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ABSTRACT

Multinationals, Technological Incompatibilities, and Spillovers*

Empirical studies provide evidence of positive spillovers from multinational firms to upstream suppliers coupled with 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 foreign technologies require specialized inputs, some local suppliers self-select into production for multinational firms. This ”technological segmentation” in the upstream industry magnifies the productivity advantage of multinationals by restricting backward and forward linkages to groups of firms using the same technology. In this setting, we study the role of heterogeneity among domestic firms. We show that only the best suppliers adopt the foreign technology and cater to multinationals. In the long run, technology adoption by the most productive downstream firms creates complementarities with multinationals that can offset the negative impact of segmentation.

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1 Introduction

The host country effects of Foreign Direct Investment (FDI) constitute a traditional concern in international and development economics. One of the consequences of the impressive surge in FDI flows in recent decades has been to bring this debate back to the fore. The current view of the impact of multinationals is optimistic, and the general feeling is that, in many circumstances, their arrival can significantly contribute to the development process in destination economies. One manifestation of this feeling is the inclusion of FDI attraction policies as a core element of wider development policy packages by governments all over the developing world. Moreover, the attraction of foreign investment seems to be high on the policy agendas of development agencies such as the World Bank, the IMF and the OECD.

Among the potential channels through which FDI is thought to enhance the development process in host economies, productivity and technological externalities to domestic firms is often cited as a salient one. Nevertheless, we have a far from full understanding of this issue. Much of the work done by economists is empirical and concentrates on testing whether spillovers of this kind actually occur. Typically, studies regress a measure of firm-level productivity for domestic firms on a measure of foreign presence at sector level. Empirical work of this type has failed to provide systematic evidence of positive spillovers at horizontal level, that is, to firms operating in the same sectors as multinational enterprises (MNEs). Furthermore, many studies have found negative impacts.[1] On the other hand, studies testing for vertical spillovers, i.e. for externalities to upstream suppliers, provide far more optimistic findings. Multinational presence appears to be correlated with productivity and technological advances in firms located in supplying industries. Put together, these two empirical regularities are 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 consequently have access to a better quality supplier base.

In this paper, we argue that incompatibilities between foreign and local technologies can affect the nature of linkages between multinational and domestic firms, and explain the above-mentioned facts. Our model is built around the key assumption that foreign and domestic technologies are essentially different. A crucial aspect of these differences, other than differ-

[1] An overview of the empirical literature is provided in Section 2. Nevertheless, the empirical literature on FDI and spillovers is vast. Readers interested in extensive studies may be referred to Barba and Navaretti (2004, Ch. 7), Lipsey (2002) and Bolmstrom and Kokko (1997), among others.

ences in productive efficiency, is that the foreign technology requires specialized inputs. Upon arrival in a developing economy, foreign firms set up their production plants which operate with technologies designed in Northern headquarters.[2] In so doing, they do not merely expand the local market for intermediate goods, but rather create a new market for customized intermediates. From the moment there are costs associated with 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 such incompatibilities is provided by a recent case study on the Mexican soaps, detergents and surfactants industry by Javorcik *et al.* (2006). When Mexico opened its borders to foreign investors, incoming US multinationals brought with them technologies and product formats that were previously unavailable locally (e.g. "compact formulas"). The report documents how suppliers catering to multinationals (some foreign-owned themselves) had to reformulate their inputs by substituting foreign standard ingredients with cheaper ingredients when catering to domestic producers. Moreover, Mexican detergent producers had to incur substantial costs of reformatting their products in order to introduce the foreign technology.

We ask how multinational entry impacts on the performance of domestic competitors and consumer welfare. We first consider a short run version of the model where the number of final goods producers is exogenous. Technological incompatibilities create a segmentation in the upstream industry that endogenously amplifies the productivity advantage of foreign plants. The higher the market share of MNEs downstream, the larger the proportion of suppliers choosing to serve foreign plants. This causes a reduction in the availability of intermediates compatible with the local technology, raising costs for domestic firms. Thus, negative externalities arise, that add to conventional business stealing effects that have been the focus of earlier studies. The negative effect of segmentation in firms' cost structure might offset potential welfare gains from the introduction of a more productive technology. In this setup, we introduce heterogeneity among domestic suppliers and show that, consistently with available evidence, the most productive firms self-select as suppliers for MNEs. Whether firm heterogeneity increases multinational profits remains unclear, and dependent on the parameters of

[2] The decisions of where to source and whether to do it within the boundaries of the firm has been extensively analyzed elsewhere (see e.g. Antras, 2003 and 2005, Antras and Helpman, 2004, Grossman and Helpman, 2003, 2005). We do not attempt to add anything new to this issue here. It should be stressed, though, that all that we need is that foreign plants source at least a portion of intermediates from independent local suppliers. The mechanisms we describe in the text remain if we add in more complex sourcing strategies.

the productivity distribution. On the other hand, we obtain that, paradoxically, profits of multinationals decrease with their ability to use domestic inputs. In the light of the model, we argue that voluntary private standards might constitute a commitment device that would prevent multinational corporations from using inputs produced with the local technology.

Things can be quite different, though, if domestic firms are allowed to incorporate the foreign technology.[3] We develop a long-run version of the model with free entry, in which heterogeneous domestic firms can adopt the foreign technology by incurring a fixed cost. Technology adoption by the most productive firms creates complementarities between these firms and multinationals, which could trigger further adoption of the foreign technology and lead to a long-run equilibrium that outweighs autarky in welfare terms. We also show that technological incompatibilities can endogenously create barriers to entry for both types of firms by raising the costs of inputs.

Our paper contributes to a small, but growing body of formal literature studying backward linkages between multinational firms and local suppliers. The pioneering study in this area is by Rodriguez-Clare (1996), who develops a model in which multinationals source intermediate goods in a low-wage country: if the intensity with which they source local inputs – the "linkage potential" – is high enough, MNEs create higher net backward linkages that push 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. As in the work of Rodriguez-Clare, the demand for inputs (backward linkages) created by foreign plants causes entry upstream. This exerts downward pressure on the costs of all downstream firms, generating a forward linkage. Domestic firms, more intensive users of local inputs, gain relatively more. As a consequence, there exist dynamic paths in which foreign firms are eventually forced out and only domestic firms prevail. In both papers, however, demand for intermediate goods from multinational firms is directed to all local upstream firms. This assumption contradicts evidence suggesting that multinationals tend to source from a small base of local suppliers.

