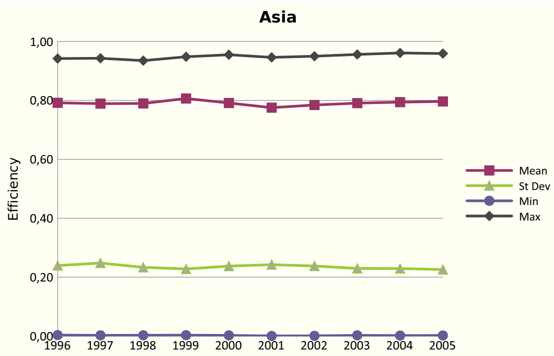

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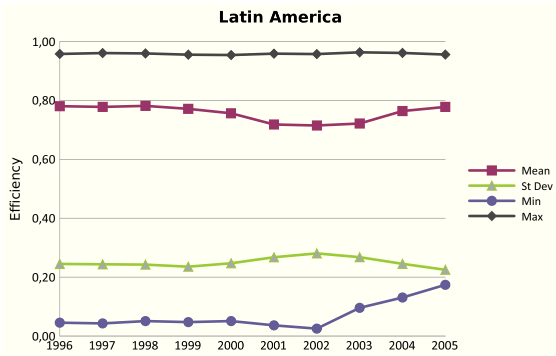


(d)

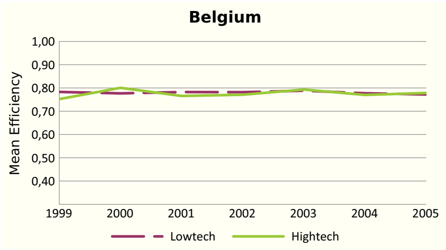
Table 10: Sector classification (ISIC Rev. 3)

15 Food and beverages	Low-tech
16 Tobacco products	Low-tech
17 Textiles	Low-tech
18 Wearing apparel	Low-tech
19 Leather, leather products and footwear	Low-tech
20 Wood products (excl. furniture)	Low-tech
21 Paper and paper products	Low-tech
22 Printing and publishing	Low-tech
23 Coke,refined petroleum products, nuclear fuel	Low-tech
24 Chemicals and chemical products	High-tech
25 Rubber and plastics products	Low-tech
26 Non-metallic mineral products	Low-tech
27 Basic metals	Low-tech
28 Fabricated metal products	Low-tech
29 Machinery and equipment n.e.c.	High-tech
30 Office, accounting and computing machinery	High-tech
31 Electrical machinery and apparatus	High-tech
32 Radio,television and communication equipment	High-tech
33 Medical, precision and optical instruments	High-tech
34 Motor vehicles, trailers, semi-trailers	High-tech
35 Other transport equipment	High-tech
36 Furniture; manufacturing n.e.c.	Low-tech

Table 11: Number of available sectors by country and year

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
Belgium				22	22	22	22	22	22	22	154
Bolivia	18	18	18								54
Chile	18	18	18	16	16	19	19	19	19		162
China								22	22	22	66
Colombia	18	18	18	18	21	20	20	20	20	20	193
Germany				18	22	22	22	22	22	22	150
Denmark	22	22	22	22	20	20	20	19	19	19	205
France	21	21	21	21	21	21	21	21	21	21	210
Indonesia					22	22	22	22	22	22	132
India	18	18	22	22	22	22	22	22	22	22	212
Italy	22	22	22	22	22	22	22	21	21	21	217
Japan	22	22	22	22	22	22	22	22	22	22	220
Korea	22	22	22	22	22	22	22	22	22	22	220
Mexico	22	22	22	22	22	22	22	21			175
Netherlands	22	22	22	22	22	21	21	21	21	21	215
Norway		21	22	22	21	21	21	21	22	21	192
Philippines							22	22	22	22	88
Sweden		21	21	21	21	21	21	21	21	21	189
Singapore	21	21	21	21	21	21	21	21	21	21	210
United Kingdom	22	22	22	22	22	22	22	22	22	22	220
United States	18	22	22	22	22	22	22	22	22	22	216
Urugay	18	18	21	21	21	21	21	21	21	21	204
Total	304	350	358	378	404	405	427	446	426	406	3,904

Figure 16: Mean efficiency by country - OECD



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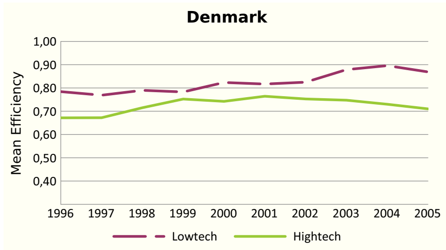

