Multinationals, Technological Incompatibilities, and Spillovers *

Juan Carluccio and Thibault Fally

Paris School of Economics

Abstract

Empirical studies provide evidence of strong, positive spillovers from multinational firms to upstream suppliers, coupled with weak or negative spillovers to firms in the same industry. This paper shows that these empirical regularities can be rationalized in a model with incompatibilities between foreign and domestic technologies. When the availability of specialized intermediates affects productivity, technological incompatibilities create a competition between foreign and domestics firms in attracting local suppliers. This leads to an equilibrium with "technological segmentation", under which some entrepreneurs self-select into the production for MNEs. This type of segmentation in the upstream industry amplifies the productivity advantage of multinationals, by restricting backward and forward linkages to groups of firms using the same technology. In the long run, the possibility of technology adoption by the most productive domestic firms creates complementarities between them and multinationals that might, depending on certain conditions, offset the negative impact of segmentation and lead to welfare gains from foreign entry. *JEL: F23, O14.*

*We are indebted to Thierry Verdier for helpful comments and suggestions. We also thank Jerome Pouyet for helpful discussions on earlier drafts of the paper and the seminar participants at the RIEF doctoral meetings 2008, the University of Modena, the Paris School of Economics, and the 2007 Spring Meeting of Young Economists. We are responsible for any remaining errors. Contacts: juan.carluccio@ens.fr and fally@ens.fr

1 Introduction

The host country effects of Foreign Direct Investment (FDI) constitute a traditional concern in development economics. One of the consequences of the impressive surge in FDI flows witnessed in last decades was to bring this debate back into the fore. Current view about the impact of multinationals is optimistic, and there is a general feeling that, in many circumstances, their arrival can significantly contribute to the development process in destination economies. A manifestation of this feeling is given by the inclusion of FDI attraction policies as a central element in wider development policy packages by governments all over the developing world[1]. Moreover, the attraction of foreign investment seems to be also a high priority in the policy agenda of development agencies such as the World Bank, the IMF and the OECD.

Among the various potential channels through which Foreign Direct Investment (FDI) is expected to enhance the development process in host economies, productivity and technological externalities to domestic firms is often cited as a salient one. Nevertheless, our understanding of this issue is far from being exhaustive. Much of efforts from the economics profession has been put on the empirical side, trying to test whether in fact spillovers of this kind do occur in the real world. Typically, studies regress a measure of firm-level productivity for domestic firms on a measure of foreign presence at the sectoral level. Empirical work of this type has failed to find evidence of positive spillovers at the horizontal level, that is, to firms acting in the same sectors are MNEs. Furthermore, many studies have found negative impacts[2]. On the other hand, works testing for vertical spillovers, i.e. for externalities to upstream suppliers, provide much more optimistic results. Multinational presence do appears to be correlated with productivity and technological improvements in firms located in supplying industries.

Put together, these two empirical regularities are somewhat puzzling. If the arrival of multinational firms causes substantial improvements in the local supply chain, then we would expect these in turn to spill over, to some extent, to domestic producers, who as a result have access to a base of suppliers of improved quality.

This paper develops a simple model to study spillovers from multinational to domestic firms via the development of linkages. We argue that one plausible explanation for the above mentioned facts might be found in the nature of backward and forward linkages between multinational firms and local suppliers. The model is built around the key assumption that foreign and domestic technologies are essentially different. Other than differences in productive efficiency, a crucial aspect of these differences is that the foreign technology requires specialized

[1]For example, UNCTAD (2006) documents that the annual number of worldwide changes in regulations that favor FDI grew from 77 in 1992 to 205 in 2005.

[2]A synthetic review of the empirical literature is provided in Section 2. Nevertheless, the empirical literature on FDI and spillovers is vast. Readers interested in comprehensive surveys may be referred to Barba and Navaretti (2004, Ch. 7), Lipsey (2002) and Bolmstrom and Kokko (1997), among others.

inputs. This is what we term technological incompatibilities.

Upon arrival to a developing economy, foreign firms set up their production plants which operate with technologies designed in northern headquarters. Doing so, they do not simply extend the local market for intermediates goods, but rather they create a new market for customized intermediates. Provided that there are costs associated to the specialization of inputs, local entrepreneurs in supplying industries are faced with the decision of whether to upgrade their products to make them compatible with foreign plants, or to stick to domestic methods and cater to local producers. One example of this type of incompatibilities is provided by a recent case study on the Mexican Soaps, Detergents and Surfactant industry by Javorcik et al (2006). When Mexico opened its borders to foreign investors, a massive entry of US multinationals occurred. Incoming US multinationals brought with them technologies and product formats which were previously unavailable locally, and that had been developed based on environmental awareness of American consumers (e.g. "compacts formulas"). These products require inputs of high quality and tailored to the particular specifications of the technology. The report documents how suppliers that were catering to multinationals (some themselves foreign-owned) had to reformulate their inputs by substituting foreign standards with cheaper ingredients when catering to domestic producers. Moreover, Mexican producers of detergents were impeded to incorporate the foreign technology without incurring in substantial costs of reformatting their products.

Incompatibilities give rise to a competition for suppliers arises, giving rise to an industry equilibrium with "technological segmentation", in which some local suppliers are attached to the multinationals value chain and cease to supply domestic firms. In cases where technology is such that productive efficiency increases with the number of available intermediate varieties, equilibrium in input markets have direct consequences in the productivity of downstream firms.

The model shows how the productivity advantage of foreign plants is endogenously amplified in equilibrium, because segmentation of the upstream industry makes the virtuous circularity of backward and forward linkages remain within the limits of groups of firms using the same technology. Furthermore, in some cases, the harmful effects of segmentation might go as far as to outweigh consumer welfare gains from the introduction of a more advanced technology.

An extension of the baseline model to a situation in which inputs are partially, but not completely, compatible across technologies reveals that the basic mechanisms we describe are robust to allowing for the more realistic case of partial compatibility. Moreover, we argue that it is suggesting of a mechanism that understands voluntary private standards as a commitment device preventing multinational corporations to deviate from common technological standards. Further, we show how segmentation rationalizes anecdotal evidence suggesting that multinationals tend to source from a small group of local suppliers that are located at the right tail of the productivity distribution. We then suggest that the dispersion in suppliers capabilities might be a relevant variable defining MNE's preferred locations.

In the basic model, domestic final producers cannot benefit from the presence of multinationals. We acknowledge that this assumption, however useful, is extreme. We then develop a long run version of the model in which domestic final producers are able to adopt the technology operated by foreign plants, by imitation or reverse engineering for example. Given that this knowledge is otherwise unavailable for local producers, FDI can be seen as an international conductor of technology. To account for the fact that only a portion of local firms tend to benefit from the contact with multinationals, we assume that domestic firms are heterogeneous in productivity, and that downstream adoption requires extra fixed costs, as in the case of suppliers. The model develops a self-selection mechanism by which most productive firms decide to adopt the foreign technology, a result that is in line with empirical work showing that firms at the highest range of productivity are those that benefit from positive spillovers[3]. Technology adoption by the most productive firms creates complementarities between them and multinationals that might trigger further adoption of the foreign technology. We study the conditions leading the economy with FDI to a long run equilibrium that outweighs autarky in welfare terms.

Our model contributes to a small, but growing, formal literature studying backward linkages between multinational firms and local suppliers. The initiative work is that by Rodriguez-Clare (1996) who develops an aggregate model in which multinationals sources headquarters services in the home economy and take advantage of low wages in the underdeveloped host economy. If the intensity with which they source local inputs, the "linkage potential", is high enough, MNEs create higher net backward linkages, pushing the underdeveloped region out of the "bad" equilibrium. Markusen and Venables (1999), develop a similar intuition in an industrial organization approach that is closer to ours. They show how, under certain conditions, multinationals may boost the upstream industry by a cumulative causation process. MNEs, contrary to imports, create backward linkages in the local economy. The increase in the number of available intermediate varieties that follows puts downward pressure in the costs of all downstream firms, including domestic ones; a forward linkage. In their model, domestic firms, by assumption more intensive users of local inputs, benefit relatively more from this forward linkage. As a consequence, there exist dynamic paths leading to a long run equilibrium in which only foreign firms are forced-out and only domestic firms prevail. Finally, Lin and Saggi (2007) develop a related idea in a model of a two-tier Cournot oligopoly in which multinationals propose exclusivity contracts to local suppliers, that might include vertical technology transfers. This allows them to study how exclusivity affects the level of backward linkages and welfare. Nevertheless, none of these papers emphasizes the role of technological differences between multinationals and domestic firms, and their different requirements in terms of intermediates, as a relevant factor.

The rest of the papers is organized as follows. Section 2 reviews empirical evidence regarding multinationals and local firms, which is gathered in a series of stylized facts. Section 3 presents the set up of the model and discusses its main assumptions. Section 4 provides a solution of a "short run" version of

[3]e.g. Girma and Gorg (2005).

the model, with an exogenous number of domestic and multinational firms, of two extensions are developed in Section 5. In Section 6 we develop a long run version of the model in which we introduce free entry conditions as well as the possibility for heterogeneous domestic firms to adopt the foreign technology. Section 7 concludes.

2 Multinationals and local firms: some stylized facts

In this section we review available empirical and anecdotal literature regarding relationships between multinational firms and local suppliers in developing countries, that we take as motivation for our theoretical analysis. In order to ease exposition, we gather the different aspects of interest in a series of stylized facts.

Fact 1: MNEs are more productive than purely domestic firms, and use different technologies.

Multinational firms have been systematically found to display higher measures of productivity than domestic firms acting in the same industries, for both developed and developing economies. These differences persist even after controlling for the fact that FDI tends to be directed to skill- and technology-intensive sectors, and apply to comparisons against firms in both host and home economies. Examples of evidence for developed countries includes the UK (Griffith and Simpson 2001, Criscuolo and Martin 2001), the US (Doms and Jensen (1998)), and Italy (Benfratello and Sembrenelli 2002). Productivity premia seems to be higher in the case of developing countries. Studies confirming this include Blomstrom and Wolff (1994) for Mexico, Haddad and Harrison (1994 for Morocco, 1999 for Venezuela), Sjholm (1999) for Indonesia and Kokko et al (1994) for Uruguay. In correspondence with their higher productivity, MNEs tend also to be larger than purely domestic firms, both in comparison with non-MNEs in host as well as at home countries (Barba Navaretti and Venables 2004, page 13 and Ch. 7).

These observed differences in labor or total factor productivity are consistent with the notion that foreign affiliates have access to more complex and efficient technological and managerial methods than domestic firms in host developing countries. An illustrative example of the consequences this implies for the relationships with suppliers in developing economies is given by the Mexican industry case study by Javorcik et al cited in the introduction.

Fact 2: Multinational firms increasingly source inputs in host countries.