In a recent paper, Lin and Saggi (2007) incorporate exclusivity contracts from a multinational firm to local suppliers in a model of a two-tier Cournot oligopoly, and allow the foreign firm to transfer technology to upstream firms. Exclusive contracts restrict technology transfers from the multinational firm within the group of exclusive suppliers, thus leaving domestic

[3] The presence of firms operating a new technology provides opportunities for domestic firms to adopt the new technology by imitation or reverse engineering. In this regard, there is evidence showing that firms with high absorptive capacity are those that benefit from positive spillovers from multinational presence (e.g. Girma and Gorg, 2005). Our model explicitly incorporates this feature and studies its implications.

producers with suppliers that do not benefit from technology transfers. In our paper, segmentation and spillovers occur instead through structural incompatibilities between modern and backward technologies. In less developed countries, these incompatibilities may be particularly important, while it is plausible to argue that exclusive contracts are less likely to be enforceable.

Another difference is that our model highlights externalities between firms. As in the work of Lin and Saggi (2007), foreign entry increases the cost of inputs for domestic firms. However, in our model, the scale of multinational entry plays a central role: the higher the level of foreign entry, the greater the productivity advantage of foreign plants. This suggests the existence of strategic complementarities among multinationals.[4] Our tractable framework also allows for the analysis of the effects of segmentation at the industry equilibrium.[5] Finally, contrary to existing work, we study the role of productivity heterogeneity among domestic firms. We show that technological incompatibilities create complementarities between multinationals and the most productive firms. In line with available evidence, only the best suppliers adopt the foreign technology and cater to multinational firms. In the long run, we allow for horizontal technological externalities from multinationals to domestic firms in the downstream sector, and show that most productive domestic firms adopt the foreign technology and benefit from the same base of suppliers as multinationals. The increase in the demand for inputs reduces costs for all of the firms using the foreign technology and encourages entry of both foreign and domestic firms.

Our work can also be seen as complementary to the literature that highlights the role of FDI in the international transmission of technology, focusing on human capital, absorptive capacity and intellectual property rights as key determinants (see Hoeckman and Javorcik, 2006, for a survey). This literature has not yet looked at the technological incompatibilities that are central to our argument, in spite of the fact that virtually all studies acknowledge the large differences between multinational and domestic firms. Lastly, a different approach to technological incompatibilities is central to the debate on appropriate technology (e.g. Acemoglu and Zilibotti, 2001, Acemoglu, 2007, and Thoenig and Verdier, 2003), which posits that technologies developed in Northern countries are incompatible with factor endowments in the South.

The rest of the paper is organized as follows. Section 2 reviews empirical evidence on

[4] Lin and Saggi (2007) consider only one multinational firm, and a fixed number of domestic producers.

[5] Some of our results (e.g. Proposition 3) would not necessarily hold in partial equilibrium.

multinationals and local firms gathered into a series of stylized facts. Section 3 presents the model's set-up and discusses its main assumptions. Section 4 provides a solution of a "short-run" version of the model, with an exogenous number of domestic and multinational firms, two extensions of which are developed in Section 5. Section 6 develops a long-run version of the model with free entry conditions and 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 the available empirical and anecdotal literature on relationships between multinational firms and local suppliers in developing countries. We gather together the different stylized facts that inspired our theoretical analysis.

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

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

These observed differences in labor and 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 how this affects the relationships with suppliers in developing economies is given by the Mexican industry case study by Javorcik *et al.* mentioned in the introduction.

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

Evidence shows that multinationals create linkages with local suppliers in their countries of operation. Batra *et al.* (2003) use a manufacturing survey on Malaysia to 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 keeping with the trend seen in that industry in the world. Alfaro and Rodriguez-Clare (2003) develop a linkage coefficient as the ratio of the quantity of inputs bought domestically to the number of employees. They empirically apply this measure to a comparative study of four Latin American economies to find that, in three cases, the foreign affiliates' "backward linkage potential" is statistically significantly higher than that of the domestic firms. O'Malley (1995) uses the same measure for the Irish manufacturing industry with similar conclusions. Evidence on Ireland is also found in Forfas (1999) and Gorg and Ruane (2001), the latter showing 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.

Studies testing for horizontal externalities turn up mixed results, generally failing to find positive externalities and often identifying negative effects. A widely cited example is that of Aitken and Harrison (1999), who study the case of Venezuela and find that while foreign ownership raises plant productivity, higher MNE presence is associated with a negative effect on domestic-owned plant productivity. Other examples of failure to find positive horizontal externalities from MNEs in developing countries are Djankov and Hoekman (2000) for the Czech Republic and Konings (2000) for a set of countries. Findings regarding the existence of vertical spillovers are much more consistent and optimistic. In her study of a panel of Lithuanian manufacturing firms for the period 1996-2000, Javorcik (2004) finds evidence consistent with positive externalities on suppliers from increased foreign presence in downstream sectors. This effect is higher for firms with sales oriented towards the local market. However, her data rejects the hypothesis of horizontal externalities. Blalock and Gertler (2007) present similar evidence for Indonesia. Along the same 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 externalities between sectors by showing that FDI in one sector in Colombian manufacturing can Granger-cause productivity gains in other sectors, but he does not find evidence of within-sector spillovers. Lastly, in the abovementioned case study of the Indian and Chinese automotive industries, Sutton reports that first-tier suppliers of multinational carmakers raised their productivity and quality levels, attaining European best practices in terms of defect rates. However, these improvements did not filter down 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 to the notion that foreign affiliates tend to develop close relationships with a small base of local suppliers selected by a long, meticulous process. The following paragraph from the UNCTAD World Investment Report 2001 (page 137) is illustrative of this point:

> "[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 this regard, one characteristic often highlighted is the role played by local capabilities in the development of deep backward linkages between local and foreign firms. Multinational firms single out the failure of local suppliers to comply with their quality, price and delivery time requirements as major obstacles to the development of backward linkages in the host economy.[6] Foreign affiliates have been described as "'talent scouts' in search of local SMEs capable of becoming global suppliers to the firm" (OECD, 2002).

