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The choice of transport technology in the presence of exports and FDI

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Abstract

In a set-up with intermediate production, we analyze how a shipper's choice of transport technology, traditional *versus* modern, interacts with the mode of foreign expansion by an service firm, export *versus* foreign direct investment (FDI). In terms of the mode of foreign expansion by the service firm, we obtain that: due to trade in intermediate goods, trade and FDI can be complements; the export strategy dominates when the economies of scale at plant level are high and trade costs are low; the FDI strategy is preferable when market size is large and trade costs are intermediate. In what concerns the choice of transport technology by the shipper, we find that: the modern technology tends to be implemented in larger markets; economic integration can encourage the adoption of modern technology *vis-à-vis* the traditional one; the modern technology adoption is more likely for intermediate levels of transport costs. We then have that modern technology adoption usually occurs under the FDI strategy, since both emerge when trade costs are intermediate and market size is large.

Keywords: Transport Technology, Foreign Direct Investment, Trade, Service Sector, Firm Location.

JEL Classification: F23, L12, R30, R40.

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1 Introduction

The literature in international trade and economic geography emphasizes the role of trade costs for economic outcomes, such as trade patterns (Krugman, 1980), location of industry (Krugman, 1991) and multinational activity (Horstmann and Markusen, 1992). In these models, trade costs for example give rise to the well known home market effects, agglomeration effects and the proximity-concentration trade-off, respectively¹. In addition, the empirical evidence shows that trade costs, transportation technology and the transportation sector play a major role for economic exchange (see amongst others Boylaud and Nicoletti, 2001; Combes and Lafourcade, 2005; Head and Mayer, 2004; Sjostrom, 2004 and Teixeira, 2006). In spite of this important role, transportation has mostly been left in the background of the theoretical analyses. In fact, Paul Samuelson's (1954) seminal formalization of trade costs, the well known iceberg trade costs, was introduced to avoid precisely dealing directly with the transport sector.

Recently, though, there has been a growing interest on the issues related to transportation. This is the case with for example Mori and Nishikimi (2002), Behrens et al. (2006, 2009), Behrens and Picard (2010) and Takahashi (2006). The common topic linking these papers is the relation between transport costs and the location of economic activity. For instance, Mori and Nishikimi (2002) and Behrens et al. (2006) analyze the role of density economies for transport costs. Behrens et al. (2009) and Behrens and Picard (2010) endogenize transport cost rates in a spatial economy. In turn, Takahashi (2006) studies the interdependence between the choice of transport technology and economic geography.

In this paper, we follow Takahashi (2006) by focusing on a shipper's choice of transport technology, modern *versus* traditional. However, contrary to Takahashi (2006) as well as to the others papers previously mentioned, our main concern is not economic geography but rather to analyze how transport

¹The home market effect states that, due to trade costs and increasing returns to scale, countries with a higher share of the world's demand tend to have a disproportionately larger share of the world's industry than of the world's demand (Krugman, 1980). Consequently, as trade costs decrease, agglomeration effects can be triggered in the larger regions conducting to core-periphery spatial patterns (Krugman, 1991). In turn, the proximity-concentration trade-off (Horstmann and Markusen, 1992) says that when a firm decides on the mode of foreign expansion, export *versus* multinational, it weights the benefits of concentrating production in one location (economies of scale) against the advantages of being closer to consumers (avoid trade costs).

technology is affected by the mode chosen by the service sector to serve the foreign market: export *versus* foreign direct investment (FDI).

To accomplish this, we develop a model with two players: a monopolist service firm and a shipper. The economy has two locations: the monopolist headquarters and a foreign (city) market where all the final demand is located. We adopt the export-FDI formalization with intermediate goods by Pontes (2007)². In particular, the monopolist service firm produces a final good using an intermediate good as input. Following the literature on FDI (see Carr et al., 2001), the intermediate good can be seen as firm-specific knowledge assets (like blue-prints, patents and tacit knowledge) that need to be passed onto the final product. We can think, for example, that the intermediate good is training given by a firm's expert to the firm's workers. In turn, the final good is a consumption private service good.