Evidence show that multinationals create linkages with local suppliers in their countries of operation. Batra et. al. (2003), using a manufacturing survey for Malaysia, calculate that foreign affiliates have a higher probability of establishing vertical linkages with local suppliers than domestic firms. Similarly, a detailed case study report by Sutton (2001) on the development of the automotive industry in India and China in the 1990s concludes that foreign car manufacturers rely intensively on local suppliers, in concordance with the trend seen in that industry in the developing world. Rodriguez-Clare and Alfaro (2003) develop a linkage coefficient as the ratio of inputs bought domestically to workers. They empirically apply this measure in a comparative study of four Latin American economies to find that, in three cases, foreign affiliates' "backward linkage potential" is statistically significantly higher than that of domestic firms. O'Malley (1995) uses the same measure for Irish manufacturing industry, arriving to similar conclusions. Evidence for Ireland is also found in Forfas (1999) and Gorg and Ruane (2001), the latter gives evidence that linkages increase over time.

Fact 3: Positive externalities from FDI tend to diffuse vertically along the supply chain rather than horizontally to firms in the same sector as MNEs

A large amount of empirical work has paid attention to the question of whether increased foreign presence is positively correlated with productivity of domestic firms. Results of work studying horizontal externalities tend to be mixed, with a general failure to find positive externalities, and in fact many times providing evidence of negative externalities. A widely-cited example is given by Aitken and Harrison (1999), who study the case of Venezuela and find that while foreign ownership increases the productivity of a plant, higher MNE presence is associated with a negative effect on domestic-owned plants' productivity. Other examples failing to find positive externalities from MNEs at the horizontal level for developing countries are those of Djankov and Hoekman (2000) for the Czech Republic and Konings (2000) for a set of countries. Findings regarding the existence of vertical spillovers are are much more consistent and optimistic. In her study using a panel of Lithuanian manufacturing firms for the period 1996-2000, Javorcik (2004), finds evidence consistent with positive externalities of suppliers from increased foreign presence in downstream sectors, which implies a higher probability of supplying MNEs. This effect is higher for firms with sales oriented to the local market. On the other hand, her data rejects the hypothesis of horizontal externalities. Similarly, Blalock and Gertler (2007) provide evidence for Indonesia. Along these lines, Batra et al (2003) find that vertical linkages result in productivity gains for Malaysian suppliers when technology transfers are taken into account. Using an alternative method, Kugler (2005) supports the notion of inter-sectoral externalities by showing that FDI in one sector in Colombian manufacturing can Granger-cause productivity gains in other sectors, but does not find evidence of intra-sectoral spillovers. Finally, in the already cited case study in Indian and Chinese automotive industries, Sutton reports that first-tier suppliers of multinational carmakers increased their productivity and quality measures, arriving to European best practices in terms of defect rates; however, these improvements did not diffuse to lower-tier suppliers.

Fact 4: Multinational firms tend to deal with a small, selected base of "best" suppliers, who comply with international standards.

Case study evidence points towards the notion that foreign affiliates tend to develop close relationships with a limited base of local suppliers, which are selected through a lengthy and careful process. The following paragraph of the UNCTAD World Investment Report 2001 (page 137) is illustrative:

> "[MNEs] tend to reduce the number of first-tier suppliers and enter into closer relationships with those that remain. These core suppliers are expected to have a capability to manufacture and supply –on a global basis – complex systems, to have independent design capacity and to solve problems jointly with the assembler. Such requirements make it more difficult for domestic suppliers in host countries to enter the supply chain (Suzuki's affiliate in Hungary, for example, only negotiates with potential suppliers that are already ISO9000 and QS9000 certified)".

In relation to this, one characteristic that is often cited is the role played by local capabilities in the development of deep backward linkages between local and foreign firms. Multinational firms name the failure of local suppliers to comply with their requirements in terms of quality, price, and time delivery as major obstacles to the development of backward linkages in the host economy[4]. Foreign affiliates have been described as "'talent scouts' in search of local SMEs capable of becoming global suppliers to the firm" (OECD, 2002).

Rigorous econometric studies testing the proposition that only suppliers in the upper tail of the distribution of local capabilities qualify to cater to large foreign-owned corporations are not available to date[5]. However, support to this view can be found in indirect as well as anecdotal evidence. Javorcik and Spatareanu (2008), based on a panel of Romanian firms, find that only in the case of partially-owned foreign downstream projects a positive effect on suppliers' productivity takes place. They attribute their findings to the fact that firms with some local ownership have better information about the host economy and thus may have easier access to the best local suppliers. Some studies differentiate suppliers according to human capital and R+D intensity to find that only those firms with higher capacities are those receiving positive externalities from inward FDI (Chudnovsky et al (2004) for the case of Argentina, Schoors and van der Tol (2001) for Hungary); selection effects are one plausible explanation for

[4]FIAS (1997).

[5]Such a study might prove quite exigent in terms of the required data. One would have to know the ex ante (i.e. before FDI) distribution of local capabilities and match the most capable suppliers to the ex post distribution of contracts with multinationals. Note that evidence that show that MNEs suppliers are on average more capable than firms supplying only domestic firms would not be much telling, as there is evidence that working for MNEs increases suppliers capabilities (e.g. Sutton 2001)

this result[6]. Blalock and Gertler (2007) provide some anecdotal evidence from interviews to managers of American and Japanese companies with presence in Indonesia. Among other things, responses included the following two assertions: 1) The process of qualifying domestic suppliers involves several stages over some years. In a first stage foreign firms would visit the local factory, analyze a sample product and send the local supplier to the home market so to understand the MNEs production systems. Once the sample was approved, they would ask the local firm to produce a small amount and if they met on-time delivering standards then they would accept it as a large-scale supplier; 2) "Suitable" suppliers are rare to find. To this, a Japanese manager added that many times they find a suitable supplier they would introduce it to affiliate companies both in Indonesia and outside, so they could by this increase supplier's economies of scale and smooth their capacity utilization. Their goal was to be supplied by a handful of the best suppliers in the region.

Related to this, multinational firms increasingly impose prospective suppliers to have already incorporated international standards. While these practices are widespread across industries, some sectors show higher pervasiveness. A clear example is given by the automotive industry. In Slovakia, Volkswagen require that all suppliers first get VDA quality certificates, in concordance with the requirements of the German automotive industry[7]. Standards are an important requisite for entering global supply chains in the Food industry as well. For example, UNCTAD 2007 (page 18) reports the case of the European supermarket industry where supermarkets impose suppliers, indistinctive of country of origin, to comply with private protocols of food safety standards, logistical requirements, and process documentation. regardless of the industry in question, ISO norms are by far the most prominent type of standards. A survey conducted by Mobil Corporation found that ISO 9000 registration is now recognized as the basis for quality process definition in 68 countries[8].

3 Setup of the model

In this section we develop a model that explicitly incorporates the role of technological incompatibilities in shaping the interactions between multinational and domestic firms in the host economy. We consider two vertically related monopolistically competitive industries. Downstream, domestic and multinational firms produce consumer goods using locally produced intermediates. Multinationals have access to a foreign technology that is assumed to be more productive and essentially different than the domestic one. One key aspect of this difference is that inputs need to be tailored to the specificities of foreign plants, and, if customized, they cease to be usable by domestic producers. In such a situa-

[6] A complementary, and more commonly advanced, explanation is the fact that firms with higher levels of human capital or R+D are those able to reap potential knowledge spillovers associated with foreign presence.

[7] UNCTAD (2001), page 157.

[8] Cited by Shoemaker et al (1995)

tion, if multinational firms import the foreign technology, an equilibrium with technological segmentation arises: some suppliers produce inputs compatible with the domestic traditional technology and other suppliers specialize into the production of inputs designed for the foreign technology.

The relationship between the performance of firms in the final good sector and the development of the upstream industry in terms of the variety and complexity of available intermediates has been widely recognized by economists, as early as the work of Alfred Marshall. When alternative technologies which require technology-specific inputs coexist, differences in productivity across technologies may arise endogenously from the relative number and quality of suppliers producing inputs of each type. At the same time, with free entry and endogenous technological specialization by suppliers, this is itself determined by the demand and productivity of the downstream firms operating under each technology. The model we develop in what follows, identifying multinationals and domestic firms as firms operating with different technologies, attempts to provide an understanding of the implication for spillovers from FDI of these complex linkages and circular causality[9].

Preferences

Formally, consumers preferences are assumed to be represented by an utility function of the CES form:

$$Y = \left(\int_0^N Y_j^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

where $\eta > 1$ is the elasticity of substitution of any two varieties of the generic consumption good Y. N represents the total number of downstream varieties.[10] If E denotes the exogenous income spent in the Y industry, the producer of a given variety j will face a demand curve of the form

$$Y_j = \left(\frac{P_j}{P} \right)^{-\eta} \frac{E}{P}.$$

where P_j is the price of variety j and $P = \left(\int_0^N P_j^{1-\eta} \right)^{\frac{1}{1-\eta}}$ the price index of final goods.

Production

The final goods industry is populated by N_D domestic firms, and N_M multinationals. In the short term (Sections 4 and 5), N_D and N_M are taken as

[9] As Young (1928), cited by Ciccone and Matsuyama (1996, p. 4), put it: "The division of labour depends upon the extent of the market", ...the extent of the market depends on the division of labour".

[10] For simplicity in exposition, we shall henceforth denote all variables pertaining to the downstream industry with capitals, as opposed to lowercase for those for the upstream industry.

exogenous; later on, (Section 6), this assumption is relaxed to allow for free entry of domestic and multinational firms.

Final goods firms are basically assemblers of intermediate goods[11]. There are two alternative technologies for final good production. A domestic "D-technology" is available to all firms regardless of nationality, while a foreign "M-technology" is accessible only by multinational firms. The productivity advantage of the foreign technology is reflected by a parameter λ indexing the quantity of intermediate inputs required to produce one unit of final good. Thus, $\lambda_M < \lambda_D$, with λ_M/λ_D (inversely) reflecting the technological backwardness of the host economy.

We follow Either (1982) and assume that horizontally differentiated intermediate goods enter final production as a CES composite, with the elasticity of substitution between any two varieties denoted by σ (and equal for both technologies). In order to ensure uniqueness of equilibrium in upstream varieties, we assume $\sigma > \eta$[12].

A central assumption is that each technology requires "customized" intermediate goods. In the baseline specification, we analyze the extreme case in which inputs conceived for one type of technology are completely useless for producers operating under the alternative one[13]. To carry on with notation, we call D-type inputs those compatible with the D-technology, and M-type inputs produced for use with the M-technology. Then, if $T \in \{D, M\}$ the corresponding production function is

$$X_T = \left(\int_0^{n_T} x_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

and the variable cost of producing with technology T is equal to $\lambda_T p_T$, where λ_T is the efficiency parameter and p_T the price index of T-type inputs (obtained by duality on X_T);

$$p_T = \left(\int_0^{n_T} p_{iT}^{1-\sigma} d_i \right)^{1/(1-\sigma)}$$

thus, for a sufficiently large number of downstream firms $N_D + N_M$, the price of a single variety j produced under technology T is $P_j = \frac{\eta}{\eta-1}\lambda_T p_T$.

We now turn to upstream producers. Applying Sheppard's lemma on the price index, we obtain the demand for each variety of a given type

$$x_{iT} = \left(\frac{p_{iT}}{p_T} \right)^{-\sigma} I_T$$

where I_T is total demand for inputs of type T (an endogenous variable to be derived later). The problem of a single upstream producer is to maximize profits

[11] For simplicity, we assume that no labor is required for assembly. Given our partial equilibrium framework, this assumption is non essential.