To the best of our knowledge, there is not as yet any rigorous econometric study available to test the proposition that only suppliers in the upper tail of the distribution of local capabilities

[6] FIAS (1997).

qualify to cater to large foreign-owned corporations.[7] However, support for this view can be found in indirect as well as anecdotal evidence. Javorcik and Spatareanu (2003) look at a panel of Romanian firms and find a positive effect on supplier productivity only in the case of partially foreign-owned downstream projects. 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 based on human capital and R&D intensity. They find that only firms with higher capacities reap positive externalities from inward FDI (Chudnovsky *et al.* (2004) in the case of Argentina, Schoors and van der Tol (2001) on Hungary). Selection effects are one plausible explanation for this result.[8] Blalock and Gertler (2007) provide some anecdotal evidence from interviews with managers of American and Japanese companies operating in Indonesia. Among other things, these managers stated that: 1) Domestic supplier accreditation is a multistage process that takes years. In the first stage, foreign firms visit the local factory, analyze a sample product and send the local supplier to the home market to understand the MNEs' production systems. Once the sample is approved, they ask the local firm to produce a small amount and, if delivery time and quality is up to standard, take it on as a large-scale supplier; 2) "Suitable" suppliers are hard to find.

In this regard, multinational firms increasingly impose on prospective suppliers that they should already have taken on board international standards. While these practices are found across all industries, they are more frequent in certain sectors. A clear example is given by the automotive industry. In Slovakia, Volkswagen require that all suppliers first get VDA[9] quality certificates, in keeping with the requirements of the German automotive industry.[10] 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 require that suppliers, irrespective of their country of origin, comply with private protocols of food safety standards, logistical requirements and process documentation. Generally, ISO norms are by far the most prominent type of standards, regardless of the indus-

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

[8]A complementary, and more frequently 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.

[9]Verband der Automobilindustrie.

[10]UNCTAD (2001), page 157.

try in question: a survey conducted by Mobil Corporation found that ISO 9000 registration is now recognized as the basis for quality process definition in 68 countries.[11]

3 Setup of the model

We now develop a partial equilibrium model of an economy composed of two vertically related industries. Multinational firms are assumed to enter the local downstream industry to serve local consumers.

Preferences

Consumer preferences are assumed to be represented by a utility function of the 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 consumer good Y. N represents the total number of downstream varieties.[12] If E denotes the exogenous income spent in Y industry in terms of numeraire good[13], the producer of a given variety j will have 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 the final goods.

Production

The final goods industry is populated by N_D domestic and N_M multinational firms.

Two technologies for final goods production co-exist: a domestic "D-technology" and a foreign "M-technology". The efficiency of each is given by a technological parameter λ indexing the quantity of intermediate inputs required to produce one unit of final good. The assumption $\lambda_M < \lambda_D$ reflects the relative technological backwardness of the domestic technology.

[11] Cited by Shoemaker *et al.* (1995).

[12] For ease of reading, we shall henceforth denote all variables pertaining to the downstream industry in uppercase, as opposed to lowercase for upstream industry variables.

[13] Our results hold if, for example, the size of the industry decreases with price index P.

A central assumption is the requirement of technology-specific intermediate goods. We call D-type inputs those compatible with the D-technology, and M-type inputs those produced for use with the M-technology. Following Ethier (1982), horizontally differentiated intermediate goods are assumed to enter final production as a CES composite, with the elasticity of substitution between any two varieties denoted by σ, and assumed to be equal for both technologies. Throughout, we assume for stability that $\sigma > \eta$. Formally, if $T \in \{D, M\}$, the corresponding production function is

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

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

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

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 $P_j = \frac{\eta}{\eta-1} \lambda_T p_T$.

In the baseline specification, we study the extreme case in which inputs designed for one type of technology are completely useless to producers operating under the alternative one. Later on, we show that our results hold as long as inputs are not completely compatible.

We now turn to upstream producers. Applying Sheppard's lemma to 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 (endogenous) demand for inputs of type T. With a continuum of local entrepreneurs, individual decisions are made taking the environment as given, and this results in the usual mark-up pricing formula $p_i = \frac{\sigma}{\sigma-1} c_i$, where c are unit costs in terms of the numeraire good.

Entry into 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. Conversely, the production of M-type inputs requires extra overhead costs of magnitude f_q.[14]

4 Solution of the model: short run

We now proceed to the solution of the model in the short run, where the number of downstream firms N_D and N_M is taken as exogenous, and only multinationals have access to the foreign technology.

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.

Suppliers make technology decisions by weighing the gains from specializing in the M-technology against their costs in terms of fixed costs and lost demand from domestic firms. An equilibrium is defined by a situation in which the net profits of specializing in either technology are equal. Moreover, the free entry condition imposes zero net profits at 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 via business stealing effects) and positively on 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 as follows:

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

[14] Alternatively, one could assume that the fixed entry cost for producing M-type inputs is higher than the fixed entry cost for producing D-type inputs by an amount f_q.

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

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

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

where θ is defined by $\theta \equiv \frac{\sigma-1}{\sigma-\eta} > 1$.

The proportion of suppliers switching to the M-technology in equilibrium increases with the relative efficiency of the foreign technology and the scale of foreign entry. This last effect points to a positive externality among multinationals and highlights a major idea of this paper, which is that technological similarities among foreign plants are a source of strategic complementarities. Massive multinational entry puts pressure on to develop a more complete supply chain attached to the modern technology. Inversely, it has a negative effect on domestic firms relying on a smaller number of suppliers.

It impacts directly on equilibrium profits. Plugging (3) into (1), we obtain:

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

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 (i.e. taking into account the cost of creating new input varieties).