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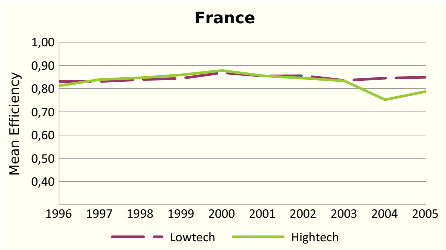

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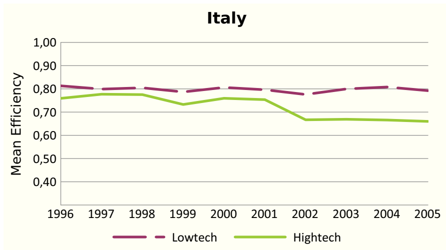

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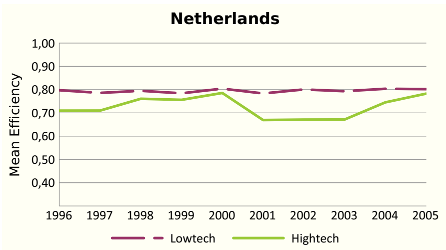

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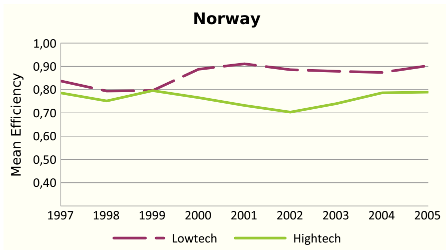

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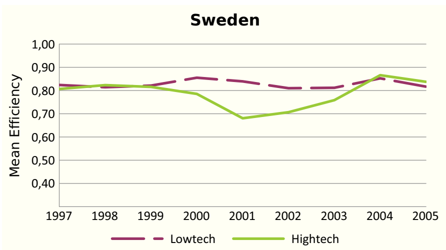

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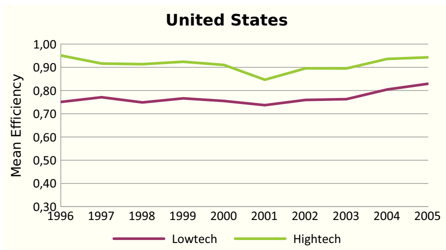

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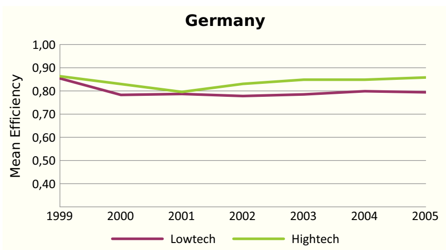

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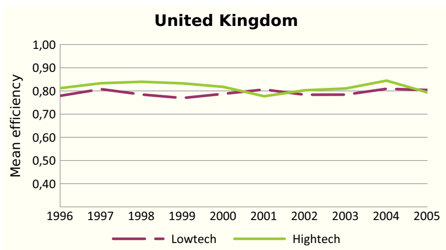
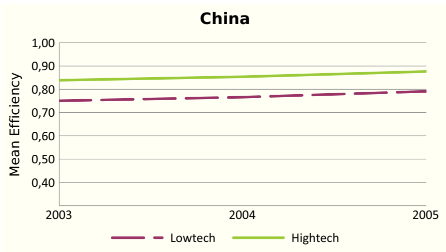
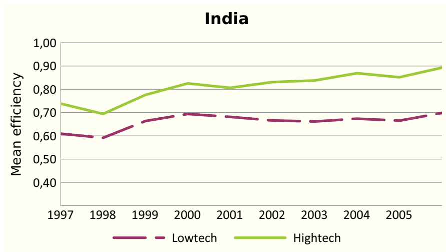


(j)

Figure 17: Mean efficiency by country - Asia



(a)



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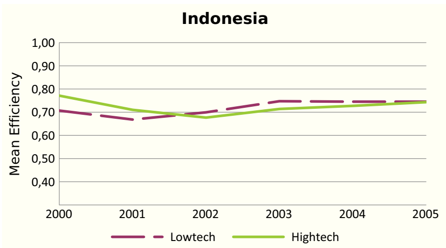

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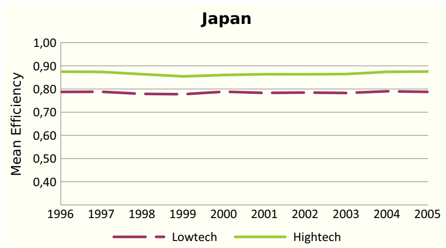