[12] This means that intermediate varieties are better substitutes of each other in the production process than varieties of the final goods are in the views of consumers. This assumption ensures that business stealing effects in the upstream industry always dominate, and avoids situations in which local suppliers become strategic complements.

[13] In Subsection 5.1, we allow some flexibility in the use of inputs across technologies

in light of the individual demand curve it faces. We assume that there is a continuum of local entrepreneurs, each of which ignores the impact of its own actions on the industry equilibrium (i.e. the "large group assumption"). This results in the usual mark-up pricing formula $p = \frac{\sigma}{\sigma-1}c$, where c are unit costs in terms of the numeraire good. Since costs are homogeneous across suppliers, we omit the subscript i[14].

Entry in the upstream industry requires a fixed cost f_e measured in terms of the numeraire. Local entrepreneurs are assumed to be "born" with the knowledge to produce inputs for the domestic backward D-technology. On the contrary, the production of M-type inputs requires extra overhead costs of size f_q [15].

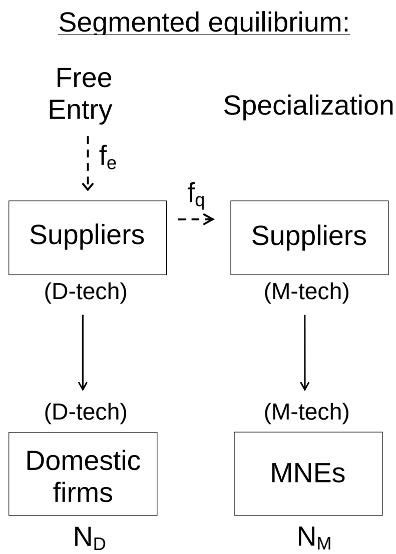

Figure 1: Downstream and upstream industries under technological segmentation

Timing of the game

The timing of events is described by the following sequence (see figure 2):

1. N_M multinationals and N_D domestic firms enter the downstream industry.

[14]Later, in Subsection 5.2, we relax this assumption and consider heterogeneity in suppliers' productivity

[15]Alternatively, one can think that the fixed entry cost for producing M-type inputs is higher than the fixed entry cost for producing D-type inputs f_e.

2. Multinational firms choose whether to produce with the M-technology or adapt to the D-technology.

3. Suppliers pay a fixed cost f_e and enter the upstream industry.

4. Suppliers decide whether to produce D-type inputs or upgrade their technology by paying a fixed cost f_q.

5. Production and consumption take place, and profits are realized

From the timing of moves it follows that the decision by upstream firms to enter and produce with a given technology is conditional on the prevailing strategy by multinationals. Conversely, foreign affiliates take their technology decision by anticipating the resulting structure of the local upstream industry. In the next section we solve for the industry equilibrium.

4 Solution of the model: short run

Equilibrium under technological segmentation

A "technological segmentation" regime refers to a situation in which foreign affiliates import the foreign technology, and (some) local suppliers adapt their intermediates.

Decisions on technology by suppliers are made by weighting the gains from specializing in the M-technology against its costs both in terms of fixed costs, as well as in terms of lost demand from domestic firms. An equilibrium is defined by a situation in which net profits of specializing in either technology are equal. On the other hand, the free entry condition imposes zero net profits at the equilibrium. If we denote by $q \in [0, 1]$ the proportion of suppliers choosing to produce for multinationals and n the equilibrium number of suppliers, equilibrium in the upstream industry is defined by the following system of equations:

$$\begin{cases} \pi_M(q, n) = f_e + f_q \\ \pi_D(q, n) = f_e \end{cases}$$

where π_T represents *ex post* profits accruing from specializing in T-type inputs. Note that profits for a supplier choosing T depend negatively on the number of suppliers choosing T as well (affecting the slope of the perceived demand curve through business stealing effects) and positively on the total demand for T-type inputs (affecting the position of the perceived demand schedule). However, total demand for T-type inputs depends on the market share of downstream firms using technology T, which is itself a function of the number of suppliers choosing to produce for the T technology. Relative market shares and profits of downstream firms are a function of relative costs, which depend on q in the following way:

$$\frac{\Pi_M}{\Pi_D} = \frac{C_M^{1-\eta}}{C_D^{1-\eta}} = \frac{\lambda_M^{1-\eta} q^{\frac{1-\eta}{1-\sigma}}}{\lambda_D^{1-\eta} (1-q)^{\frac{1-\eta}{1-\sigma}}} \tag{1}$$

Incorporating these expressions we get the unique pair (n, q) satisfying the system of equations (see appendix). It is characterized by:

$$n = \frac{\alpha E}{f_e + q f_q} \tag{2}$$

which gives the equilibrium number of upstream varieties as a function of average fixed costs paid by upstream firms, and

$$\frac{q}{1-q} = \left(\frac{N_M}{N_D} \frac{\lambda_M^{1-\eta}}{\lambda_D^{1-\eta}} \frac{f_e}{f_e + f_q} \right)^{\theta} \tag{3}$$

with $\theta = \frac{\sigma-1}{\sigma-\eta} > 1$.

Expression (3) above shows how the proportion of suppliers switching to the M-technology is determined in the industry equilibrium. q is increasing in the relative efficiency of the foreign technology: the lower λ_M, the higher is demand captured by a typical multinational, and thus the more profitable is technological upgrading. The same effect arises for the number of MNE's[16].

This last effect indicates a positive externality among multinational firms, and highlights a main idea if this paper. In our model, interaction between multinational and domestic firms are not restricted to the market for goods. The effect of technological similarities among foreign plants is to create strategic complementarities in the attraction of input suppliers. Massive entries of multinationals put pressure to the development of a more complete supply chain attached to the modern technology. Given that domestic firms are not able to benefit from the upgrading of intermediates, and that the size of the market limits the number of intermediate varieties (see (2)) strong MNE entry infringes a negative externality on domestic firms.

To appreciate this, it is useful to take a look at the equilibrium ratio of profits[17], obtained by substituting (2) and (3) into the costs function for each type of firm. This gives:

$$\frac{\Pi_M}{\Pi_D} = \frac{C_M^{1-\eta}}{C_D^{1-\eta}} = \left(\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} \right)^{\theta} \left(\frac{N_M}{N_D} \right)^{\theta-1} \tag{4}$$

where $\Lambda_M = \lambda_M (f_e + f_q)^{\frac{1}{\sigma-1}}$ and $\Lambda_D = \lambda_D f_e^{\frac{1}{\sigma-1}}$ are indices for the social cost of each technology (ie. taking into account the cost to create new input varieties).

Form expression (4) it is clear that the equilibrium ratio of profits is increasing in the ratio of foreign to domestic firms, given that $\theta > 1$. It illustrates the positive externalities within groups of firms and negative across groups.

The ratio of profits is also increasing in the ratio of technological efficiency. More precisely, its elasticity is higher than one: differences in technological efficiency amplify differences in terms of "real" efficiency (i.e taking into account

[16]On the other hand, as expected, higher fixed costs of technological reduce the proportion of suppliers that decide to upgrade.

[17]Since market size is assumed to be constant, the ratio of profits also pins down the level of profits for each type of firms.

the costs of intermediates), because the more productive technology attracts more suppliers, resulting in a wider range of intermediate varieties. This mechanism is more important the higher the parameter θ. When the elasticity of substitution upstream σ is low and close to that downstream η, the mechanisms of allocation of firms across technologies are amplified. For example, if $\sigma = 3$ and $\eta = 2$ so that $\theta = 2$, a 10 percent advantage in the cost parameters λ translates into an advantage of 21 percent in the equilibrium.

Thus, the model generates a mechanism through which technological specialization of suppliers results in a causal link from technological to "real" advantages for foreign plants. Note that industry-wide equilibrium effects add to the more conventional business stealing effects, and provide an intuition that is consistent with empirical evidence showing positive externalities for firms upstream and negative horizontal effects[18]. In this model, technological incompatibilities create a new type of competition among downstream firms, one that takes place in the market for inputs. Backward and forward linkages are limited to the scope of firms using the same technology, and do not propagate to all firms in the industry. We summarize these findings in the following proposition.

Proposition 1 *In a segmented equilibrium, the technological advantage of multinational firms is amplified by the endogenous specialization of suppliers toward the foreign technology and increases with the relative proportion of multinational firms in the downstream sector.*

The above proposition is a testable prediction of the model, that has been confirmed by a recent study on two transition economies, the Czech Republic and Russia. Indeed, Sabirianova et al (2005), found that greater presence of foreign firms in a sector affected negatively the average productivity of domestic firms, while the impact on the productivity of other firms firms was found to be positive. Further, while many existing studies confirm a "foreign" productivity premium, it would be worthwhile to consider it endogenous and study its determinants, in particular relating it to the structural features of the host economy. Our model particularly highlights the role of upstream markets in shaping differences between multinational and domestic firms in the downstream industry.

Note also that, in cases where proximity to suppliers is economically relevant, the above provides an intuition for mutual advantages for foreign plants to locate close to each other in clusters. There is some evidence of agglomeration effects by multinationals (unfortunately, evidence is limited to developed countries). Examples are Barrios et al (2002), who find evidence of a foreign-specific agglomeration force in Ireland, and Head and Swenson (1995), who show that Japanese firms tend to locate close to each other in the US. Besides implications on the localization of multinational firms, this intuition is consistent with clustering based on technological compatibilities (i.e. high-technology clusters like Silicon Valley).

[18]Variables costs λ_M and λ_D may also be interpreted as the product of variable costs downstream and variable costs upstream. Assuming $\lambda_M < \lambda_D$ is thus consistent with the fact that the introduction of the foreign technology improves suppliers' performance.

Technological segmentation and consumer welfare

After having discussed the main properties of a technological segmentation equilibrium and its impact on firm performance, we now derive a relationship between its feasibility and its impact on consumer welfare. In this model, an important channel through which the arrival of multinationals impacts welfare is through the introduction of a more efficient technology to the host economy, which would be otherwise unavailable. Nevertheless, the introduction of the foreign technology brings along a segmentation in the upstream industry, by which each type of downstream firm sources from a smaller range of varieties compared to an equilibrium where all suppliers produce for the same technology.

Segmentation, thus, reduces overall efficiency and thereby impinges negative welfare effects. Thus, the overall effect of multinational entry in consumer welfare will depend upon the relative strength of these two opposing effects. In cases where the foreign technology advantage is moderate, and backward and forward linkages are strong, the positive effect of introducing a more efficient technology may be offset by the negative effects on input prices that are brought up by segmentation. Formally, we can state the following condition, determining whether the equilibrium under technological segmentation (if multinationals import the foreign technology) is preferable to the non-segmented equilibrium from the point of view of consumers (if we suppose that multinational firms adopt the local technology).

Proposition 2 *Compared to the equilibrium without segmentation, the segmented equilibrium improves consumer welfare when the following condition (W) is verified:*

$$\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} > \left[\left(1 + \frac{N_D}{N_M}\right)^{\theta} - \left(\frac{N_D}{N_M}\right)^{\theta} \right]^{\frac{1}{\theta}}.$$

(W) implies that the foreign technology is more efficient ($\Lambda_M^{1-\eta}/\Lambda_D^{1-\eta} > 1$) but the opposite does not hold: the introduction of a more efficient technology may be welfare reducing.