Interestingly, θ measures the elasticity of relative efficiency to relative profits, which is higher than one: differences in technological efficiency amplify differences in terms of "real" efficiency (i.e. taking into account the costs of intermediates), because the more productive technology attracts more suppliers, resulting in a wider range of intermediate varieties.

Thus, the model gives rise to a mechanism by which the suppliers' technological specialization creates 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, prompting an intuition that is consistent with empirical evidence showing positive externalities for firms upstream and negative horizontal effects.[15] Backward and forward linkages are

[15] Variable 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 supplier performance.

limited to the scope of firms using the same technology and do not spread 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 it increases with the relative proportion of multinational firms in the downstream sector.*

Proposition 1 is a testable prediction. While we are not aware of any studies positing supplier selection as a determinant of the "multinational" productivity premium, a recent study on the Czech Republic and Russia by Sabirianova *et al.* (2005) found that a greater presence of foreign firms in a sector negatively affected the average productivity of domestic firms while it impacted positively on the productivity of other foreign firms. Note also that, in cases where proximity to suppliers is economically relevant, the above provides an intuition as to the mutual advantages for foreign plants to locate close to each other in clusters. Evidence of foreign-specific agglomeration forces has been found by Barrios *et al.* (2002) in Ireland.

Technological segmentation and consumer welfare

In the short run, the overall effect of multinational entry on consumer welfare will depend upon the relative strength of two forces. Firstly, the arrival of multinationals improves welfare through the introduction of a more efficient technology. Secondly, this comes at a cost of segmentation in the upstream industry, by which each type of downstream firm sources from a smaller range of varieties compared with an equilibrium where all suppliers produce for the same technology. Formally, we can state the following condition, determining whether the equilibrium under technological segmentation is preferable to autarky.

Proposition 2 *The introduction of the foreign technology improves consumer welfare when the following condition (W) holds:*

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

(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 under technological segmentation.

Proof. See Appendix C.

When $\theta = \frac{\sigma-1}{\sigma-\eta}$ is close to one, welfare effects are positive where the foreign technology is more efficient. Distortions appear as θ grows (according to expressions (3) and (4), a higher θ yields stronger backward and forward linkages), in which case the introduction of a more advanced technology may be welfare-reducing.

The above proposition compares the impact of the introduction of the foreign technology with a case where multinationals enter and adopt the domestic technology. If we make the alternative hypothesis that multinational firms can choose between the two technologies[16], it is possible to show that a segmented equilibrium can be feasible and welfare-reducing in a range of parameters (see Appendix A).

Finally, note that a strict comparison with autarky would depend on the mode of entry chosen by multinationals. If FDI occurs exclusively through acquisitions of domestic firms, the total number of downstream varieties remains constant. Therefore, the counterfactual comparison with autarky is equivalent to the comparison with the case where multinational firms produce using the local technology. If, on the other hand, FDI takes the form of greenfield investment, consumers also benefit from an increase in the number of available varieties.[17]

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, and show that our mechanisms are robust to allowing for a more flexible view of technology. Specifically, suppose that in foreign plants, $m > 1$ units of D-type inputs are equivalent to one unit of the M-type, with the symmetric parameter for domestic plants being $d > 1$. Hence, these parameters measure the degree of incompatibility across technologies; the higher their value, the less compatible the technologies are. Analytically, the characterization of the equilibrium is as before. Solving for the equilibrium ratio of

[16] There are a number of instances of multinational firms in developing countries producing low-quality goods that would not match international standards. For example, Renault's production of the "Logan" in India and Volkswagen's production of the original Beetle in Mexico using technologies dating from the 1950s (Verhoogen, 2008).

[17] The drop in price index from autarky to a non-segmented equilibrium would be equal to $\left(\frac{N_D}{N_D+N_M}\right)^{\frac{1}{\eta-1}}$.

profits (see Appendix C) gives the equivalent of expression 4 in this new setting:

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

As in the baseline case, equilibrium profits for the 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 for the 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 incentive for suppliers to specialize in the foreign technology, which in turn reduces the multinational firms' competitive advantage.

If the degree of technological compatibility is symmetric, that is $m = d = \tau$, this finding holds for multinational firms: multinational firms' profits increase with τ whereas domestic firms' profits decrease with τ. Thus, generally, we can put forward the following proposition:

Proposition 3 *In an equilibrium with technological segmentation, the competitive advantage of multinational firms decreases with their ability to use inputs produced using the local technology.*

Interestingly, individual incentives regarding m are the opposite: a single multinational's profits increase with the possibility of incorporating more inputs. Imagine that several technologies are available and that they differ only in the value of parameter m as defined above. Taken individually, the multinational prefers the technology with high compatibility with the local technologies. Thus, in the absence of a commitment device, a situation where multinational firms choose the technologies with the highest incompatibilities (a strategy that maximizes their profits collectively) would not be a Nash equilibrium.

There would hence be collective incentives for the design of a commitment device to prevent firms from individually deviating from common technological standards. We argue that this mechanism could offer a new insight into collective "voluntary private standards". Imagine if we were to re-interpret our M-technology as corresponding to a commitment to use only inputs certified as being produced under some safety, quality or environmental standards. As stated by *Fact 4*, the most prominent example of these are clearly the ISO standards, but an array of similar certifications has sprung up in recent decades.[18] Typically, these standards are developed by private or quasi-private organizations in which multinational corporations play a

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

significant role.[19] The intuitions developed here might help explain why even when these practices risk impacting negatively on the cost structure (by preventing firms from buying inputs produced by non-compliant suppliers), they can still be a profitable strategy, as expression (5) suggests.

An alternative interpretation is that parameters m and d measuring the costs of adopting alternative inputs are generated by trade costs if groups of firms are physically distant from each other – for example if $\tau = m = d$ represents symmetric trade costs in intermediate inputs. In this scenario, domestic firms prefer to locate closer to multinational firms whereas multinational firms may collectively prefer to locate further away.