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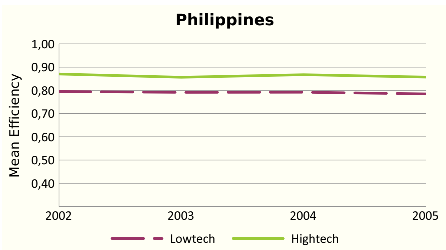

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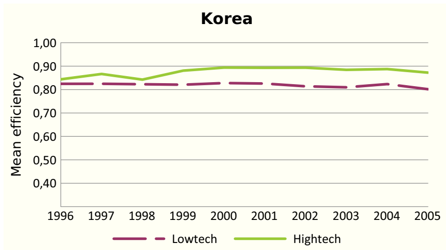

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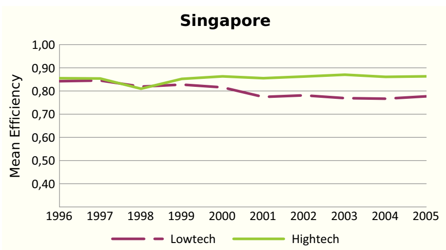
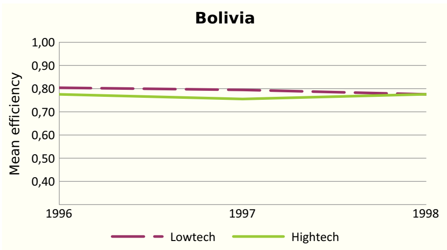
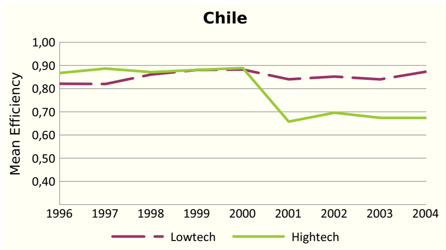


(g)

Figure 18: Mean efficiency by country - Latin America



(a)



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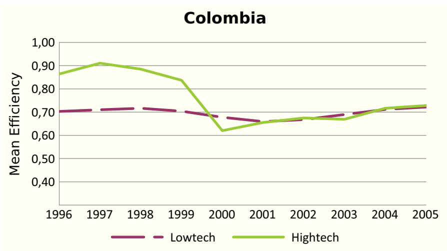

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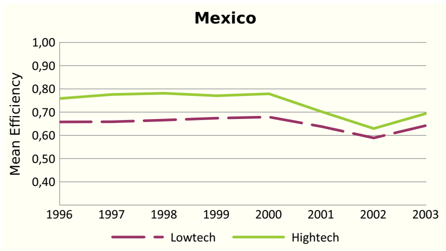

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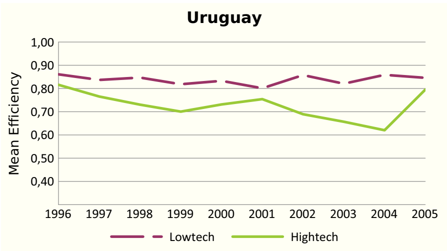

(e)

Chapter 5

Conclusion

In a world that is characterized by increasing economic integration, the spread of technology from the North to the South, and by concomitant productivity improvements in many emerging countries, two questions are of central importance. Should a country welcome productivity improvements in its backward trading partner? What are the factors that affect a country's ability to absorb foreign technology? My thesis is investigating these questions. The first chapter surveys the literature on international technology transfer through trade and FDI, on the welfare effects of productivity improvements in emerging countries, and on absorptive capacity. Some of the main results are summarized below. Trade and FDI are, both in theory and in practice, important vehicles for international technology transfer. Traditional trade models and product cycle models predict that productivity improvements in developing countries may hurt developed countries. However, a promising literature based on new trade models is offering more interesting frameworks to answer this question, where welfare is affected through channels that had so far remained unexplored. Absorptive capacity is quantitatively important in explaining differences in productivity across countries, with human capital and trade openness being important factors to enhance a country's ability to adopt foreign technology. In the second chapter, I investigate whether productivity improvements in emerging countries affect welfare of advanced countries they are trading with. I use a two-country model featuring pro-competitive effects of trade, where countries differ in the technology they have access to. To my knowledge, this is the first work combining an endogenous market structure framework with asymmetric countries that is also looking at the welfare effects generated by productivity improvements in backward countries. Calibrated to match firm-level and aggregate statistics of the US economy, the model predicts that the advanced country has a higher productivity cutoff level, higher average productivity and higher welfare than the laggard country, both in a closed and an open economy setting. Productivity improvements in the backward country lead to more selection and generate positive welfare effects in both countries, with both effects being stronger in the laggard country. A first extension to this work would be to allow for heterogeneous country preferences, which is a more realistic assumption in a world where countries have different technological capabilities. Second, it would be interesting to see if the main results still hold in a richer environment, where only the most productive firms export, and where the number of firms in each industry is endogenously determined by the response of the market structure. The third chapter, co-authored with Michael Rochlitz, explores differences in two determinants of absorptive capacity, namely human capital and local R&D, across three groups of ten OECD countries, seven Asian countries and five Latin American countries. To our knowledge, this paper is the first using stochastic frontier analysis and sectoral data to comparatively analyse efficiency levels and determinants across a group of both developed and developing countries. Secondly, instead of R&D expenditure, we use the stock of patents as a proxy for R&D. We find that human capital has a strong positive effect on efficiency, especially in low-tech sectors and for developing countries. The stock of patents positively affects efficiency in high-tech sectors, whereas it has a negative effect on efficiency in low-tech sectors, especially for Asia and Latin America. Once more and better sectoral data will become available for developing countries, it would be interesting to investigate the determinants of absorptive capacity and differences in efficiency levels in a larger sample of countries and for a longer time span. In addition, other important factors might be tested as potential determinants of absorptive capacity (e.g. domestic credit provided by financial sector), as well as better proxies for human capital might be found to disentangle differences in the levels of education on efficiency (e.g. number of students in engineering).