The intermediate good can only be produced in the monopolist headquarters, but the final good can be produced in the monopolist headquarters or in the foreign market. The monopolist has to decide whether to serve the foreign market via exports or FDI. In the export strategy, the final good is produced in the monopolist headquarters, while in the FDI strategy the final good is produced in the destination market.

In the export case, a firm's expert gives training to the firm's employees in the headquarters and then they are exported to the foreign market every time the firm supplies a service there. In the FDI case, instead, a firm's expert is exported to the foreign market to give training to the firm's workers that are employed in the foreign subsidiary. These employees, in turn, supply the firm's service to consumers in the destination market. Both cases are quite common, for instance, with financial and consulting firms.

In turn, the shipper has to choose whether to supply the market with a traditional or a modern technology³. The difference between the two tech-

²Although the focus of the FDI literature has been the manufacturing sector, there is also a substantial analysis of FDI in the service sector using a very similar framework to the one used for the manufacturing sector (see Markusen and Strand, 2009; Francois and Hoekman, 2010). In fact, Ramasamy and Yeung (2010) show evidence that the standard FDI models (like Horstmann and Markusen, 1992) can also be applied to FDI in the service sector, i.e.: no new theories are necessary to explain the determinants of services FDI (see also Brown and Stern, 2001, Buch and Lipponer, 2007, Moshirian, 2004, Ruckman, 2004). Furthermore, as shown by the World Investment Report 2004, the structure of foreign direct investment (FDI) has shifted towards services. All of the above justifies our choice of the modeling strategy in this paper.

³In this sense, we analyze the provision of transport services at the regional or interna-

nologies is that the traditional technology has higher marginal costs and lower fixed costs than the modern technology. In this sense, the main characteristic of the modern technology is that it is subject to increasing returns to scale⁴.

In terms of the mode of foreign expansion by the service firm, we have that the service firm only chooses to serve the foreign market (with the export or the FDI strategy) at relatively low transport costs. In addition, as in Horstmann and Markusen (1992), the usual trade-off between concentration and proximity arises in the decision of the monopolist service firm. In particular, while the export strategy is preferred when the economies of scale at the plant level are high and transport costs are low (concentration), the FDI strategy is favored when market size is large and trade costs are intermediate (proximity). However, contrary to Horstmann and Markusen (1992), but in line with Pontes (2007), due to intermediate consumption, FDI does not necessarily eliminate exports. In other words, FDI and exports need not be substitutes, since under FDI, international trade continues to arise due to the exports of intermediate goods (i.e.: FDI and exports can be complements). This result has two advantages: first, our model mirrors better the real world than standard horizontal FDI models such as Horstmann and Markusen (1992), since the data show that FDI and exports tend to be complements (see Markusen, 2002); second the demand for transportation under FDI is positive (and not zero as is the case when FDI and exports are substitutes)⁵.

tional level, i.e.: inter-city transport infrastructure but not intra-city. Larch (2007) show evidence of the growing importance of the multinationalization of the transport sector. For the study of intra-city (urban) transport infrastructure, see Zenou (2000, 2011).

⁴The metaphor modern *versus* traditional does not need to be read literally. We can instead think of an established transport technology (which can be hi-tech or not) and a new technology, where for the former the fixed costs have already been incurred, but the same is not the case for the latter.

⁵Horizontal FDI occurs when production takes place in the final destination. The other type of FDI usually considered in the literature is vertical FDI. Vertical FDI emerges when a firm has different stages of production in different countries (for instance, design at home and production at foreign). As we have just discussed, horizontal FDI is motivated by the proximity-concentration trade-off. In turn, vertical FDI tends to be motivated by cost reasons (for example, considering that production is labor intensive then it is more cost effective to delocalize production to a labor abundant country). In this sense, our model is a hybrid of horizontal and vertical FDI. This is so, because while in our framework the motives for FDI are the proximity-concentration trade-off from horizontal FDI models, the type of FDI we are considering involves the delocalization of one stage of production like in vertical FDI models.