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, suppliers are differentiated by technological specialization. In this section, we introduce differences in the suppliers' capabilities. A selection process occurs whereby only the best suppliers specialize in the M-technology. Hence, multinational firms source at equilibrium only from suppliers with the more efficient technology and the highest productivity, in keeping with *Fact 4*.

To account for supplier heterogeneity in our framework, we modify the baseline model as follows. We assume that, upon entry, and once final firms have entered and multinationals have made decisions about 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 using the D-technology or to pay the upgrading cost to produce M-type inputs and serve multinationals. We use this set-up to study how decisions about technology upgrading are determined by heterogeneous individual capabilities.

A supplier will choose the foreign technology if, and only if, the profits associated with the production of the M-type inputs exceed the profits associated with the production of D-type inputs plus the fixed cost of technology upgrading, given that suppliers only serve downstream firms using the same technology. If we denote A_D and A_M as the demand for each input type (endogenous in the system, but taken as given by individual suppliers), then post-entry profits

[19] Morrison (2006).

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, necessarily $A_M > A_D$. If this were not the case, then obviously no supplier would choose the M-technology. Yet if multinational firms were to need M-type inputs, the 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 higher the supplier's productivity, the greater the gains from producing M-type inputs. It follows that best suppliers specialize in the foreign technology and other suppliers produce inputs suited for the local technology.

Proposition 4 *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:

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

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 equilibrium, there is always 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 can be used to solve the total number of upstream firms n. Under the assumption that $\sigma > \eta$ and that the distribution of capabilities is not too distorted[20], both conditions uniquely determine n and c^*.

Finally, a natural question arises: does heterogeneity benefit multinational firms? In other

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

words, would they prefer to locate in sectors supplied by upstream industries with higher dispersion in productivity, *ceteris paribus*? Although best suppliers choose to serve multinational firms, productivity dispersion among suppliers does not always raise multinational firms' profits. It all depends on the shape of the distribution of capabilities, as well as the fixed costs of technology adoption and the proportion of M-type suppliers. Appendix B analyzes the conditions under which productivity dispersion positively impacts on multinational firms' profits.

6 Long-run industry equilibrium

In this section we solve a long-run version of the model in which entry and exit of downstream domestic firms and multinational firms is endogenized. Further, we allow for domestic firms to have the opportunity of incorporating the foreign technology brought in by foreign plants; the idea being that FDI acts as an international conductor of technology, by bringing in methods otherwise unavailable in autarky. Technological adoption can occur by means of imitation, reverse engineering or licensing. We make the assumption that it requires extra fixed costs. Nevertheless, some domestic firms might find it optimal to upgrade since what they stand to gain can offset 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 the technological incompatibilities described in the previous sections.

Domestic firms are assumed to be heterogeneous in productivity, in the spirit of Melitz (2003). Upon entry, domestic producers draw a (positive) productivity level φ_i from a continuous cumulative distribution $G(\varphi)$, assumed to be common knowledge. This firm-specific productivity parameter is independent of the unit costs associated with the choice of technology. A firm receiving a draw φ_i and choosing technology T has a unit cost equal to $\frac{C_T}{\varphi_i}$. 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 thus driven by a self-selection mechanism. Clearly, when $C_M^{1-\eta} < C_D^{1-\eta}$ then no domestic firm chooses the foreign technology. On the contrary, in the case where $C_M^{1-\eta} > C_D^{1-\eta}$, profits from producing final goods with the M-technology are greater than with the D-technology and the difference may exceed the technology upgrading costs F_q. Moreover, the higher the productivity draw, the larger the profit differential 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 indifferent to whether it adopts or not. This is implicitly given by:

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

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

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

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. The free entry condition for domestic firms (FED) is then written $E[\Pi_D] = F_D$.

Multinationals are assumed to enter the host country as long as expected profits are positive. This induces a free entry condition equating profits to fixed costs of entry, $\Pi_M = F_M$, labeled (FTM). Note that this implies that multinationals make their entry decisions by anticipating that some local firms will imitate their technology. For the sake of simplicity, foreign firms are assumed to be homogeneous in productivity. Hence the individual productivity parameter φ_{Mj} equals average productivity $\widetilde{\varphi}_M$.[21] We assume that fixed costs for foreign plants are high

[21] Since no firm exits after entry, heterogeneity among multinationals has no effect.

enough for multinationals to only be able to survive in equilibrium by importing their more efficient technologies.[22]

Lastly, interactions in the upstream industry remain the same as in the basic model.

Under these specifications, 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 that defines the adoption of the M-technology by domestic producers.

We would like to provide an analysis of the welfare economics of foreign entry. The right counterfactual here is the level of welfare attained in the equilibrium without multinationals (and thus without the introduction of the foreign technology). Given that profits are driven to zero in the long run, the only source of welfare is consumer surplus. We thus need to look at changes in the price index for consumer goods under the two regimes.

We can reformulate the initial system of five equations on five unknowns as a system of two equations on two unknowns to study the different equilibria in terms of welfare. The two variables that we will focus on are the proportion of suppliers adopting the foreign technology and the downstream industry price index (inversely related to competitive pressure and consumer welfare).

The rationale for this choice of variables is based on the fact that both free entry conditions for downstream firms (equations 5.3 and 5.5) represent combinations of the fixed entry costs, variable costs (determined by the number of suppliers for each technology) and competitive pressure (derived from the inverse of the price index in the downstream industry) that leave individual firms with no profits. Therefore, they can be rewritten[23] as an equality between the

[22] Formally, this implies $\frac{F_M}{F_D} > \frac{\widetilde{\varphi}_M^{\eta-1}}{\widetilde{\varphi}_D^{\eta-1}}$. The fact that foreign firms can be forced out in the non-segmented equilibrium is equivalent to the case of Markusen and Venables (1999) and will not be developed here.