Proof. See Appendix.

The above proposition compares the impact on consumer welfare in cases where multinational firms import the foreign technology or adopt the local technology. A comparison with autarky would depend on the mode of entry that is chosen by multinationals. If FDI occurs exclusively through acquisitions of domestic firms, the total number of downstream varieties remain constant, and so the counterfactual comparison with autarky is equivalent to the comparison with a non-segmented equilibrium. If, on he other hand, FDI occurs through greenfield investments, consumers also benefit from an increase in the number of available variety[19].

[19]More precisely, the drop in price index from autarky to a non-segmented equilibrium is equal to $\left(\frac{N_D}{N_D+N_M}\right)^{\frac{1}{\eta-1}}$

In cases where the introduction of the foreign technology is welfare reducing, and the local technology may be adopted at no cost, a relevant question to ask is whether the economy may still end up in an equilibrium where multinational firms choose to import the foreign technology[20]. Hence, we need to derive the condition under which the segmented equilibrium is feasible[21].

Formally, if the adoption of the local technology is costless, multinational firms prefer the local technology as soon as the cost of using the local technology C_D is lower than the cost of using the M-technology, C_M. From equation (4), where the relative cost is endogenously determined by the relative efficiency of the foreign technology and the relative number of firms in the downstream industry, we can derive the following proposition:

Proposition 3 *An equilibrium with technological segmentation is feasible only when the following condition (S) is verified:*

$$\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} > \left(\frac{N_D}{N_M}\right)^{1-\frac{1}{\theta}}.$$

Furthermore, condition (W) (see proposition 2) implies (S) but the opposite does not hold: technological segmentation might arise even if it is welfare reducing and the adoption of the local technology is costless.

Conditions (S) and (W) strongly depend on the parameter θ defined by upstream and downstream elasticities of substitution, which determines the strength of reinforcing linkages between the upstream and the downstream industry. When this mechanism is weak (θ is close to one) the industrial organization will be efficient in terms of consumer welfare but when θ is large, distortions appear. These insights are summarized as follow:

Corollary 1 *When θ tends to 1, both conditions (S) and (W) are verified if and only if the foreign technology is more efficient ($\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} > 1$).*

Corollary 2 *When θ tends to infinity, condition (S) is equivalent to $\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} > \frac{N_D}{N_M}$ and condition (W) is equivalent to $\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} > 1 + \frac{N_D}{N_M}$. Because of externalities among groups of firms using the same technology, group size matters and there is a range of parameters where the segmented equilibrium is feasible but not welfare improving.*

[20]There are several examples of multinational firms in developing countries that produce low-quality goods that would not match international standards. Such examples may be given by Renault producing the "Logan" in India, or Volkswagen producing the original Beetle in Mexico, with technologies dating from the 1950s (Verhoogen, *forthcoming*). Thus, the possibility that multinational firms adopt local standards is worth considering.

[21]It is possible to show that, if MNEs can choose between the foreign and the local technology, either all multinational firms produce with the foreign or the local technology. An equilibrium where some multinational firms produce with the local technology and others with the foreign technology is not stable.

Generally, FDI generates welfare improvements through increased competition in the downstream market, at least from the point of view of consumers. Another positive impact often comes from the introduction of new technology by multinational firms that is globally more efficient than the domestic one. The technological segmentation effects we describe here, though, might generate situations in which the net effects of foreign entry can be welfare reducing, in spite of the fact that multinationals bring in a technology that is globally more efficient than the domestic one.

These results provide an analysis of short run effects, that is, when the number of downstream firms remains unchanged. Section 6 studies the long term by allowing effects on the entry of domestic and multinational firms, as well as the adoption of the foreign technology by domestic firms in the downstream sector. Beforehand, section 5 analyzes two extensions of the basic model in the short term by considering more general assumptions in the use of inputs across technologies and heterogenous capabilities among suppliers.

5 Two extensions to the baseline model

5.1 Partial Compatibility of Inputs

We now relax our assumption to allow for the more realistic situation in which there is some degree of compatibility among technologies. We assume that inputs conceived to be used in one technology are susceptible to be used by downstream firms using the alternative technology, however at a cost in terms of efficiency. Therefore, now for a typical supplier the decision of specializing in the foreign technology no longer implies giving away selling to domestic firms. However, as long as inputs are not perfectly substitutes, the mechanics of the model continue to prevail.

Suppose that in foreign plants, $m > 1$ units of D-type input are equivalent to one unit of the M-type, and the symmetric parameter for domestic plants, is $d > 1$. These parameters measure the degree of incompatibility across technologies, the higher their value, the less compatible technologies are. The characterization of the equilibrium in this modified setting is similar: as before, we need to solve for the endogenous pair (n, q), in a system of two equations representing zero profits conditions (profits equal fixed entry cost). Incorporating this solution we can solve for the ratio of profits in this case:

$$\frac{\Pi_M}{\Pi_D} = \frac{C_M^{1-\eta}}{C_D^{1-\eta}} = \left(\frac{\lambda_M^{1-\eta}}{\lambda_D^{1-\eta}}\right)^{\theta} \left(\frac{N_M}{N_D}\left[\frac{f_e - m^{1-\sigma}(f_e + f_q)}{(f_e + f_q) - d^{1-\sigma} f_e}\right]\right)^{\theta - 1} \tag{5}$$

As before, equilibrium profits of multinationals increase with N_M/N_D and decrease with λ_M/λ_D. However, note the role of the new parameters, m and d. As can be seen, and somewhat paradoxically, the relative cost of multinational firms decreases with the cost of adopting D-type inputs. This is due to the fact that higher compatibility of the M-technology with D-type inputs (lower

m) reduces the incentives for suppliers to specialize in the foreign technology, which in turn decreases the competitive advantage of multinational firms.

If the degree of technological compatibility is symmetric, that is $m = d = \tau$, this result remains true for multinational firms: profits of multinational firms increase with τ whereas profits for domestic firms decrease with τ. Thus, generally, we can state the following proposition:

Proposition 4 *In an equilibrium with technological segmentation, the competitive advantage of multinational firms decreases with their ability to use inputs produced with the local technology.*

Note, on the other hand, that individual incentives regarding m are different: given the properties of the production function, profits of a single multinational are increasing with the possibility of incorporating more inputs. Imagine that several technologies are available, which differ only in the value of the parameter m as defined above. Individually taken, a multinational prefers the technology with high compatibility with local technologies. Thus, absent a commitment device, a situation where multinational firms choose technologies with highest incompatibilities (a strategy that maximizes their profits collectively) would not be a Nash equilibrium.

Is there some evidence of multinational firms collectively trying not to adapt to domestic technologies? We argue that this mechanism may provide a new insight on collective "voluntary private standards". Imagine that we re-interpret our M-technology as corresponding to a commitment to use only inputs that are certified to be produced under some safety, quality or environmental standards. As stated by *fact 4*, the most prominent example of such are clearly ISO norms, but an array of certifications on the like has been rising in last decades [22]. Typically, these standards are developed by private or quasi-private organizations in which multinational corporations play a significant role[23]. Firms that source exclusively from compliant suppliers are able to send signals to consumers which increase the positioning of their products. Therefore, deviation from such a norm could plausibly be associated with a loss in demand, which helps explaining why even when these practices might impact negatively on the short-run cost structure (by preventing firms from buying inputs produced by non-compliant suppliers) they might be a profitable strategy in the long run, as equation (5) suggests. Such a mechanism might provide an insight to understanding why quality, safety and environmental collective standards have been flourishing in late years, and warn about their possible anti-competitive effects.

Another interpretation is that parameters measuring the costs of adopting alternative inputs represent trade costs if groups of firms are physically distant from each other. For example, if $d = m = \tau$ where τ represents symmetric trade cost in intermediate inputs (final goods being perfectly tradable). We obtain that domestic firms tend to locate closer from multinational firms, whereas multinational firms may collectively prefer to locate further.

[22] Examples of business associations developing private standards in the food industry are EurepGAP, International Food Standards, and BRC Global Standard.

[23] Morrison (2006).

5.2 Heterogeneous suppliers

As documented by *fact 4*, multinational firms tend to source only from a selected base of the best suppliers. In the baseline model, differences between suppliers arise from technological specilization. In this section, we introduce differences in capabilities among suppliers. As a result, a process of selection occurs in which only the best suppliers specialize into the M-technology. Hence, multinational firms source at equilibrium only from suppliers with the more efficient technology and the best entrepreneurial capabilities, consistently with *fact 4*.

To account for supplier heterogeneity in our framework, we modify the baseline model in the following way. We assume that, upon entry, and once final firms have entered and multinationals have made decisions regarding technology, upstream entrepreneurs draw their variable cost c_i from a cumulative generic distribution $H(c)$. Then, with full knowledge of their cost parameter, suppliers choose whether to produce with the D-technology or pay the upgrading cost to produce M-type inputs and serve multinationals. This timing permits us to study how heterogenous decisions regarding technology upgrading are determined by heterogeneous individual capabilities.

As before, the decision to specialize in the M-technology has costs in terms of higher fixed costs and the lost in demand coming from domestic firms. These are weighted against the gains from serving input demand coming from multinationals. The difference is that now firms' decisions depend on the draw.

A supplier will choose the foreign technology if and only if profits associated with the production of the M-type inputs exceed profits associated with the production of D-type inputs plus the fixed cost of technology upgrading. If we label A_D and A_M the demand for inputs of each type (endogenous in the system but taken as given by individual suppliers), then profits after entry associated with each technology for a firm receiving a draw c_i are

$$\begin{cases} \pi_D(c_i) = A_D c_i^{1-\sigma} \\ \pi_M(c_i) - f_q = A_M c_i^{1-\sigma} - f_q \end{cases}$$

Note that at equilibrium we necessarily have $A_M > A_D$. If this is not the case, then obviously no supplier would choose the M-technology. But if multinational firms require M-type inputs, profits of the marginal supplier choosing the M-technology would be infinite since it would face no competition: such a case is therefore impossible ($A_M < A_D$ implies $A_M = \infty$). Thus we can safely state that $A_M > A_D$, that is, once fixed upgrading costs are paid, it is more profitable to produce inputs compatible with the new technology. Moreover, the gains from producing M-type inputs are larger the higher is the productivity of the supplier. It follows that best suppliers specialize into the foreign technology and other suppliers produce inputs suited for the local technology.

Proposition 5 *In an equilibrium with technological segmentation, the best suppliers produce inputs designed for the foreign technology.*

Formally, the cutoff cost c^* that equates profits from both technologies, is defined by the condition:

$$\pi_M(c^*) - f_q = \pi_D(c^*)$$

With the above notation, c^* verifies:

$$c^* = \left(\frac{A_M - A_D}{f_q}\right)^{\frac{1}{\sigma-1}}$$

Firms with costs below c^* switch to the M-technology and firms with costs above c^* remain with the D-technology. Note that the stability assumption (i.e. $\sigma > \eta$) ensures that at the equilibrium there will always be a positive number of suppliers for each technology (that is, $0 < c^* < \infty$ and $0 < q < 1$).