The latter feature is central in a set-up like ours that aims to analyze the choice of transport technology. In fact, if FDI and trade are substitutes, the demand for transportation when the monopolist chooses the FDI strategy would be zero, given that there is no trade. As a consequence, under the FDI equilibrium, the shipper would never adopt the modern technology, since it could not pay for the modern technology's fixed cost. On the contrary, if FDI and trade are complements, even under the FDI regime the shipper can choose between the modern and the traditional technology, since international trade in intermediate production creates a demand for transportation. Accordingly, it might then be possible for the shipper to pay for the modern technology's fixed cost.

In what concerns the shipper's choice of transport technology, we obtain three main results. First, the modern technology tends to be implemented in larger markets. This is so, given that a larger market size reduces the fixed costs per capita of the modern technology, making its adoption more attractive relatively to the traditional one. Second, economic integration may encourage the adoption of the modern technology *vis-à-vis* the traditional one. The rationale for this is that closer economic integration increases trade, thereby allowing the shipper to pay for the higher fixed costs of the modern technology. Third, the relation between transport costs and modern technology adoption is non-monotonic. More precisely, the adoption of modern technology takes place for intermediate levels of transport costs. To understand this, note that for high transport costs the demand for transportation is low, and for low transport costs the returns from transportation are low (although demand is high).

We then observe that the shipper's choice of transport technology is directly related to the service firm's mode of foreign expansion. First, the modern technology will only be adopted if the service firm enters the foreign market (with either the export or FDI strategies), i.e.: when trade costs are not extremely high. The reason for this is straightforward: only when trade exchanges emerge in the economy is it worthy for the shipper to incur the fixed costs of the modern transport technology. Second, the modern technology is more likely to be adopted under FDI. The basis for this outcome is that both the FDI strategy and the modern technology are more profitable in larger markets and for intermediate levels of trade costs.

The remainder of the paper is organized as follows. In section 2, we discuss the available empirical evidence on the adoption of modern transport technologies with the case study of the high-speed rail (HSR). In section 3,

we introduce the base model. In section 4, we study the choice of foreign expansion by the monopolist service firm. In section 5, we analyze the choice of transport technology by the shipper. In section 6, we conclude.

2 Case Study: The High-Speed Rail

To our knowledge there is very little empirical evidence on the adoption of modern transport technologies. In order to find support for our theoretical results we look, instead, to the pattern of development of the HSR in some countries and regions of the world⁶. We base our analysis on a review on the following HSR literature: Campos et al. (2007); Freemark (2009); Hood (2006); Perren (1998), The Economist (2010) and The World Bank Railway Database.

The HSR is a modern train technology, and as the name says the HSR operates significantly faster than conventional trains⁷. The first HSR was Japan's Shinkansen, also known as the "bullet train", which started officially operating in 1964 between Tokyo and Osaka. In the 1970's, France began to develop the French version of the bullet train, the TGV (*Train à Grande Vitesse*, literally high-speed rail). In 1981, France opened the first HSR connection between Paris and Lyon. Since then, France's HSR network has been expanded to connect cities not only across France but also in adjacent countries, in particular Belgium, Netherlands and England. In addition, the European Union (EU) is currently financing a trans-European network of high-speed rail that will link France's TGV to other European countries, such as Italy, Spain, Germany, Poland, Austria, Switzerland and Portugal⁸. In the rest of this section, we will focus our analysis in four countries (Japan,

⁶This exercise, however, cannot enlighten us on how the choice of transport technology interacts in the real world with the mode of foreign expansion by firms. In our view, and given the shortage of studies on the topic, this is an interesting issue for future research.

⁷A train connection is considered to be high speed if it runs 200 km/h (120 mph) for upgraded tracks or 250 km/h (160 mph) or faster for new tracks. HSR is mostly used for passenger transportation. However, in some cases is also used for goods transportation, especially light goods, but also in some cases for bulk transportation (for instances the French post uses HSR to transport mail).