[23] See Appendix C.

price index and a function of fixed and (expected) variable costs which, as shown in Section 4, depend on q. We denote $f_M(q)$ as the resulting function for multinationals, and $f_D(q)$ as the resulting function for domestic producers.

$$\begin{cases} P^{1-\eta} = f_M(q) \\ P^{1-\eta} = f_D(q) \end{cases}$$

Note that $f_M(q)$ must be an increasing function. Intuitively, the higher q, the greater the competitive advantage of firms using the M-technology and the greater the incentives for multinationals to enter the host industry. The case of domestic firms is slightly more complex, as the relationship is non monotonic. When q is low, no domestic firm finds it optimal to pay the fixed costs and adopt the M-technology. In this case, expected profits decrease with the proportion of upgrading suppliers, as this implies higher costs for firms using the D-technology. It follows that the competitive pressure from domestic firms decreases with q when q is low. However, when q reaches a threshold such that a sufficient proportion of domestic firms adopts the M-technology after entry, increases in the proportion of upgrading suppliers may have positive effects on the domestic firms' expected profits. In other words, the higher q, the greater the competitive advantage of using the M-technology, the larger the proportion of upgrading domestic firms and the more beneficial the decrease in the cost of M-type inputs. This makes the derivative of f_D with respect to q increase faster than that of f_M. This property ensures that the system has at most two interior solutions.

Figure 1 plots these two functions when the distribution of domestic firms' capabilities is parameterized with a Pareto distribution.[24] The price index $P^{1-\eta}$ is expressed as a ratio to the autarky price index (values higher than one correspond to welfare gains). The curves $f_M(q)$ and $f_D(q)$ are zero-profit contours for foreign and domestic plants and are represented in red and black respectively. In each case, points below the curves are combinations of $P^{1-\eta}$ and q generating positive profits, whereas points above the curves represent situations where profits are negative.

The vertical line in the graph is defined by the equality between C_M and C_D and gives the minimum value of q whereby the most productive domestic firm finds it optimal to upgrade to the foreign technology. Below this value, there is no adoption by local firms.

[24]Details as well as values used in the simulations are provided in Appendix C.

[Figure 1 about here]

There are two stable equilibria. A first equilibrium is similar to autarky, with no welfare gain. When $q = 0$, only domestic firms can survive (as the f_D curve is above the f_M curve) and no firm adopts the foreign technology. The second stable equilibrium corresponds to the interior solution for the highest value of q. This equilibrium is mixed as both multinational and domestic firms co-exist, with the most productive domestic firms adopting the foreign technology. This equilibrium is stable because, for example, when q decreases, entry is more profitable for the multinational firms than for the domestic firms, which in turn positively affects q.

In the latter equilibrium, welfare is higher than in autarky.[25] The negative effect of segmentation that prevails in the short run may be offset by the adoption of the foreign technology by domestic firms, which also leads to wider adoption of the foreign technology by upstream firms. Firm heterogeneity plays an important role, given that the most productive firms upgrade their technology and increase their profits. Hence we obtain a stable and mixed equilibrium where positive welfare gains are derived from the complementarities between multinational firms and the most productive domestic firms, both of which benefit from a more advanced technology and a larger base of local suppliers.

Note, however, that the interior solution for the lowest value of q is not stable: if q increases slightly, entry by multinationals is more likely than entry by domestic firms, which tends to increase q.

Also note that, if we start with a situation where the downstream industry is populated solely by multinational firms and $q = 1$, domestic firms will enter (as the f_D curve is above the f_M curve in Figure 1) until the economy reaches the stable interior equilibrium. Yet this mechanism is restricted to the case where the cost of adopting the foreign technology is not too high.[26]

Figure 2 shows how the equilibria are distorted when we increase the costs of technology adoption.

[Figure 2 about here]

This is reflected by a downward shift in the FED curve. In this case, there is no interior

[25] As there is no analytical solution, it is unfortunately not possible to derive a necessary and sufficient condition for welfare improvements in the general case.

[26] In Appendix C, we provide a sufficient and necessary condition on the cost of technology adoption.

(stable) equilibrium. In the long run, the economy is either populated by domestic firms (as in autarky where $q = 0$) or by multinational firms only (where $q = 1$). Thus, when technology adoption costs are high, a policy favoring large entry of multinational firms can result in an endogenous barrier to entry for domestic firms. In a situation where the downstream industry is populated mostly by multinational firms, the cost of technology adoption prevents domestic firms from benefiting from the large base of local suppliers producing using the foreign technology. This creates a barrier to entry in stark contrast to the conclusions drawn by Markusen and Venables (1999).

Similarly, technological incompatibilities also create a barrier to entry by multinational firms when the proportion of suppliers using the foreign technology is small. In Figures 1 and 2, the multinational firms' profits are smaller than the domestic firms' profits when the proportion of suppliers using the foreign technology remains small. Therefore, only massive entry by multinational firms would trigger a switch from an equilibrium with domestic firms only to an equilibrium with a positive number of firms using the foreign technology.

7 Concluding remarks

The effects of FDI on the host country are a matter of ongoing debate. Economists have emphasized the role of backward and forward linkages with local firms, as well as the introduction of more advanced technologies. In this paper, we develop a tractable model to show how technological incompatibilities may affect the nature of the linkages with local suppliers and the nature of competition between foreign affiliates and domestic firms. FDI effects on the host-country industry depend on its technological backwardness interacting with local capabilities and initial competition, as well as the scale of entry by foreign affiliates.

To be more precise, we argue that local downstream firms may not benefit from technological improvements in the upstream industry as these can reduce the base of suppliers producing inputs that are compatible with the local technology. Furthermore, technological segmentation in the upstream industry amplifies the productivity advantage of multinational firms. This mechanism can explain the puzzling evidence of positive vertical externalities at the same time as negative horizontal externalities. As suggested by the model, this also implies some potentially perverse effects of voluntary private norms, which have played an increasing role in the recent years. When firms are heterogeneous in terms of productivity, we show that only the most productive suppliers adopt the foreign technology and cater to multinational firms.

We then develop a long-run version of the model in which the entry and exit decisions of all types of firms are made endogenous. Further, we allow domestic firms to benefit from contacts with multinationals by assuming that they themselves are able to adopt the modern foreign technology. With the combined assumptions of productivity heterogeneity and fixed cost of technology adoption, we find that the most productive firms self-select into the foreign technology. We then study the long-run welfare effects of multinational entry and its impact on local industrial development. We find that technological incompatibilities interact with the cost of adoption of the foreign technology in non-monotonic ways, and that given the multiplicity of equilibria, initial conditions matter.