References

Abramovitz M (1986) Catching up, forging ahead, and falling behind. The Journal of Economic History 46(02):385–406 20, 57

Acemoglu D, Aghion P, Zilibotti F (2006) Distance to frontier, selection, and economic growth. Journal of the European Economic Association 4(1):37–74 20, 58

Aghion P, Howitt P (1992) A model of growth through creative destruction. Econometrica 60(2):323–51 10

Aghion P, Howitt P (2005) Growth with quality-improving innovations: an integrated framework. In: Aghion P, Steven D (eds) Handbook of Economic Growth, Handbook of International Economics, vol 1, chap 2, pp 68–97 59

Aigner D, Lovell CAK, Schmidt P (1977) Formulation and estimation of stochastic frontier production function models. Journal of Econometrics 6(1):21–37 22

Alcalà F, Ciccone A (2004) Trade and productivity. The Quarterly Journal of Economics 119(2):612–645 11

Amiti M, Konings J (2007) Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia. American Economic Review 97(5):1611–1638 13

Amsden AH (1989) Asia’s Next Giant: South Korea and Late Industrialization. Oxford University Press, Oxford 58

Amsden AH (2001) The Rise of the Rest: Challenges to the West from Late-Industrializing Economies. Oxford University Press, Oxford 58

Anderson JE, van Wincoop E (2004) Trade costs. Journal of Economic Literature 42(3):691–751 42, 43

Andrea Fosfuri MM, Ronde T (2001) Foreign direct investment and spillovers through workers' mobility. Journal of International Economics 53(1):205–222 15

Anthony Bende-Nabende JF, Slater J (2001) FDI, regional economic integration and endogenous growth: some evidence from Southest Asia. Empirical Economics 6(3):383–399 15

Axtell RL (2001) Zipf distribution of U.S. firm sizes. Science 293(5536):1818–1820 42, 43

Baldwin R, Braconier H, Forslid R (2005) Multinationals, endogenous growth, and technological spillovers: Theory and evidence. Review of International Economics 13(5):945–963 14

Barro RJ, Lee JW (2010) A new data set of educational attainment in the world, 1950-2010. NBER Working Paper 15902, National bureau of economic research 78

Bassanini A, Nunziata L, Venn D (2009) Job protection legislation and productivity growth in OECD countries. Economic Policy 24:349–402 72

Basu S, Fernald JG (1994) Constant returns and small markups in u.s. manufacturing. International Finance Discussion Papers 483, Board of Governors of the Federal Reserve System (U.S.) 43

Battese GE, Coelli TJ (1993) A stochastic frontier production function incorporating a model for technical inefficiency effects. Working Papers in Econometrics and Applied Statistics 69, Department of Econometrics. University of New England. Armidale 62

Battese GE, Coelli TJ (1995) A model for technical efficiency effects in a stochastic frontier production function for panel data. Empirical Economics 20(2):325–332 22, 60, 61

Benhabib J, Spiegel MM (1994) The role of human capital in economic development evidence from aggregate cross-country data. Journal of Monetary Economics 34(2):143–173 59

Benhabib J, Spiegel MM (2005) Human capital and technology diffusion. In: Aghion P, Durlauf S (eds) Handbook of Economic Growth, Handbook of Economic Growth, vol 1, Elsevier, chap 13, pp 935–966 59

Bhaumik SK, Kumbhakar SC (2010) Is the post-reform growth of the indian manufacturing sector efficiency driven? empirical evidence from plant-level data. Journal of Asian Economics 21(2):219–232 73