In order to fully characterize the industry equilibrium, we need to consider the free entry condition. Free entry implies that net expected profits (before capabilities are revealed) are equal to zero after subtracting the fixed entry cost f_e. This condition gives us a second equation that permits to solve for the total number of upstream firms n. Under the assumption that $\sigma > \eta$ and the distribution of capabilities are not too distorted [24], both conditions uniquely determine n and c^* (see appendix for existence and uniqueness).

A natural question then arises: does heterogeneity benefits MNEs? In other words, would MNEs, *ceteris paribus* prefer to locate in sectors supplied by upstream industries with higher productivity dispersion?

We want to compare the relative "real" cost $\frac{C_M}{C_D}$ of multinational firms with suppliers heterogeneity with the case of homogenous capabilities (as previously, relative costs determine the profits of downstream firms). In the case of homogenous suppliers, relative productivity is given by expression (4). Since no tractable solution is available for n and c^* at equilibrium in the case of heterogenous suppliers, it is not possible to express the relative productivity of MNEs as a function of exogenous parameters. However, since endogenous equilibrium outcomes are observable, it is still interesting to formulate conditions that could be empirically tested. Formally (see appendix), we obtain that supplier heterogeneity yields large profits for multinational firms if and only if the following condition (H) is verified:

$$\int_0^{c^*} (c^{1-\sigma} - c*^{1-\sigma})dH(c) < \frac{f_e}{f_e + f_q}\int_{c^*}^{\infty} (c*^{1-\sigma} - c^{1-\sigma})dH(c)$$

where $H(c)$ is the cumulative distribution of supplier costs and c^* is the equilibrium cost threshold below which suppliers switch to the M-technology.

Because this condition may not always be verified, there is no clear cut answer on the effect of heterogeneity in suppliers capability. However we can draw two main conclusions:

[24] When the distribution is similar or less skewed than Pareto distributions at both ends, we can show that an unique solution exists. The solution, however, is generally not analytically tractable.

1. Productivity dispersion benefits MNEs when the total demand for M-type inputs is low, which means that they source from only few of them (c^* is low). This effect may be simply explained by increasing returns to scale: heterogeneity permits to increase the relative production of the best suppliers for a given proportion of firms paying the fixed upgrading costs.

2. For a given threshold c^*, productivity dispersion among best suppliers, which increases competition among firms producing M-type inputs, tend to reduce MNEs profits. Inversely, productivity dispersion among low productivity suppliers increases MNEs profits.

Hence, when multinationals only source from the very best suppliers, consistently with fact 3, it is more likely that productivity dispersion favors them. A simple illustrative example may be provided by the case where supplier costs are drawn from a set of two cost levels: either $c = c_L$ or $c = c_H > c_L$. Productivity dispersion may be indexed by the ratio of costs: c_H/c_L. If MNEs only source from low-cost suppliers, and domestic firms source from both low and high cost suppliers, then profits for multinational firms increase with productivity dispersion (in condition (H), the left hand side is equal to zero whereas the right hand side is strictly positive). The intuition is that when MNEs source from a larger proportion of best suppliers, they are able to capture a larger market share of the upstream industry compared to the increase of investments in technology upgrading costs. Inversely, if MNEs source from both low-cost and some high-cost suppliers, profits for multinational firms decrease with productivity dispersion.

Note that in equilibrium where multinational firms choose to adopt the local technology, productivity dispersion among suppliers does not affect the relative productivity of multinational and domestic firms. Hence, depending on whether suppliers' heterogeneity positively affect the profits of multinational firms in segmented equilibria, heterogeneity accordingly affects their choice to either import the foreign technology or adopt the local technology.

6 Long Run Industry Equilibrium

Finally, this section extends the basic model developed in Sections 3 and 4 to a long run version in which entry and exit of domestic firms in the downstream sector and of multinational firms is endogeneized. Further, we assume that domestic firms have the opportunity to incorporate the foreign technology that is brought in by foreign plants. The idea is that, in this model, FDI acts as an international conductor of technology, by bringing in methods which are otherwise unavailable in autarky. Domestic producers in the downstream sector might incorporate this modern technology, by imitating their foreign counterparts or by reverse engineering. A key assumption is that adoption of the foreign technology is assumed to entail extra fixed costs. Nevertheless, some domestic firms might find it optimal to upgrade since what they stand to gain can compensate the extra costs. Gains from switching to the foreign technology come from two sides. On the one hand, the foreign technology is assumed to be more efficient than the domestic one, as indexed by the ratio λ_M/λ_D. On the other hand, and contrary to our static version of the model, by incorporating the foreign technology, domestic producers can benefit from complementarities with multinationals in the upstream market. Depending on the equilibrium, this might act as a reinforcing mechanism favoring technological adoption among indigenous firms and reducing the negative impact of technological incompatibilities described in the previous sections.

Domestic firms are assumed to be heterogeneous in productivity. Upon entry, domestic producers draw a productivity level φ_i from a cumulative distribution $G(\varphi)$, assumed to be common knowledge. This firm-specific productivity parameter is independent of units costs associated with the choice of technology. A firm receiving a draw φ_i and choosing technology T has a measure of observed productivity $(\frac{C_T}{\varphi_i})^{1-\eta} = \varphi_i^{\eta-1} C_T^{1-\eta}$.

Right after receiving their draw, domestic firms decide whether to adopt the foreign technology, which implies paying extra fixed costs F_q, or alternatively to produce with the D-technology at no extra cost. Profits associated with each of these decisions are:

$$\Pi_{Di} = \frac{\varphi_i^{\eta-1} C_D^{1-\eta} E}{P^{1-\eta}}$$
$$\Pi_{Di}^q = \frac{\varphi_i^{\eta-1} C_M^{1-\eta} E}{P^{1-\eta}} - F_q$$

where P is the industry price index and the superscript q indicates profits for a domestic firm that has incorporated the M-technology.

Technological adoption in the downstream sector is driven by a self-selection mechanism, similar to that described in Subsection 5.2 with heterogenous suppliers. Clearly, if $C_M^{1-\eta} < C_D^{1-\eta}$ then no domestic firm would prefer the foreign technology, and multinational firms would even have incentives to adopt the local technology. On the contrary, in the case in which $C_M^{1-\eta} > C_D^{1-\eta}$, profits from producing final goods with the M-technology are larger than with the D-technology and the difference may exceed the technology upgrading costs F_q. Moreover, the higher the productivity draw, the larger is the differential of profits, and thus the more profitable it is to pay the fixed costs of adoption. Hence, there exists a cutoff level for φ_i making a firm just indifferent between adopting or not. This is implicitly given by:

$$\Pi_D^q(\varphi^*) - \Pi_D(\varphi^*) = F_q \quad \text{(FTD)}$$

which we label as the "free technological adoption" condition for domestic firms (FTD). Given that firms have knowledge of the underlying cumulative distribution $G(\varphi)$, they are able to anticipate ex post profits and thereby will take entry decisions by calculating the ex ante expected gains from entering. Expected profits are

$$E[\Pi_D] = \int_0^{\varphi^*} \Pi_D(\varphi) dG(\varphi) + \int_{\varphi^*}^{\infty} \Pi_D^q(\varphi) dG(\varphi)$$

with an unbounded pool of potential entrants, expected profits will adjust until their value net of fixed entry costs F_D is driven to zero, thus the free entry condition for domestic firms (FED) writes as $E[\Pi_D] = F_D$.

Multinationals are assumed to enter the host country as soon as expected profits are positive. This induces a free entry condition equalizing profits to fixed costs of entry, $\Pi_M = F_M$, labeled (FTM). It should be noted that this implies that multinationals take their entry decisions by anticipating the fact that some local firms will imitate their technology. For the sake of simplicity, foreign firms are assumed to be homogeneous in productivity, and thus the individual productivity parameter φ_{Mj} equals average productivity $\widetilde{\varphi}_M$.[25] We assume $\frac{F_M}{F_D} > \frac{\widetilde{\varphi}_M^{\eta-1}}{\widetilde{\varphi}_D^{\eta-1}}$. This ensures that, if multinationals produce with the local technology, they would be forced out in equilibrium[26].

Finally, interactions in the upstream industry remain the same as in the basic model. Suppliers decide on the technology to which they specialize their intermediates taking into account the demand for each type coming from the downstream side of the economy, which is determined by the proportion of firms in each technology and their productivity.

Summing up, the long run equilibrium is formally defined by the following system of equations,

$$\begin{cases} \pi_M(q,n) & = f_e + f_q \quad (5.1) \\ \pi_D(q,n) & = f_e \quad (5.2) \\ E[\Pi_D] & = F_D \quad (5.3) \\ \Pi_D^q(\varphi^*) - \Pi_D(\varphi^*) & = F_q \quad (5.4) \\ \Pi_M & = F_M \quad (5.5) \end{cases}$$

The set of unknowns is composed of the following 5-tuple: $(n, q, N_D, N_M, \varphi^*)$. These are, respectively: the number of upstream varieties, the proportion of suppliers specializing in the M-technology, the number of domestic final producers, the number of multinationals, and the cutoff productivity defining adoption of the M-technology by domestic producers.

In order to solve for the equilibrium of the economy, we first need to account for the equilibrium of the upstream industry. Suppliers' decisions determine the costs associated with each technology, as has been widely discussed in Section 4. In turn, their choices are determined by the demand for each type of inputs coming from the downstream industry. At equilibrium, the number of suppliers in each technology is determined by the number of downstream firms in each technology, their capability and technological efficiency.[27]

[25] Since no firm exits after entry, heterogeneity among multinationals has no effect: it is equivalent to assume that all firms have the same productivity parameter $\widetilde{\varphi}_M^{\eta-1}$ that equals the average of $\varphi_{Mj}^{\eta-1}$ across multinational firms.

[26] Note that this seems plausible, as it amounts to assuming that fixed costs of entry are high enough for multinationals. The case where after entry foreign firms can be forced out in the non-segmented equilibrium is central in the analysis of Markusen and Venables (1999).

[27] Thus, it is possible to solve for (n, q) as a function of (N_D, N_M, φ^*).

Unfortunately, it is not possible to obtain an analytical solution for the complete system. The complexity comes from multiple interactions: on the one hand, the number of domestic firms is not only determined by the cost of producing with the D-technology but also with the M-technology as soon as there is a positive probability to adopt the foreign technology; on the other hand, the relative number of downstream firms in each technology, and thus the cost of using each technology, depends on the number of multinationals, the number of domestic firms and the proportion of domestic firms adopting the M-technology.