Finally, the spillover effects of FDI on the host economy with technological incompatibilities could be tested. We hope that our paper will inspire future empirical research on the basis of the model's results. For instance, according to expression (1) and Proposition 1, one possibility would be to regress the productivity difference between domestic and multinational firms on the proportion of upstream suppliers with ISO certification or another technological index. Another possibility would be to test whether the positive externalities between multinational firms and qualified suppliers that we formalize affect the location of foreign affiliates.

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Appendix A: Endogenous technological choice of multinational firms

Formally, if the adoption of the local technology is costless, multinational firms prefer the local technology as long 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 5 *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.

Appendix B: Productivity dispersion among suppliers and profits by multinational firms

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, we obtain that supplier heterogeneity yields large profits for multinational firms if and only if the following condition 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:

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.

Appendix C: Proofs of Propositions and results

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:

$$\begin{array}{l} \pi_M = \frac{\alpha E}{nq} S_M \\ \pi_D = \frac{\alpha E}{n(1-q)}(1 - S_M) \end{array}$$

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 variable costs in the downstream industry:

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

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

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

• **Solving the system**

First, by multiplying both equations by q and $(1 - q)$ respectively and summing them, 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 (3) in the text.

• **Proof of Proposition 2**

First note that, given that mark-ups are constant, the price index in the downstream industry, 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 costs charged by downstream producers. 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:

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

The proposition compares these two expressions.

Section 5

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

Incorporating the compatibility parameters, costs for each technology are given by:

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

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

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

The system of equations characterizing the equilibrium 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 as in expression (4) in the main text, but now equilibrium q verifies:

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

relative costs are found by introducing this expression into the previous one for C_D and C_M.

- **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 guaranteed 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).

Section 6: Long run

- **How to derive $f_M(q)$**

In autarky, the free entry condition for domestic firms yields:

$$F_D = \frac{\beta E}{P_a^{1-\eta}} C_{Da}^{1-\eta} \widetilde{\varphi}_D^{\eta-1}$$

where $C_{Da}^{1-\eta}$ denotes the variable cost of using the D-technology under autarky, β is a constant (depending only on η and σ), and $\widetilde{\varphi}_D^{\eta-1} = \int_0^{\infty} \varphi^{\eta-1} dG(\varphi)$ denotes the average capability of domestic firms.

With FDI, free entry for multinational firms (FEM, equation 5.5) writes: $F_M = \frac{\beta E}{P^{1-\eta}} C_M^{1-\eta} \widetilde{\varphi}_M^{\eta-1}$. Then, compared to autarky, we obtain:

$$\frac{P^{1-\eta}}{P_a^{1-\eta}} = \frac{F_D}{F_M}\frac{C_M^{1-\eta}}{C_{Da}^{1-\eta}}\frac{\widetilde{\varphi}_M^{\eta-1}}{\widetilde{\varphi}_D^{\eta-1}}$$

Finally, given equation (2) and (3) of Section 4 (equilibrium in the upstream sector) and using $\frac{1-\eta}{1-\sigma} = 1 - \frac{1}{\theta}$, we have $C_{Da}^{1-\eta} = \lambda_D^{1-\eta}\left(\frac{1}{f_e}\right)^{1-\frac{1}{\theta}}$ and $C_M^{1-\eta} = \lambda_M^{1-\eta}\left(\frac{q}{f_e + q f_q}\right)^{1-\frac{1}{\theta}}$. If we suppose that the distribution of capabilities is Pareto: $G(\varphi) = 1 - \left(\frac{\varphi}{\underline{\varphi}}\right)^{-\gamma}$, with $\gamma > \eta - 1$, we finally obtain:

$$\frac{P^{1-\eta}}{P_a^{1-\eta}} = f_M(q) \equiv \Omega_M \left(\frac{q}{1 + q \cdot (\frac{f_q}{f_e})}\right)^{1-\frac{1}{\theta}}$$

where $\Omega_M \equiv \frac{F_D}{F_M}\frac{\gamma+1-\eta}{\gamma}\frac{\widetilde{\varphi}_M^{\eta-1}}{\underline{\varphi}^{\eta-1}}$.

• **How to derive $f_D(q)$**

The threshold φ^* above which domestic firms choose the foreign technology is determined by equation (FTD, equation 5.4) which can be written:

$$F_q = \frac{\beta E}{P^{1-\eta}} C_M^{1-\eta} (\varphi^*)^{\eta-1} - \frac{\beta E}{P^{1-\eta}} C_D^{1-\eta} (\varphi^*)^{\eta-1}$$

The free entry equation for domestic firms (FED, equation 5.3) gives:

$$F_D = \int_0^{\varphi^*} \left(\frac{\beta E}{P^{1-\eta}} C_D^{1-\eta} \varphi^{\eta-1} \right) dG(\varphi) \;\; + \;\; \int_{\varphi^*}^{\infty} \left(\frac{\beta E}{P^{1-\eta}} C_M^{1-\eta} \varphi^{\eta-1} - F_q \right) dG(\varphi)$$

Comparing with autarky, and incorporating the equation for φ^*, this can be rewritten:

$$\frac{P^{1-\eta}}{P_a^{1-\eta}} = \frac{C_D^{1-\eta}}{C_{Da}^{1-\eta}} \left[1 + \left(\frac{C_M^{1-\eta}}{C_D^{1-\eta}} - 1 \right) \left(\frac{\int_{\varphi^*}^{\infty} (\varphi^{1-\eta} - (\varphi^*)^{\eta-1}) dG(\varphi)}{\int_{\varphi^*}^{\infty} \varphi^{1-\eta} dG(\varphi)} \right) \right]$$

When G is a Pareto distribution, the last term can be written as a simple function of φ^*:

$$\left(\frac{\int_{\varphi^*}^{\infty} (\varphi^{1-\eta} - (\varphi^*)^{\eta-1}) dG(\varphi)}{\int_{\varphi^*}^{\infty} \varphi^{1-\eta} dG(\varphi)} \right) = \frac{\eta - 1}{\gamma} \left(\frac{\varphi^*}{\underline{\varphi}} \right)^{\eta-1-\gamma}$$

By using both the equation for technological choice and the free entry equation for multinational firms, we obtain that $(\varphi^*)^{\eta-1} = \widetilde{\varphi}_M^{\eta-1} \frac{F_q}{F_M} \left(1 - \frac{C_M^{1-\eta}}{C_D^{1-\eta}} \right)^{-1}$.