Bitzer J, Grg H, Schrder PJ (2008) Can trade really hurt? An empirical follow-up on Samuelson's controversial paper. Discussion Papers 08/34, University of Nottingham, GEP 19, 26

Blalock G, Gertler P (2003) Technology from foreign direct investment and welfare gains through the supply chain. Working papers, Department of Applied Economics and Management, Cornell University 16

Brander J, Krugman P (1983) A 'reciprocal dumping' model of international trade. Journal of International Economics 15(3-4):313–321 27

Breznitz D, Murphree M (2011) Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China. Yale University Press, New Haven 58

Brian Aitken AH, Lipsey RE (1996) Wages and foreign ownership a comparative study of Mexico, Venezuela, and the United States. Journal of International Economics 40(3-4):345–371 15

Brouwer E, Kleinknecht A (1999) Innovative output, and a firm's propensity to patent: An exploration of CIS micro data. Research Policy 28(6):615–624 76

Caselli F, Wilson DJ (2004) Importing technology. Journal of Monetary Economics 51(1):1–32 57, 63

Castillo LL, Salem DS, Guasch JL (2012) Innovative and absorptive capacity of international knowledge: an empirical analysis of productivity sources in Latin American countries. Policy Research Working Paper Series 5931, The World Bank 69

Cimoli M, Katz J (2003) Structural reforms, technological gaps and economic development: A Latin American perspective. Industrial and Corporate Change 12(2):387–411 69

Coe DT, Helpman E (1995) International R&D spillovers. European Economic Review 39(5):859–887 12, 63, 68, 69

Cohen WM, Levinthal DA (1989) Innovation and learning: The two faces of R&D. Economic Journal 99(397):569–96 59

Connolly M (2003) The dual nature of trade: measuring its impact on imitation and growth. Journal of Development Economics 72(1):31–55 13

Das S (1987) Externalities, and technology transfer through multinational corporations. a theoretical analysis. Journal of International Economics 22(1-2):171–182 14

David T Coe EH, Hoffmaister A (1997) North-South R&D spillovers. Economic Journal 107(440):134–49 12

D'Costa AP (2003) Uneven and combined development: Understanding India's software exports. World Development 31(1):211–226 73

Demidova S (2008) Productivity improvements and falling trade costs: Boon or bane? International Economic Review 49(4):1437–1462 18, 26, 45, 46

Dollar D (1992) Outward-oriented developing economies really do grow more rapidly: Evidence from 95 LDCs, 1976-1985. Economic Development and Cultural Change 40(3):523–44 11

Dollar D, Kraay A (2003) Institutions, trade, and growth. Journal of Monetary Economics 50(1):133–162 11

Eaton J, Kortum S (1996) Trade in ideas patenting and productivity in the OECD. Journal of International Economics 40(3-4):251–278 12

Eaton J, Kortum S (2001) Trade in capital goods. European Economic Review 45(7):1195–1235 57, 63

Edwards S (1993) Openness, trade liberalization, and growth in developing countries. Journal of Economic Literature 31(3):1358–93 12

Fagerberg J (1994) Technology and international differences in growth rates. Journal of Economic Literature 32(3):1147–75 59

Gary Koop JO, Steel MFJ (2000) Modeling the sources of output growth in a panel of countries. Journal of Business & Economic Statistics 18(3):284–99 22

Gerschenkron A (1962) Economic Backwardness in Historical Perspective: A Book of Essays. Harvard University Press, Cambridge 20, 57

Gershenberg I (1987) The training and spread of managerial know-how, a comparative analysis of multinational and other firms in kenya. World Development 15(7):931–939 15

di Giovanni J, Levchenko AA, Zhang J (2011) The global welfare impact of China: Trade integration and technological change. Working Papers 625, Research Seminar in International Economics, University of Michigan 19, 26

Glass AJ, Saggi K (2001) Innovation and wage effects of international outsourcing. European Economic Review 45(1):67–86 17

Glass AJ, Saggi K (2002) Intellectual property rights and foreign direct investment. Journal of International Economics 56(2):387–410 11, 14, 15

Griffith R, Redding S, Reenen JV (2003) R&d and absorptive capacity: Theory and empirical evidence. Scandinavian Journal of Economics 105(1):99–118 59

Griffith R, Redding S, Reenen JV (2004) Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. The Review of Economics and Statistics 86(4):883–895 59, 61, 68

Griliches Z (1984) Market value, r&d, and patents. In: R&D, Patents, and Productivity, NBER Chapters, National Bureau of Economic Research, Inc, pp 249–252 66