⁸Even more ambitious is China's plan for 50 000 kilometers (31 000 miles) of HSR lines by 2020. This will make China the country in the world with the longest HSR system. In turn, the US has a single HSR connection, the Acela Express, between Washington and New York (passing by Baltimore and Philadelphia). The US has however plans to build a new HSR line in California.

France, Spain and Italy) and one region (Europe) with established HSR networks. Our main conclusions do not change if we consider other countries with HSR.

Anticipating the results from our small case study, we observe three patterns related to the HSR adoption. First, the target areas for HSR connections are pairs of major cities. Second, economic integration can promote the adoption of the HSR across countries. Third, the HSR tends to be built between cities that are not too far apart or too close together⁹. As we will see in the next sections, this is exactly what our model finds. Next we seek to provide evidence that supports our claims.

We start by analyzing the argument on population and HSR links. In Japan, after the construction of the line between Tokyo and Osaka in 1964 (the first and third cities in Japan, respectively)¹⁰, Osaka-Hakata (Fukuoka) followed in 1972, Tokyo-Hachinohe and Ōmiya-Niigata in 1982, Takasaki-Nagano in 1997 and Shin Yatsushiro-Kagoshima Chūō in 2004. Fukuoka is the largest Japanese city west of Osaka. Hachinohe is the largest city in the eastern Aomori prefecture. Ōmiya is one of the hub stations in the Greater Tokyo Area. Niigata has a population of approximately 800 000 (but the population of the Niigata prefecture is around 2.4 million) and Kagoshima is located at the southwestern tip of the island of Japan with a population of about 600 000. Takasaki, Nagano and Yatsushiro are smaller cities. However, Takasaki functions as a regional transportation hub for Japan's Shinkansen. In turn, Nagano and Yatsushiro are intermediate stops on the planned extension of the Osaka-Fukuoka line to the south and west regions of Japan, respectively.

As already mentioned, in France the link between Paris and Lyon (first and second regional agglomerations in France) was completed in 1981. This was followed by Paris-Tours-Le Mans in 1990, Lyon-Valence in 1992, Valence-Marseille in 2001 and Paris-Strasbourg in 2007. While Tours and Le Mans are not very large cities, they are part of the commuter belt of Paris¹¹. In turn, the Paris-Valence connection was developed as a step on the way to Marseille (the third largest agglomeration in France). Strasbourg is only the seventh largest city of France but it hosts several important European institutions

⁹In our model, the rate of transportation is proxied by distance.

¹⁰Yokohama is the second largest city in Japan but is part of the Greater Tokyo Area.

¹¹In addition, the Paris-Tours-Le Mans link is planned to be extended to Bordeaux (the famous wine region and also the eight-largest city in France with approximately 1 million inhabitants) and to Spain as part of the trans-European HSR network.

such as the Council of Europe, the Eurocorps, the European Parliament and the European Union Ombudsman.

In Spain the main existing HSR connections are Madrid-Seville, opened in 1992; Madrid-Valladolid in 2007 and Madrid-Barcelona in 2008. Madrid, Seville, and Barcelona are respectively the first, fourth and second largest cities in Spain. Valladolid is not a very large city (it has a population of just 320 000) but it is planned to be part of the HSR connection to the Basque country (third largest region in Spain after Madrid and Catalonia) and to Portugal¹².

In turn, the aim of the Italian HSR network is two-fold: to connect Naples-Rome-Florence-Bologna-Milan and Turin-Milan-Venice. The following segments of these two lines are already in operation: Florence-Rome opened in 1991, Rome-Naples in 2005, Milan-Bologna in 2008, Turin-Milan and Bologna-Florence in 2009 (Milan-Venice is still under construction). Milan, Rome, Naples and Turin are the first, second, third and fourth largest metropolitan areas in Italy, respectively. Florence, Venice and Bologna are only in the second tier of the largest cities in Italy. However, Florence and Venice are amongst the world's top tourist cities and Bologna is a hub in Italy's train network. From the above, we can conclude that the countries analyzed have prioritized HSR connections between larger cities.