Finally, by incorporating the value for φ^*, $C_M^{1-\eta}$ and $C_{Da}^{1-\eta}$ derived above, and using $\frac{C_M^{1-\eta}}{C_D^{1-\eta}} = \frac{\lambda_M^{1-\eta}}{\lambda_D^{1-\eta}} \left(\frac{q}{1-q} \right)^{1-\frac{1}{\theta}}$, we obtain that $\frac{P^{1-\eta}}{P_a^{1-\eta}} = f_D(q)$ where:

$$f_D(q) \equiv \left[1 + \Omega_D \left[\frac{\lambda_M^{1-\eta}}{\lambda_D^{1-\eta}} (\tfrac{q}{1-q})^{1-\frac{1}{\theta}} - 1 \right]^{\frac{\gamma}{\eta-1}} (\tfrac{\lambda_M^{1-\eta}}{\lambda_D^{1-\eta}})^{-(\frac{\gamma}{\eta-1}-1)} (\tfrac{q}{1-q})^{-(1-\frac{1}{\theta})(\frac{\gamma}{\eta-1}-1)} \right] \left(\frac{1-q}{1+q \cdot (\frac{f_q}{f_e})} \right)^{1-\frac{1}{\theta}}$$

and where $\Omega_D \equiv \frac{\eta-1}{\gamma} \frac{\widetilde{\varphi}_M^{\eta-1-\gamma}}{\underline{\varphi}^{\eta-1-\gamma}} (\frac{F_M}{F_q})^{\frac{\gamma+1-\eta}{\eta-1}}$.

• **Entry barrier for domestic firms**

A necessary and sufficient condition for the entry of domestic firms when the downstream industry is populated only by multinational firms (with equilibrium in the upstream industry) is: $\lim_{q \to 1} f_D(q) > \lim_{q \to 1} f_M(q)$, which is equivalent to $\Omega_D > \Omega_M$.

• **Figures**

Figure 1 in the text was built with by plugging in the following values in the above expression: $\theta = 5$, $\Omega_M = 0.9$, $\Omega_D = 1.3$, $\frac{\lambda_M^{1-\eta}}{\lambda_D^{1-\eta}} = 1.5$, $f_q = 0$ and $\frac{\gamma}{\eta-1} = 3$.

And Figure 2 changes to $\Omega_D = 0.7$.

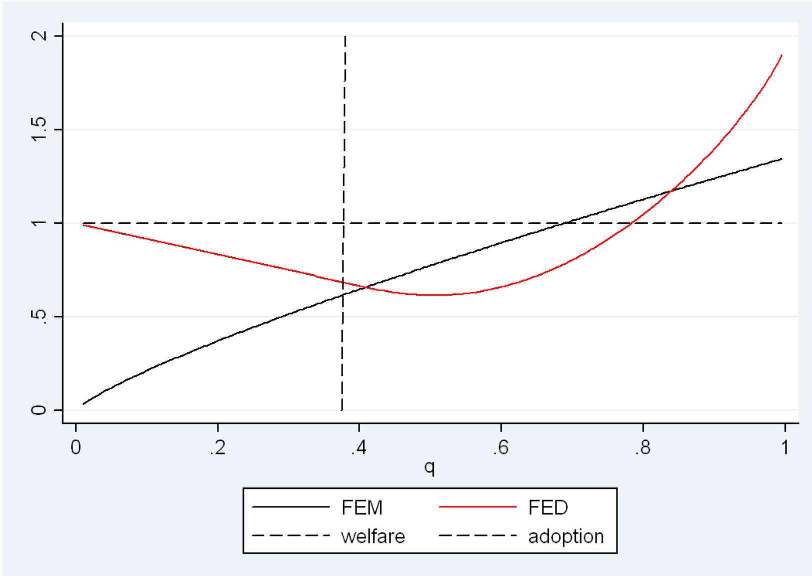

Figure 1: Long run equilibria with low technology adoption costs

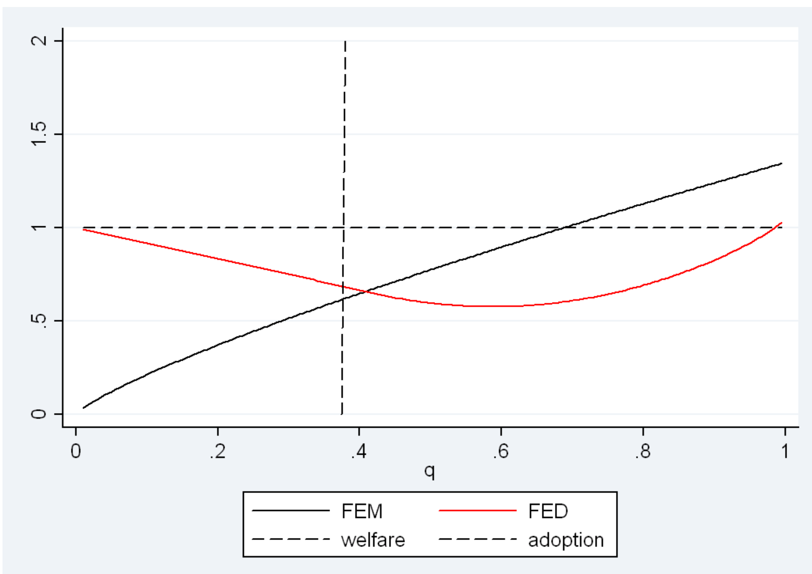

Figure 2: Long run equilibria with high technology adoption costs