However, it turns out that it is possible to reformulate the initial system of five equations in five unknowns as a system of two equations on two unknowns, that allow us to study the different equilibria in terms of welfare. The two variables that we will focus on are the proportion q of suppliers adopting the foreign technology and the downstream industry price index. We define:

$$\mathbf{P} \equiv \frac{P^{1-\eta}}{P_a^{1-\eta}}$$

This variable is the ratio of (an inverse measure of) the price index in the regime with technological segmentation to the analogous measure in a regime under autarky (without the M-technology and multinational firms). Two things are worth highlighting. First, given the restriction on the fixed cost F_M, a regime under non-segmented equilibrium would be similar to the case of autarky. Secondly, in this long run version of the model, profits are zero for all firms provided that free entry is ensured. Thus, the only source of welfare is given by consumer surplus. Taking this into account, $\mathbf{P}$ provides us with a measure of welfare changes from autarky to the economy with multinationals: if $\mathbf{P} > 1$, then consumers are better off, the opposite holds if $\mathbf{P} < 1$. It should be remarked that $P_a^{1-\eta}$ is independent, by definition, from q.

According to the definition of the price index, $\mathbf{P}$ measures the competitive pressure in the downstream industry in the long term equilibrium (compared to autarky). Actually, both free entry conditions on downstream firms (5.1 and 5.3) may be interpreted as a relationship between fixed entry costs, productivity and the competitive pressure. Therefore, it is possible to rewrite these equations as an equality between $\mathbf{P}$ and a function of fixed and (expected) variable costs. Two properties permit to simplify this system. First, given the equilibrium in the upstream industry, it is possible to obtain all technological costs as a function of q. Second, equation (5.2) permits to express φ^* as a function of x, and replacing φ^* by this expression in the free entry condition for domestic firms. As a result, we obtain a system of the form:

$$\begin{cases} \mathbf{P} = f_M(q) \\ \mathbf{P} = f_D(q) \end{cases}$$

where $f_M(q)$ indicates the function derived from the free entry condition for multinationals, and $f_D(q)$ the one derived from the equation pertaining to domestic firms and suppliers; each of them predicts a relation between $\mathbf{P}$ and q.

In order to parameterize the distribution of domestic firms' capabilities, we suppose that the cumulative distribution is a Pareto. More precisely:

$$G(\varphi) = 1 - \left(\frac{\varphi}{\underline{\varphi}}\right)^{-\gamma}$$

where the coefficient γ is supposed to be larger than $\eta - 1$. Under this specification, the function $f_M(q)$ and $f_D(q)$ take the following analytical form:

$$f_M(q) = \frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} \, \Omega_M \, q^{1-\frac{1}{\theta}}$$
$$f_D(q) = \left[1 + \Omega_D \left[\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} (\tfrac{q}{1-q})^{1-\frac{1}{\theta}} - 1\right]^{\frac{\gamma}{\eta-1}} (\tfrac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}})^{-(\frac{\gamma}{\eta-1}-1)} (\tfrac{q}{1-q})^{-(1-\frac{1}{\theta})(\frac{\gamma}{\eta-1}-1)}\right] (1-q)^{1-\frac{1}{\theta}}$$

where:

$$\Omega_M \equiv \frac{F_D}{F_M} \frac{\gamma+1-\eta}{\gamma} \frac{\widetilde{\varphi}_M^{\eta-1}}{\underline{\varphi}^{\eta-1}}$$
$$\Omega_D \equiv \frac{\eta-1}{\gamma} \frac{\widetilde{\varphi}_M^{\eta-1-\gamma}}{\underline{\varphi}^{\eta-1-\gamma}} (\tfrac{F_M}{F_q})^{\frac{\gamma+1-\eta}{\eta-1}}$$

as long as there are some domestic firms switching to the new technology, which requires $\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}}(\frac{q}{1-q})^{1-\frac{1}{\theta}} > 1$. Otherwise $f_D(q) = (1-q)^{1-\frac{1}{\theta}}$. Then, as will become clear below, there is a lower bound on q that is necessary for the equilibrium to display adoption on the part of domestic firms.

Note that $f_M(q)$ is an increasing function. Intuitively, the higher is q, the larger the productivity and competitive advantage of firms using the M-technology, and the larger are incentives for multinationals to enter the host industry, increasing $\mathbf{P}$. To see why, recall from our previous analysis that the relative productivity of using the foreign technology is a simple function of q, the proportion of suppliers with the new technology:

$$\frac{C_M^{1-\eta}}{C_D^{1-\eta}} = \frac{\lambda_M^{1-\eta} q^{\frac{1-\eta}{1-\sigma}}}{\lambda_D^{1-\eta}(1-q)^{\frac{1-\eta}{1-\sigma}}}$$

The case of domestic firms is slightly more complex, as one can notice from the shape of $f_D(q)$. The effect of a change in q in this new equality is non monotonic. When q is low enough, no domestic firm finds it optimal to adopt the M-technology; in that case, expected profits are decreasing with the proportion of suppliers that upgrades to the new technology, as this implies tougher competition. When a sufficient proportion of domestic firms adopts the M-technology, however, increases in the proportion of suppliers that upgrade have positive effects on expected profits of domestic firms. In other words, the higher is q, the higher is the productivity of using the M-technology, the higher is the proportion of domestic firms adopting the foreign technology, and the more beneficial is the increase in productivity within the M-technology for domestic firms. It thus follows that the derivative of f_D with respect to q increases faster than that of f_M.

The above property ensures that the system has at most two interior solutions. In what follows, we describe several cases in which we vary the costs of foreign technology adoption for local firms. We concentrate in this case since it gives interesting and somewhat unexpected results.

Case 1: Low technology adoption costs

Figure 2 provides a numerical example leading to two interior solutions. This case corresponds to low adoption costs, which imply a high value of Ω_D . Specifically, the example was built with the following values: $\theta = 5$, $\Omega_M = 0.9$, $\Omega_D = 1.3$, $\frac{\Lambda_M^{1-\eta}}{\Lambda_D^{1-\eta}} = 1.5$ and $\frac{\gamma}{\eta - 1} = 3$.

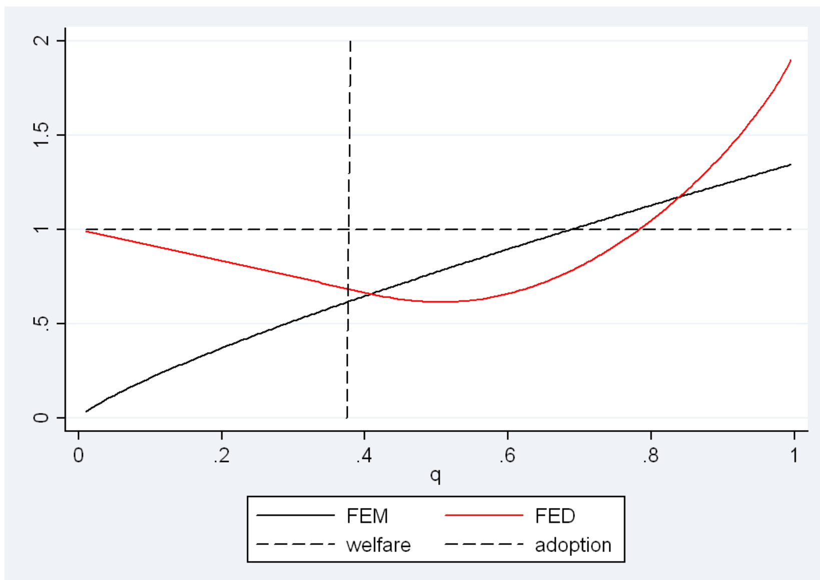

Figure 2: Case 1. Low technology adoption costs

The interior equilibrium for the lowest value of q is unstable: if q slightly increases, entry by multinational firms is more likely than entry by domestic firms (the FEM curve is above the FED curve) which tends to increase q. The opposite mechanism happens when q decreases. On the contrary, the interior solution with the highest value of q is stable. As shown in the graph, this point is above the line $\mathbf{P} = 1$ which means that welfare is higher than in autarky. The extreme case where $q = 0$ is also a stable equilibrium: no multinational firm enters the market and thus welfare remains unchanged.

What happens when we start from an situation where there are only multinational firms in the downstream market, which means that $q = 1$? Given that the cost of technology adoption is not too high, the curve f_D is above f_M which means that domestic firms start entering the market. The long-term equilibrium is necessarily the interior solution, which is welfare improving (for these parameters).

In brief, there are only two stable equilibrium in this case: an equilibrium populated only by domestic firms and a welfare-improving equilibrium where both type of firms coexist, characterized by a large proportion of domestic firms adopting the foreign technology.

Case 2: Medium technology adoption costs

We now look, in Figure 3 at a case where technology adoption costs lie in an intermediate level, we then lower Ω_D to 1.0 while leaving the rest of parameters unchanged. This change has no effect in cases where q is low, since no domestic firm adopt. However, for values of q such that domestic firms adopt, entry becomes harder.

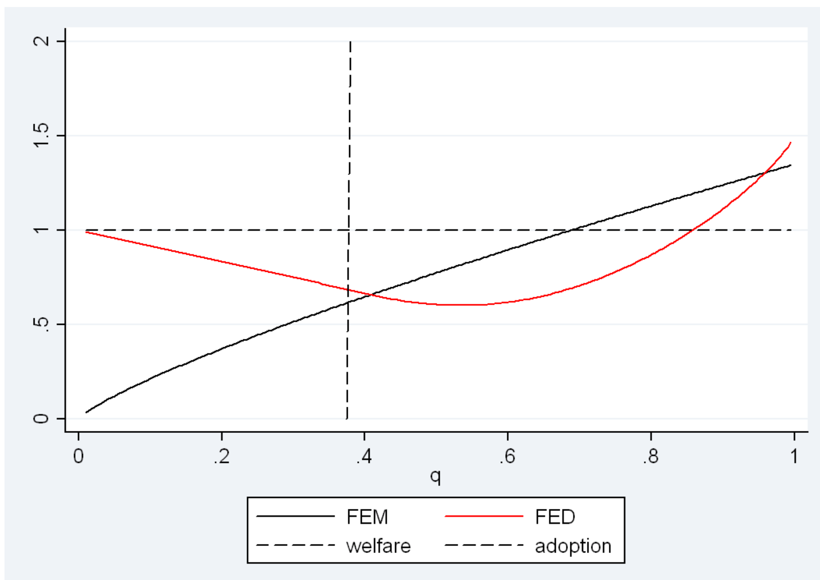

Figure 3: Case 2. Medium technology adoption costs

Interestingly, the unique stable equilibrium with a positive number of multinational firms (ie. the interior solution for high values of q) yields higher welfare compared to the previous case. The reason is that in light of the higher fixed costs, only very few domestic firms are productive enough to adopt the foreign technology. This equilibrium is therefore very close to a situation where all firms use the M-technology.

Case 3: High technology adoption costs

When technology adoption costs are very high (here illustrated with a value of $\Omega_D = 0.7$ in Figure 4), almost no domestic firm adopt the foreign technology. It follows that domestic firms are almost completely hurt from suppliers adopting the foreign technology, which is reflected by a downward shifting curve f_D.