We now turn to the second point related to economic integration. Economic integration lowers the costs of exchanging goods across borders. It is a well established fact that transport costs are higher at the international than at the national level. For example, if two regions are equally distant from each other, the trade costs tend to be higher when the two regions belong to two different countries than when they are part of the same country (see Anderson and van Wincoop, 2003, 2004).

It can be easily noted that of all the regions in the world with HSR, only in Europe were international connections established. As already mentioned, the center of the trans-European HSR network has been France. The first international HSR link in Europe was opened in 1993 between Paris and Brussels and was shortly afterwards extended to Amsterdam¹³. In 1997 the high speed line between Paris and London began operation with trains pass-

¹²A HSR connection to Valencia, Spain's third largest city, is also under construction.

¹³Brussels is the *de facto* capital city of the EU and the largest urban area in Belgium with around 1.8 million residents. The city of Amsterdam has a population of 1.36 million and is the sixth-largest metropolitan area in Europe with around 6.7 million inhabitants.

ing undersea through the famous purpose built Channel Tunnel¹⁴. Shortly afterwards, Brussels was linked with Cologne in Germany¹⁵. Currently, connections of the France's HSR system to Spain (Madrid and Barcelona), Italy (Turin and Milan), Switzerland (Zurich), and Germany (Frankfurt) are under construction. In addition, other international links are being planned: Netherlands with Germany, Austria with Germany, Italy with Germany, Slovenia with Switzerland, Sweden with Denmark and Germany, Poland with Germany, and Spain with Portugal.

Given that Europe constitutes the most developed experience of regional economic integration (via the EU) in the world, this seems to confirm that the adoption of modern technologies in transportation is facilitated by closer economic integration.

We close by discussing the third argument on distance and HSR. Start by noticing that if we compare HSR with other modes of transportation, like air and road travel, we have the following. The HSR is less competitive than air travel for longer distances (like Paris-Moscow), and more competitive for journeys of up to two to three hours (250-900 kilometers or 150-550 miles)¹⁶. In turn, the HSR is more competitive than road transportation for longer distances, while the latter compares favorably for shorter distances, especially when there is little congestion (i.e.: when road transportation occurs between locations with a small market size).

In fact, and as we have mentioned, HSR tends to link cities within the same country, where distances are usually smaller than between cities in different countries. Also, when international connections were established (which, as we have seen, is only the case in Europe), the first lines opened were amongst cities located at intermediate distance from each other. For example, there is a HSR between Paris and Brussels situated 261 kilometers apart (162 miles) but not between Paris and Berlin at a distance of 876 kilometers (544 miles), although Berlin is more populated than Brussels. In this sense, we have that HSR networks tend to connect cities located at mid

¹⁴London is UK's largest and most populous metropolitan area and the largest urban zone in the European Union with about 14 million inhabitants.

¹⁵Cologne is Germany's fourth-largest city, and one of the major European metropolitan areas with around 10 million inhabitants.

¹⁶The reason for this is that not only are the formalities with checking-in and security less time consuming with trains than with air travel, but train stations are also usually located in city centers while airports are outside. Due to this, some air companies already include a HSR ticket for a segment of the journey (for example, between Paris and Brussels).

distance from each other, but not cities that are either too close or too far apart¹⁷.

3 The Model

The model has two players: a monopolist service firm (henceforth player I) and a shipper (player S). The economy consists of two locations: the monopolist headquarters and the foreign market with n consumers where all final demand is located. The monopolist has to choose whether or not to supply the foreign market, and if it does, the monopolist has to decide the mode of entry: by means of export or FDI. In turn, the shipper has to select which transport technology to adopt: traditional or modern. Let $f(p)$ be a demand function (p is the delivered price), which we assume to be:

- Continuous
- Decreasing
- Revenue function $pf(p)$ is strictly concave.