Griliches Z, Lichtenberg FR (1984) R&d and productivity growth at the industry level: Is there still a relationship? In: R&D, Patents, and Productivity, NBER Chapters, National Bureau of Economic Research, Inc, pp 465–502 63

Grossman GM, Helpman E (1991) Endogenous product cycles. Economic Journal 101(408):1214–29 17

Grossman GM, Helpman E (1993) Innovation and Growth in the Global Economy, MIT Press Books, vol 1. The MIT Press 10, 11

Grossman GM, Helpman E (1995) Technology and trade. In: Grossman GM, Rogoff K (eds) Handbook of International Economics, Handbook of International Economics, vol 3, Elsevier, chap 25, pp 1279–1337 12

Gustafsson P, Segerstrom P (2010) North-South trade with increasing product variety. Journal of Development Economics 92(2):97–106 11

Hall BH, MacGarvie M (2010) The private value of software patents. Research Policy 39(7):994–1009 66

Hallak JC, Levinsohn J (2004) Fooling ourselves: Evaluating the globalization and growth debate. Working Papers 509, Research Seminar in International Economics, University of Michigan 12

He Y, Maskus KE (2012) Southern innovation and reverse knowledge spillovers:A dynamic FDI model. International Economic Review 53(1):279–302 14

Heathcote J, Perri F (2002) Financial autarky and international business cycles. Journal of Monetary Economics 49(3):601–627 43

Helper JP Susan; MacDuffie (1997) Creating lean suppliers: Diffusing lean production through the supply chain. California Management Review 39(4):118–151 16

Helpman E (1993) Innovation, imitation, and intellectual property rights. Econometrica 61(6):1247–80 14

Hicks J (1953) An inaugural lecture. Oxford Economic Papers 5(2):117–135 7, 18

Howitt P (1999) Steady endogenous growth with population and R&D inputs growing. Journal of Political Economy 107(4):715–730 11

Hsieh CT, Ossa R (2011) A global view of productivity growth in China. NBER Working Papers 16778, National Bureau of Economic Research, Inc 18, 19, 26

Huizinga H (1995) Taxation and the transfer of technology by multinational firms. Canadian Journal of Economics 28:648–655 14

IMF (1997) World Economic Outlook. World Economic and Financial Surveys 1

Impullitti G, Licandro O (2010) Trade, firm selection, and innovation: the competition channel. UFAE and IAE Working Papers 841.10, Unitat de Fonaments de l'Anàlisi Econòmica (UAB) and Institut d'Anàlisi Econòmica (CSIC) 3, 27, 35, 38, 39, 42, 47

Irwin DA, Terviö M (2002) Does trade raise income?: Evidence from the twentieth century. Journal of International Economics 58(1):1–18 12

Islam MR (2009) R&D intensity, technology transfer and absorptive capacity. Monash Economics Working Papers 13-09, Monash University, Department of Economics 21

Islam MR (2010) Human capital composition, proximity to technology frontier and productivity growth. Monash Economics Working Papers 23-10, Monash University, Department of Economics 21

Javorcik BS (2004) Does foreign direct investment increase the productivity of domestic firms? in search of spillovers through backward linkages. American Economic Review 94(3):605–627 16

Jones CI (1995a) R&D-based models of economic growth. Journal of Political Economy 103(4):759–84 11

Jones CI (1995b) Time series tests of endogenous growth models. The Quarterly Journal of Economics 110(2):495–525 11

Jones RW, Ruffin RJ (2008) The technology transfer paradox. Journal of International Economics 75(2):321–328 18, 25

Keller W (1998) Are international R&D spillovers trade-related?: Analyzing spillovers among randomly matched trade partners. European Economic Review 42(8):1469–1481 12, 13

Keller W (2000) Do trade patterns and technology flows affect productivity growth? World Bank Economic Review 14(1):17–47 13

Kenny M, Florida R (1993) Beyond Mass Production: The Japanese System and Its Transfer to the US. Oxford University Press 16

Kim S, M S (2012) Economic reform and total factor productivity growth in Indian manufacturing industries. Review of Development Economics 16(1):152–166 73

Kneller R (2005) Frontier technology, absorptive capacity and distance. Oxford Bulletin of Economics and Statistics 67(1):1–23 21, 61, 68

Kneller R, Stevens PA (2006) Frontier technology and absorptive capacity: Evidence from OECD manufacturing industries. Oxford Bulletin of Economics and Statistics 68(1):1–21 22, 59, 63, 64, 68, 69, 75, 77

Koop G, Osiewalski J, Steel MFJ (1999) The components of output growth: A stochastic frontier analysis. Oxford Bulletin of Economics and Statistics 61(4):455–87 22