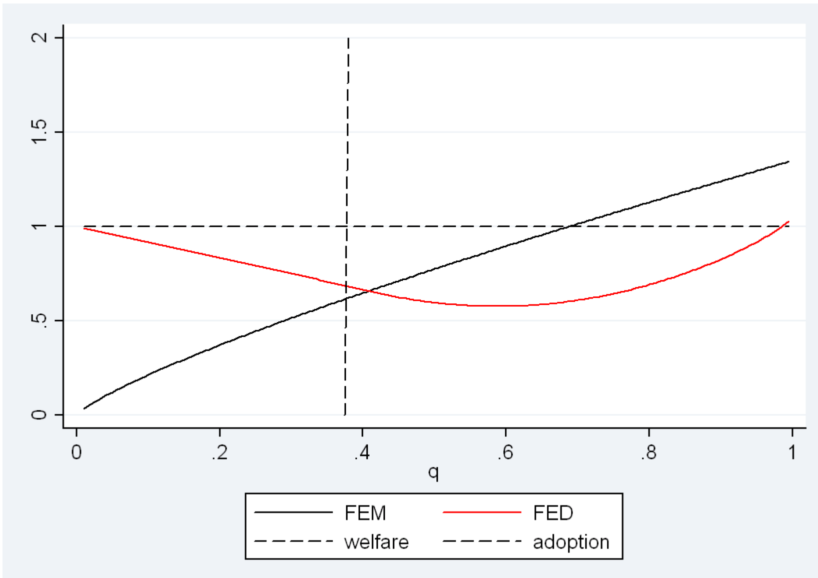

Figure 4: Case 3. High technology adoption costs

Therefore, when q is close to one, entry by domestic firms becomes harder than entry by multinational firms, and we no longer observe mixed equilibria. The long-term equilibrium can be either of two: one where only domestic firms using the D-technology prevail, or the opposite in which only multinational firms survive. Thus, in the presence of technological incompatibilities and the difficulty to adopt the foreign technology on the part of locals, the outcome depends pretty much on the size of foreign entry. When multinationals enter in small numbers, they are unable to attract a sufficiently large base of suppliers, and they are eventually forced out. The equilibrium is the same as in autarky, and thus welfare does not change. On the contrary, when entry by multinational is massive (leading to $q \cong 1$), the attraction of suppliers provides the M-technology with a great advantage that, in light of the large costs of adoption, does not reach domestic firms and in fact ends up acting as an endogenous barrier to entry. Formally, this barrier to the entry of domestic firms when $q = 1$ arises if and only if:

$$\Omega_D < \Omega_M$$

Note that since the local economy is populated exclusively by multinationals that operate the more efficient technology, welfare is unambiguously higher in this case. Nevertheless, the effect on local industry development we obtain here contrast starkly with the conclusions obtained by Markusen and Venables (1999), and so in the source of welfare improvements.

As we have shown in these three cases, the impact of FDI and technology adoption costs on welfare and local industrial development depends strongly on the type of equilibrium and initial conditions. Related to this, the already mentioned study for the case of the Czech Republic and Russia shows that negative spillovers to domestic firms declined over time in the Czech case, while it became stronger with time in the case of Russia. Among other differences, Czech firms were found to be located closer to the productive efficiency of the frontier foreign firms than were Russian firms. For example, the Russian firm at the 90th percentile was at the same distance that the median Czech firm. In our model, this implies that the parameter λ_D was much closer to λ_M in the former case than in the latter, leading to attenuated negative effects.

Finally, while in the above exercise we have concentrated in the impact of variations of the fixed costs of adoption, it should be remarked that the impact of variations in the rest of the parameters (that are not develop here) have the "expected signs" (more efficiency of the foreign technology improves welfare, higher entry fixed costs for domestic producers decrease it, etc.).

7 Conclusion

Both the nature of competition with domestic firms and of the linkages between foreign affiliates and local suppliers are a matter of ongoing debate. In this paper, we proposed a mechanism through which these two might be related. We argued that differences in technologies used by foreign and domestic plants might create a segmentation in the intermediate goods markets, given that local suppliers need to choose between two competing technologies. We developed a tractable model of inter-industry linkages and derived feasibility conditions for an equilibrium with "technological segmentation" to arrive. We found that, even though the arrival of MNEs under such a strategy might be welfare improving, domestic firms might suffer from negative externalities due to a reduction in the access to intermediate varieties that are compatible with domestic methods of production. We later showed that the mechanisms remain even if some degree of compatibility among inputs for both technologies is allowed for. We showed that in those cases, our model helps to rationalize the prominence of collective private sector standards that we have witnessed recently. Further, we extended the model to a version in which firms in the upstream industry are heterogeneous in marginal costs, to account for the observed fact that multinationals tend to source from a small group of best suppliers in the country. This allowed us to provide some relationships between productivity dispersion among suppliers and multinational profits.

We then developed a long run version of the model in which entry and exit decisions of all types of firms was made endogenous. Further, we allowed domestic firms to benefit from contacts with multinationals by assuming that they themselves are able adopt the modern foreign technology. The coupled assumptions of heterogeneity in productivity and fixed costs of technology adoption generated a self-selection of the most productive firms into the foreign technology. We used this to study the long run welfare effects of multinational entry and its impact on local industrial development. We found that technological incompatibilities interact with the cost of adoption of the foreign technology in non monotonic ways, and that due to multiplicity of equilibria, initial conditions matter. The result that the likelihood of an equilibrium in which local firms are forced out increases with the costs of adoption suggests that foreign firms might face incentives to customize their technologies in order to prevent imitation. While looking at those types of incentives is out of the scope of this work, our analysis might inform future investigation in this sense.

Along the way, we had to make some simplifying assumptions. We neglected strategic interactions by assuming monopolistic competition in the downstream industry. Moreover, we also neglected monopsony effects that might arise if groups of firms using the same technology exert this type of power in their suppliers. Future work should look at these issues in more details. Another extension of this analysis should allow more flexibility to multinationals regarding the mode of entry (i.e. exports versus FDI) and the propensity to source locally. We could in this way investigate how technological incompatibilities and the quality of the local upstream industry determine optimal linkages with the local economy, from the point of view of multinationals. Such an extension might prove quite useful in terms of public policy.

Finally, future research should also aim at testing whether the effects we describe in the model, and that we believe are a plausible explanation for already existing empirical results, are validated against the data.

References

[1] Alfaro, L. and Rodriguez-Clare, (2004) "Multinationals and Linkages: An Empirical Investigation", *Economia*, Vol. 4, Nr 2.

[2] Aitken, B. and Harrison, A. (1999), "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela", *American Economic Review*, Vol. 89.

[3] Barba-Navaretti, G. and Venables, A. (2004),*Multinational Firms in the World Economy*, Princeton University Press, Princeton.

[4] Batra, Morisset and Saggi (2002), "Vertical Linkages Between Multinationals And Domestic Suppliers: Whom Do They Benefit And Why?", manuscript, IFC.

[5] Bolmstrom, and Kokko, (1997) The Impact of Foreign Investment on Host Countries: A Review of the Empirical Evidence *World Bank Policy Research Working Paper* No. 1745

[6] Blalock, G. and Gertler, P. (2007), "Welfare gains from Foreign Direct Investment through Technology Transfers to Local Supplier", *Journal of International Economics.*

[7] Benfratello, L. and Sembrenelli, A. (2002) "Foreign Ownership and Productivity: is the direction of causality so obvious?", Centro Studi d'Agliano, Working Paper 166.

[8] Caves, R. (1974) "Multinational Firms, Competition, and Productivity in Host-Country Markets", *Economica*, Vol. 38.

[9] Chudnovsky, D., A. Lpez & Gastn Rossi (2004) "Foreign direct investment spillovers, public policies and the absorption capabilities of domestic firms in the Argentine manufacturing sector (1992-2001)" , CENIT, Buenos Aires, mimeo.

[10] Ciccone, A. and Matsuyama, K. (1996) "Start-up Costs and Pecuniary Externalities as Barriers to Economic Development", Vol. 49 Issue 1.

[11] Criscuolo, C. and Martin, R. (2003) "Multinationals, Foreign Ownership and Productivity in UK Businesses", Royal Economic Society Conference, Vol. 50.

[12] Djankov, S. and Hoekman, B. (2000) "Foreing Investment and Productivity Growth in Czech Entreprises", *World Bank Economic REview*, Vol. 14, Issue 1.

[13] Doms, M. and Jensen, J. (1998) "Comparing Wages, Skills and Productivity between Domestically and Foreing-Owned Manufacturing Establishments in the United States", in *Geography and Ownership as bases for*

Economic Accounting, Studies in Income and Wealth, R. Baldwin, et. al Vol. 59 pp 235-258, University of Chicago Press.

[14] Dunning, J. (1977). "The determinants of international production.*Oxford Economic Papers*, Vol. 25, No. 3, pp. 289-336.

[15] Ethier, W. (1982), "National and international returns to scale in the modern theory of international trade", *American Economic Review* Vol. 72, Issue 3, 389-405.

[16] Forfas (1999) "Annual Survey of Irish Economy Expenditures: Results for 1997", Dublin.

[17] Girma, S. and Gorg, H. (2005) "Foreign Direct Investments, Spillovers and Absorptive Capacity: evidence from Quantile Regressions", Discussion Papers Series 1: Economic Studies, N. 12/2005.

[18] Globerman, S. (1979), "Foreign Direct Investment and "Spillover" Efficiency Benefits in Canadian Manufacturing Industries", *Canadian Journal of Economics*, Vol. 12.

[19] Griffith, R. and Simpson, H. (2001), "Characteristics of Foreing-owned firms in British Manufacturing", The Institute for Fiscal Studies Working Paper 01/10.

[20] Gorg, H. and Ruane, F. (2001) "Multinational Companies and Linkages: Panel-Data Evidence for the Irish Electronics Sector", *International Journal of the Economics of Business*, Vol. 8, Issue 1.

[21] Haddad, M. and Harrison, A. (1993), "Are there Positive Spillovers from Direct Foreing Investment? Evidence from Panel Data from Morocco", *Journal of Development Economics*, Vol. 42.

[22] Hopenhayn, H. (1992), "Entry, Exit, and firm Dynamics in the Long-Run", *Econometrica*, Vol. 60, Issue 5.

[23] Javorcik, Beata S. (2004), "Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages", *American Economic Review* Vol. 94, Issue 3.

[24] Javorcik, Beata S. and Spatareanu, M. (2008), "To Share or Not to Share: Does Local Participation Matter for Spillovers from Foreign Direct Investment?", *Journal of Development Economics*, Vol. 85, Issues (1-2).

[25] Javorcik, Beata S., Keller, W., Tybout, J. (2006), "Openness and industrial response in a Wal-Mart world: a case study of Mexican soaps, detergents, and surfactant producers", World Bank Policy Research Working Paper 3999.

[26] Kokko, A. (1996), "Productivity spillovers from competition between local firms and foreign affiliates", *Journal of International Development*, Vol. 8, 517-530.

[27] Kokko, A., M. Zejan and R. Tansini, (1994), ""Trade Regime and Spillover Effects of FDI: Evidence from Uruguay", Review of World Economics Vol. 137, 124-49.

[28] Konings, J. (2001), "The Effects of Foreign Direct Investment on Domestic Firms: Evidence from Firm-level Panel Data in Emerging Eonomies", CEPR Discussion Paper 2586.

[29] Kugler, M (2005), "Spillovers from Foreign Direct Investment: Within or Between Industries?", *Journal of Development Economics*, Vol. 80, Issue 2.