Remark 1 *Together these assumptions imply that $\frac{dp}{dc} > 0$ for all values of c , where c stands for a constant marginal cost and p is a profit maximizing price.*

To produce the final good, the monopolist needs an intermediate product (training), which has to be produced in-house in the monopolist headquarters. In turn, the final good (service) can either be produced in the monopolist's headquarters or in a plant in the foreign market. In case of the former, we say that the monopolist follows the export strategy, since the final

¹⁷The adoption of the railway in the nineteenth century apparently had a similar behavior to the one discussed above for the HSR (see O'Brien, 1983). We believe this is so because when the railway started to be introduced it had similar characteristics to the HSR nowadays. First, the railway was a new transport technology with high fixed costs of adoption (the building of the rail network was usually in the hands of the railway companies). Second, the railway was more adequate to connect cities that were not very far away from each other. This was so, since the costs of introducing railway increased with the distance. The adoption patterns of other technologies of transport, such as roadway and air transportation, was however different from both the HSR and railway, since the technological characteristics of the former are different from the latter. For instances, very often the fixed costs of adopting the road and the air transport technologies are lower than the railway (standard or high-speed), since the physical infrastructure (roads or airports) are not built or owned by the transporting firm.

good is exported to the foreign market. In the latter case, the monopolist pursues the FDI strategy, given that a production plant is established in the destination market. In this sense, in the FDI strategy the final good is sold directly to consumers, but the intermediate good needs to be exported in order to be incorporated in the final good. We further assume that the price of the intermediate good is w and that firm I uses $\alpha \in [0, 1]$ units of the intermediate good to produce one unit of the consumer good.

As discussed in the introduction, we can think of the intermediate good as firm-specific knowledge assets (like blue-prints, patents and tacit knowledge) that are required to be transmitted to the firm's employees in order for them to be able to supply the firm's service to final consumers. We then have that in the export strategy a firm's expert gives training to the firms' employees in the headquarters. Subsequently, when a firm sells a service, the trained employees are exported to the foreign market to supply the service. In the FDI strategy, instead, a firm's expert is exported to the foreign market in order to give training to the firm's employees in the foreign subsidiary. These employees, in turn, supply the service to consumers in the foreign market.

Export has over FDI the advantage of lower fixed costs. The expert that gives training to the workers in the foreign city has to set up a local plant thus incurring in costs related with indivisible assets that we express by the fixed cost G . By contrast, FDI entails lower transport costs than Export: if m denotes the unit variable cost of the final service good, the transport cost of the intermediate good will be $\alpha m < m$. This is so because the intermediate good is a piece of information (as in Carr et al. 2001), so that it has the nature of a public good inside the firm. A single expert can jointly train several workers in the foreign city. Thus, under FDI the travel of the expert substitutes for the multiple travels the trainees would have to accomplish were the training activity occur in the home city.

Intermediate production plays a central role in our model. To see this, note that in the absence of the intermediate good, FDI and trade would be substitutes (see Horstmann and Markusen, 1992). This is so, given that with FDI all production designated for the destination market would be produced locally, and therefore there would be no trade. In turn, with intermediate production, FDI and trade can be complements. This is the case, since when a firm decides on the FDI strategy, the production plant in the foreign market still needs to import the intermediate good to produce the final good. As discussed in the introduction, although the data show that FDI and trade tend to be complements, the standard framework in the theoretical horizontal

FDI models assumes that FDI and trade are substitutes (Markusen, 2002).

With FDI and trade as potential complements, our set-up gains not only in realism, but it also becomes more suitable for analyzing the topic we propose to study. In fact, and as we have just seen, if FDI and trade are substitutes it means that there is no trade under FDI, i.e.: the demand for transportation would be zero with FDI. In this sense, the FDI decision would become redundant for the choice of transport technology, i.e.: only with exports would the shipper evaluate the alternative transport technologies (traditional *versus* modern). On the other hand, with FDI and trade as complements it means that there is trade under FDI (in our case, this is due to trade in intermediate goods), i.e.: the demand for transportation is positive with both export and FDI. Therefore, even when the service firm chooses FDI (and not only with exports), the shipper can ponder about what is the profit maximizing transport technology to serve the foreign market.