Krugman P (1979) A model of innovation, technology transfer, and the world distribution of income. Journal of Political Economy 87(2):253–266 11, 17

Kumbhakar SC, Ghosh S, McGuckin JT (1991) A generalized production frontier approach for estimating determinants of inefficiency in u.s. dairy farms. Journal of Business & Economic Statistics 9(3):279–86 60

Kumbhakar SC, Ortega-Argils R, Potters L, Vivarelli M, Voigt P (2011) Corporate R&D and firm efficiency: Evidence from european top R&D investors. Journal of Productivity Analysis, forthcoming 76

Lai ELC (1998) International intellectual property rights protection and the rate of product innovation. Journal of Development Economics 55(1):133–153 11, 14

Lee JW (1995) Capital goods imports and long-run growth. Journal of Development Economics 48(1):91–110 12

Levchenko AA, Zhang J (2011) The evolution of comparative advantage: Measurement and welfare implications. NBER Working Papers 16806, National Bureau of Economic Research, Inc 20, 26

Liao H, Liu X, Holmes M, Weyman-Jones T (2009) The impact of foreign R&D on total factor productivity in the East Asian manufacturing industry. Manchester School 77(2):244–270 68

Lin P, Saggi K (2005) Multinational firms and backward linkages: a critical survey and a simple model. In: Does Foreign Direct Investment Promote Development?, Institute for International Economics, Washington, DC. 16

López RA (2005) Trade and growth: Reconciling the macroeconomic and microeconomic evidence. Journal of Economic Surveys 19(4):623–648 11

Lotti F, Schivardi F (2005) Cross country differences in patent propensity: A firm-level investigation. Giornale degli Economisti 64(4):469–502 76

Lucas RJ (1988) On the mechanics of economic development. Journal of Monetary Economics 22(1):3–42 10

Luttmer EGJ (2007) Selection, growth, and the size distribution of firms. The Quarterly Journal of Economics 122(3):1103–1144 42

M Masoom Ali MP, Woo J (2010) On the ratio of two independent exponentiated Pareto variables. Austrian Journal of Statistics 39(4):329340 42

Madden G, Savage S, Bloxham P (2001) Asian and OECD international R&D spillovers. Applied Economics Letters 8(7):431–435 60

Madsen JB, Islam MR, Ang JB (2010) Catching up to the technology frontier: the dichotomy between innovation and imitation. Canadian Journal of Economics 43(4):1389–1411 59, 60

Markusen JR, Venables AJ (1999) Foreign direct investment as a catalyst for industrial development. European Economic Review 43(2):335–356 16

Mastromarco C (2008) Foreign capital and efficiency in developing countries. Bulletin of Economic Research 60(4):351–374 22, 57, 59, 77

Mastromarco C, Ghosh S (2009) Foreign capital, human capital, and efficiency: A stochastic frontier analysis for developing countries. World Development 37(2):489–502 23

Mastromarco C, Ghosh S (2010) Cross-border activities, human capital and efficiency. Working paper, The University of Salento, The University of Akron 23

Mastromarco C, Zago A (2009) Technology shape, distance to frontier, or frontier shift? modeling the determinants of TFP growth. Working Papers 57/2009, Universit di Verona, Dipartimento di Scienze economiche 21

Meeusen W, van den Broeck J (1977) Efficiency estimation from Cobb-Douglas production functions with composed error. International Economic Review 18(2):435–44 22

Melitz MJ (2003) The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica 71(6):1695–1725 18, 28, 46

Melitz MJ, Ottaviano GIP (2008) Market size, trade, and productivity. Review of Economic Studies 75(1):295–316 27

Michael Henry RK, Milner C (2009) Trade, technology transfer and national efficiency in developing countries. European Economic Review 53(2):237–254 22, 59, 62, 63

Miller SM, Upadhyay MP (2000) The effects of openness, trade orientation, and human capital on total factor productivity. Journal of Development Economics 63(2):399–423 20, 59, 60

Narula R, Marin A (2003) FDI spillovers, absorptive capacities and human capital development: evidence from Argentina. Research memoranda, Maastricht : MERIT, Maastricht Economic Research Institute on Innovation and Technology 20

Neary PJ (2002) Globalisation and market structure. Working Papers 200220, School Of Economics, University College Dublin 27

Neary PJ (2009) International trade in general oligopolistic equilibrium. Working papers, University of Oxford and CEPR 27

Nelson R PE (1966) Investment in humans, technological diffusion, and economic growth. American Economic Review 56(1/2):69–75 59

Noguer M, Siscart M (2005) Trade raises income: a precise and robust result. Journal of International Economics 65(2):447–460 11