[30] Lipsey, R. (2002) "Home and Host Country Effects of FDI", NBER Working Papers 9293.

[31] Lin, P. and Saggi, K. (2007) "Multinational, Exclusity, and Backward Linkages", *Journal of International Economics*

[32] Markusen, J. , and Venables, A.(1999), "Foreign direct investment as a catalyst for industrial development." *European Economic Review*, Vol. 43.

[33] Melitz, Marc J. (2003) "The Impact of Trade on Intra-Industry Reallocations on Aggregate Industry Productivity", *Econometrica*, Vol. 71, Issue 6.

[34] Morrison, J. (2006) "The Emerging Role of Private Social and Environmental International Standards in Economic Globalization", *International Environmental Law Committee Newsletter*, VOl. 1, Issue 3, Winter/Spring.

[35] 0'Malley (1995), "An Analysis of Secondary Employment Associated with Manufacturing Industry", General Research Series Paper No. 167, Dublin: The Economic and Social Research Institute.

[36] OECD (2002), "Encouraging Linkages Between Small and Medium-sized Companies and Multinational Entreprises", OECD, Paris.

[37] Rodriguez-Clare, A. (1996) "Multinationals, Linkages, and Economic Development", *American Economic Review*, Vol. 86.

[38] Rodriguez-Clare, A. (2005) "Coordination Failures, Clusters and Microeconomic Interventions", *Economia*, Vol. 6, Issue 1.

[39] Sabirianova, K., Svejnar, J., Terrell, K. (2005) "Distance to the Efficiency Frontier and FDI Spillovers", *Journal of the European Economic Association, Papers and Proceedings* Vol. 3, Issue (2-3). Reprinted in: Proceedings of the International Economic association XIV World Congress, 2007.

[40] Schoors, K. and B. Van der Tol (2002), "Foreign Direct Investment Spillovers Within and Between Sectors: Evidence from Hungarian Data", Ghent University, Working Paper 2002/157.

[41] Shoemaker, D.; Ulferts, G. and Jovanovic, V. (1995) "In search of excellence, or adequacy? The plight of multinational business looking for a quality concept", *Multinational Business Review*, Fall.

[42] Sjholm, (1999), "Technology Gap, Competition and Spillovers from Direct Foreign Investment: evidence from establishment data", *Journal of Development Studies*, Vol. 36, Issue 1.

[43] Sutton (2004) "The Auto-component Supply Chain in China and India A Benchmarking Study", mimeo, London School of Economics.

[44] UNCTAD (2001), World Investment Report 2001: Promoting Linkages. United Nations, New York and Geneva.

[45] UNCTAD (2007), "Food Safety and Environmental Requirements in Export Markets - Friend or Foe for Producers of Fruit and Vegetables in Asian Developing Countries?", United Nations, New York and Geneva.

[46] Verhoogen, E. (2008) "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector", *Quarterly Journal of Economics*, Vol. 72, Issue 2.

8 Appendix

Section 4

• **The complete system in n and q**

We first provide the complete system of equations:

$$\begin{cases} \pi_M(q,n) = f_e + f_q \\ \pi_D(q,n) = f_e \end{cases}$$

Demand for M-type inputs is proportional to the market share of multinational firms S_M whereas demand for D-type inputs is proportional to $(1 - S_M)$. It follows that:

$$\pi_M = \tfrac{\alpha E}{nq} S_M$$
$$\pi_D = \tfrac{\alpha E}{n(1-q)} (1 - S_M)$$

Total market share of multinational firms is given by:

$$S_M = \frac{N_M (C_M)^{1-\eta}}{N_M (C_M)^{1-\eta} + N_D (C_D)^{1-\eta}}$$

Given the price index of each type of inputs, we obtain the variable cost in the downstream industry:

$$C_M = c\lambda_M (nq)^{\frac{1}{1-\sigma}}$$
$$C_D = c\lambda_D (n(1-q))^{\frac{1}{1-\sigma}}$$

From these three sets of equations, we obtain the final system of two equations in two unknowns n and q:

$$\begin{cases} \pi_M = \frac{\alpha E}{nq} \cdot \frac{N_M \lambda_M^{1-\eta} q^{\frac{1-\eta}{1-\sigma}}}{N_M \lambda_M^{1-\eta} q^{\frac{1-\eta}{1-\sigma}} + N_D \lambda_D^{1-\eta} (1-q)^{\frac{1-\eta}{1-\sigma}}} & = f_e + f_q \\ \pi_D = \frac{\alpha E}{n(1-q)} \cdot \frac{N_D \lambda_D^{1-\eta} (1-q)^{\frac{1-\eta}{1-\sigma}}}{N_M \lambda_M^{1-\eta} q^{\frac{1-\eta}{1-\sigma}} + N_D \lambda_D^{1-\eta} (1-q)^{\frac{1-\eta}{1-\sigma}}} & = f_e \end{cases}$$

• **How to solve the system?**

First, by multiplying both equations by q and $1 - q$ respectively and taking the sum, we obtain n as a function of q:

$$n = \frac{\alpha E}{f_e + q f_q}$$

Second, by taking the ratio of both equations, we obtain that the ratio of market shares of downstream firms must equal the ratio of total fixed costs paid by their respective suppliers:

$$\frac{N_M \lambda_M^{1-\eta} q^{\frac{1-\eta}{1-\sigma}}}{N_D \lambda_D^{1-\eta} (1-q)^{\frac{1-\eta}{1-\sigma}}} = \frac{(f_e + f_q) q}{f_e (1-q)}$$

Solving for $\frac{q}{1-q}$, we obtain equation XXXX

- **The price index (proposition 2)**

First note that, given that mark-ups are constant, P is a simple function of downstream costs:

$$P^{1-\eta} = \rho^{1-\eta} \left[N_M C_M^{1-\eta} + N_D C_D^{1-\eta} \right]$$

where $\rho = \frac{\eta}{\eta-1}$ is the mark-up over marginal cost that is charged by each downstream producer. Replacing by the expressions for C_M and C_D in terms of the endogenous variables n and q, we have:

$$P = \rho^{1-\eta} c^{1-\eta} n^{\frac{1-\eta}{1-\sigma}} \left[N_M \lambda_M^{1-\eta} q^{\frac{1-\eta}{1-\sigma}} + N_D \lambda_D^{1-\eta} (1-q)^{\frac{1-\eta}{1-\sigma}} \right]$$

Replacing n and q for their equilibrium values, introducing Λ_T as in the text (with $T \in \{M, D\}$) and rearranging, we obtain the price index in the technological segmentation equilibrium:

$$P^{1-\eta} = \rho^{1-\eta} c^{1-\eta} (\alpha E)^{\frac{1-\eta}{1-\sigma}} \left[N_M^{\theta} (\Lambda_M^{1-\eta})^{\theta} + N_D^{\theta} (\Lambda_D^{1-\eta})^{\theta} \right]^{\frac{1}{\theta}}$$

In a non-segmented equilibrium with the same number of downstream firms, the price index would be:

$$P^{1-\eta} = \rho^{1-\eta} c^{1-\eta} (\alpha E)^{\frac{1-\eta}{1-\sigma}} \left[N_M + N_D \right] \Lambda_D^{1-\eta}$$

It is now easy to compare the two expressions.

Section 5

- **The complete system in n and q with flexibility**

Now, costs are given by:

$$\begin{aligned} C_M &= c\lambda_M n^{\frac{1}{1-\sigma}} [q + m^{1-\sigma}(1-q)]^{\frac{1}{1-\sigma}} \\ C_D &= c\lambda_D n^{\frac{1}{1-\sigma}} [1 - q + d^{1-\sigma} q]^{\frac{1}{1-\sigma}} \end{aligned}$$

Let us then define an equivalent number of supplier with more flexible use of inputs across technologies:

$$\tilde{q}_M = q + m^{1-\sigma}(1-q)$$

and

$$\tilde{q}_D = 1 - q + d^{1-\sigma} q$$

The system of equations is now:

$$\begin{aligned} \pi_M = &\quad \frac{\alpha E}{n\tilde{q}_M}.\tilde{S}_M + \frac{\alpha E d^{1-\sigma}}{n\tilde{q}_D}.(1-\tilde{S}_M) &= f_e + f_q \\ \pi_D = &\quad \frac{\alpha E}{n\tilde{q}_D}.(1-\tilde{S}_M) + \frac{\alpha E m^{1-\sigma}}{n\tilde{q}_M}.\tilde{S}_M &= f_e \end{aligned}$$

$$\text{with:} \quad \tilde{S}_M = \frac{N_M \lambda_M^{1-\eta} \tilde{q}_M^{\frac{1-\eta}{1-\sigma}}}{N_M \lambda_M^{1-\eta} \tilde{q}_M^{\frac{1-\eta}{1-\sigma}} + N_D \lambda_D^{1-\eta} \tilde{q}_D^{\frac{1-\eta}{1-\sigma}}}$$

Solving for the system above, we obtain that the expression for n (as a function of q) remains the same, but now equilibrium q verifies:

$$\frac{q + m^{1-\sigma}(1-q)}{1 - q + d^{1-\sigma} q} = \left(\frac{N_M}{N_D} \frac{\lambda_M^{1-\eta}}{\lambda_D^{1-\eta}} \left[\frac{f_e - m^{1-\sigma}(f_e + f_q)}{(f_e + f_q) - d^{1-\sigma} f_e} \right] \right)^{\theta}$$

from which the relative cost may be deduced.

- **Proof of proposition 4**

The relative productivity of multinational firms increases with:

$$\frac{f_e - m^{1-\sigma}(f_e + f_q)}{(f_e + f_q) - d^{1-\sigma} f_e}$$

This term is decreasing with $m^{1-\sigma}$ and thus increasing with m.

When $m = d = \tau$, the relative productivity of MNEs increases with:

$$\frac{f_e - \tau^{1-\sigma}(f_e + f_q)}{(f_e + f_q) - \tau^{1-\sigma} f_e}$$

It is decreasing with $\tau^{1-\sigma}$ and thus increasing with τ.

- **Heterogeneous suppliers**

Existence and uniqueness of the solution is guarantee as long as:

$$\frac{\int_0^{c^*} c^{1-\sigma} dH(c)}{c*^{1-\sigma} \, H(c^*)}$$

is bounded when c^* decreases towards zero (a formal proof may be available upon request).

With heterogeneous suppliers with costs drawn from a cumulative distribution $H(c)$, similar calculus as previously show that:

$$\frac{C_M}{C_D} = \frac{\lambda_M}{\lambda_D}^{1+\frac{\eta-1}{\sigma-\eta}} \left(\frac{N_D}{N_M} \frac{f_e + f_q}{f_e} \right)^{\frac{1}{\sigma-\eta}} \left(\frac{1 - \frac{f_q}{f_e+f_q} \int_{c^*}^{\infty} (c*^{1-\sigma} - c^{1-\sigma}) dG(c)}{1 - \frac{f_q}{f_e} \int_0^{c^*} (c^{1-\sigma} - c*^{1-\sigma}) dG(c)} \right)^{\frac{1}{\sigma-\eta}}$$

If we compare to the equilibrium relative cost with homogenous suppliers, we obtain condition (H).