The game has two stages. In the first stage, the monopolist chooses the mode of entry (exit, export or multinational) and the shipper decides on transport technology (traditional or modern). In the second stage, the monopolist sets a delivered price p .

We need to be more precise about the decision in the first stage. In what concerns the monopolist, we have that it chooses between three alternative ways to supply the foreign market:

- "0": Exit, I refrains from supplying the foreign market.
- "E": Export, I supplies the foreign market through exports.
- "D": FDI, I supplies the foreign market through a local plant.

As standard in the FDI literature (see Horstmann and Markusen, 1992), we assume that it is more costly to operate a plant away from the headquarters than close to it. This can be due to higher communication, transport or knowledge transfer costs, which are usually higher when the plant is far away from the headquarters. Without loss of generality, we then assume that the plant-specific fixed costs are zero in the case of exports and equal to G under the FDI strategy.

The choice between the export and the FDI strategy can then be modeled as in Pontes (2007):

$$\pi_0^I = 0$$

$$\pi_E^I(p, m) = n(p - \alpha w - m)f(p)$$

$$\pi_D^I(p, G, m) = n(p - \alpha w - \alpha m)f(p) - G, \quad (1)$$

Applying a positive linear transformation that consists in dividing the payoffs by $\frac{1}{n}$, we obtain the following:

$$\pi_0^I = 0$$

$$\pi_E^I(p, m) = (p - \alpha w - m)f(p)$$

$$\pi_D^I(p, G^c, m) = (p - \alpha w - \alpha m)f(p) - G^c, \quad (2)$$

where $G^c = \frac{G}{n}$ are per capita plant-specific fixed costs.

In turn, the shipper chooses between two transport technologies:

- A traditional technology "T" with positive variable costs and zero fixed costs, whose profit function is:

$$\pi_T^S = (t - m)Q, \quad (3)$$

where $t \equiv$ transport rate and $Q \equiv$ demand for transport.

- A modern technology "M" with zero variable costs and a positive fixed sunk cost F , whose profit function is¹⁸:

$$\pi_M^S = tQ - F. \quad (4)$$

In order to simplify, we assume that $t = m$ (t is a parameter for both players) because the monopolist firm can always carry the product itself "on foot" using the traditional technology.

Applying again a positive linear transformation that consists in dividing the payoffs by $\frac{1}{n}$, we have that the profit functions for the traditional and the modern technology equal (and since $t = m$):

$$\pi_T^S = 0$$

$$\pi_M^S = mQ^c - F^c, \quad (5)$$

¹⁸In this sense, we can think of the modern technology as the HSR and the traditional technology as the roadway. In fact, while the HSR is characterized by high fixed costs and low marginal costs, the contrary is the case for the roadway (see Campos et al. 2007 and Boylaud and Nicolett, 2001).

		Monopolist		
		Exit (0)	Export (E)	FDI (D)
Shipper	Traditional	0,0	$0, f(p)(p-\alpha w-m)$	$0, f(p)(p-\alpha(w-m))-G^c$
	Modern	$-F^c, 0$	$f(p)m-F^c, f(p)(p-\alpha w-m)$	$\alpha f(p)m-F^c, f(p)(p-\alpha(w-m))-G^c$

Figure 1: Payoff matrix

where $Q^c = \frac{Q}{n}$ are the per capita demand for transport and $F^c = \frac{F}{n}$ are the per capita fixed costs of the modern technology.

Note then that demand for transportation under export and FDI is $Q_E = f(p)$ and $Q_D = \alpha f(p)$, respectively. This, together with the above, implies that the first stage payoff matrix is as in figure 1.

We can now analyze in more detail the choices of the monopolist and the shipper. We start with the monopolist and then move to the shipper.