Okabe M (2002) International R&D spillovers and trade expansion: Evidence from East Asian economies. Asian Economic Bulletin 19(2):141–154 60

Pack H (1997) The role of exports in asian development. In: Pathways to growth: Comparing East Asia and Latin America, Washington, D.C.: Inter-American Development Bank 15

Pack H, Saggi K (2001) Vertical technology transfer via international outsourcing. Journal of Development Economics 65(2):389–415 16

Parente SL, Prescott EC (1994) Barriers to technology adoption and development. Journal of Political Economy 102(2):298–321 9

Paul S Segerstrom TCAA, Dinopoulos E (1990) A Schumpeterian model of the product life cycle. American Economic Review 80(5):1077–91 10, 11

Prescott EC (1998) Needed: A theory of total factor productivity. International Economic Review 39(3):525–51 58

Rauch JE (1999) Networks versus markets in international trade. Journal of International Economics 48(1):7–35 43

Reifschneider D, Stevenson R (1991) Systematic departures from the frontier: A framework for the analysis of firm inefficiency. International Economic Review 32(3):715–23 60

Rivera-Batiz LA, Romer PM (1991) Economic integration and endogenous growth. The Quarterly Journal of Economics 106(2):531–55 10

Rodriguez F, Rodrik D (2001) Trade policy and economic growth: A skeptic's guide to the cross-national evidence. In: NBER Macroeconomics Annual 2000, Volume 15, NBER Chapters, National Bureau of Economic Research, Inc, pp 261–338 12

Rodriguez-Clare A (1996) Multinationals, linkages, and economic development. American Economic Review 86(4):852–73 16

Rodrik D, Subramanian A, Trebbi F (2004) Institutions rule: The primacy of institutions over geography and integration in economic development. Journal of Economic Growth 9(2):131–165 12

Rojas-Suarez L (2010) The international financial crisis: Eight lessons for and from Latin America. Working Papers 202, Center for Global Development 73

Romer PM (1990) Endogenous technological change. Journal of Political Economy 98(5):S71–102 10

Ruhl KJ (2008) The international elasticity puzzle. Working Papers 08-30, New York University, Leonard N. Stern School of Business, Department of Economics 43

Sachs JD, Warner A (1995) Economic reform and the process of global integration. Brookings Papers on Economic Activity 26(1, 25th A):1–118 11

Saggi K (2002) Trade, foreign direct investment, and international technology transfer: A survey. World Bank Research Observer 17(2):191–235 7, 9, 11, 13

Samuelson PA (2004) Where Ricardo and Mill rebut and confirm arguments of mainstream economists supporting globalization. Journal of Economic Perspectives 18(3):135–146 18, 19, 25

Segerstrom PS (1998) Endogenous growth without scale effects. American Economic Review 88(5):1290–1310 11

Senhadji A (2000) Sources of economic growth: An extensive growth accounting exercise. IMF Staff Papers 47(1):6 59, 60

Shachmurove Y, Spiegel U (2009) Ricardo meets China, India and U.S. three hundred years later. PIER Working Paper Archive 09-015, Penn Institute for Economic Research, Department of Economics, University of Pennsylvania 18

Sinani E, Meyer KE (2004) Spillovers of technology transfer from FDI: the case of Estonia. Journal of Comparative Economics 32(3):445–466 15

Tsai KH, Wang JC (2004) R&d productivity and the spillover effects of high-tech industry on the traditional manufacturing sector: The case of Taiwan. The World Economy 27(10):1555–1570 76

UNCTAD (1992) World investment report: Transnational corporations as engines of growth. United Nations, New York 15

Van Ark B MR Inklaar R (2003) Changing gear′ - productivity, ICT and service industries in Europe and the United States. In: Christensen J Me (ed) The Industrial Dynamics of the New Digital Economy, Edward Elgar, Cheltenham 72

Venables AJ (1985) Trade and trade policy with imperfect competition: The case of identical products and free entry. Journal of International Economics 19(1-2):1–19 27

Vernon R (1966) International investment and international trade in the product cycle. The Quarterly Journal of Economics 80(2):190–207 11

Verspagen B (1991) A new empirical approach to catching up or falling behind. Structural Change and Economic Dynamics 2(2):359–380 59

Wade R (1990) Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization. Princeton University Press, Princeton 58

Wang JY (2007) Trade, human capital, and technology spillovers: An industry-level analysis. Review of International Economics 15(2):269–283 60

Wang JY, Blomström M (1992) Foreign investment and technology transfer: A simple model. European Economic Review 36(1):137–155 14

Xu B, Wang J (1999) Capital goods trade and R&D spillovers in the OECD. Canadian Journal of Economics 32:1258–1274 13