4 Choice of the Mode of Foreign Expansion

From equations 1 and 2, we can see that the decision by the monopolist is independent from the one by the shipper¹⁹. It is assumed that for each value of m , the firm selects a profit-maximizing price. Then, in both cases E and D , this price is an increasing function of m . We define:

$$\pi_E^I(m) = \max_p \pi_E^I(p, m)$$

$$\pi_D^I(G^c, m) = \max_p \pi_D^I(p, m, G^c). \quad (6)$$

To analyze the decision between the strategies E and 0, note first that $\pi_E^I(m)$ is a continuous function and that:

¹⁹In the last section paper we discuss the consequence of relaxing this restriction in our model. Remember however that the objective of this paper is to analyze how the mode of foreign expansion by firms, export versus foreign direct investment, accounts for the selection of technologies of transport by shippers, modern versus traditional (and not how they affect each other).

$$\pi_E^I(0) > 0$$

$$\lim_{m \rightarrow \infty} \pi_E^I(m) < 0. \quad (7)$$

Furthermore, function $\pi_E^I(m)$ is decreasing, since using the envelope theorem:

$$\frac{d\pi_E^I}{dm} = \frac{\partial \pi_E^I}{\partial m} = -f(p) < 0. \quad (8)$$

Hence, there is a unique threshold \tilde{m} , such that (see figure 2):

$$\pi_E^I(m) \gtrless 0 \text{ iff } m \lesseqgtr \tilde{m}. \quad (9)$$

In turn, the choice between strategies D and 0 can be analyzed by means of the implicit function:

$$\pi_D^I(G^c, m) = 0. \quad (10)$$

Using the implicit function theorem on $\pi_D^I(m, G^c)$, we find that everywhere there is a continuous function $G^c(m)$ whose first and second derivatives are:

$$\begin{aligned} \frac{dG^c}{dm} &= -\alpha f(p) < 0 \\ \frac{d^2G^c}{dm^2} &= -\alpha f'(p) \frac{dp}{dm} > 0. \end{aligned} \quad (11)$$

The $G^c(m)$ function is then decreasing and convex (see figure 2). It can be concluded that $G^c(0)$ is positive and finite and $\lim_{m \rightarrow \infty} \pi_D^I(G^c, m) < 0$, so that $G^c(m)$ intercepts the m axis. Moreover the value \tilde{G}^c is such that $\pi_D^I(\tilde{G}^c, \tilde{m}) = 0$ is positive, since the operating profit of strategy D is positive for $m = \tilde{m}$. We then have:

$$f(p)(p - \alpha w - \alpha \tilde{m}) > \pi_E^I(\tilde{m}) = 0. \quad (12)$$

Finally, the choice between strategies E and D can be examined through the implicit function:

$$H(G^c, m) = 0 \Leftrightarrow \pi_E^I(m) - \pi_D^I(G^c, m) = 0. \quad (13)$$

Using again the implicit function theorem, we have that there is a continuous function $G^c(m)$ that passes through the origin in space (G^c, m) and through the point (\tilde{G}^c, \tilde{m}) . This function has the following first and second derivatives:

$$\begin{aligned} \frac{dG^c}{dm} &= -\frac{H_m}{H_G} = (1 - \alpha)f(p) > 0 \\ \frac{d^2G^c}{dm^2} &= (1 - \alpha)f'(p)\frac{dp}{dm} < 0. \end{aligned} \quad (14)$$

$G^c(m)$ is thus increasing and concave (see figure 2). Pulling together the results obtained so far, we can plot the E , D and 0 regions in the space (G^c, m) . The different areas in figure 2 indicate where each strategy of serving the consumers in the foreign market is more profitable for the monopolist firm²⁰.

From figure 2, we can see that like in Horstmann and Markusen (1992) the proximity-concentration also holds. In this sense, the export strategy is preferred for high G^c (high economies of scale at the plant level and small market size) and low m (low transport costs). The multinational strategy, in turn, is favored for small G^c (low economies of scale at the plant level and large market size) and mid-high m (medium-high transport costs). In the next section, we will analyze the shipper's choice of transport technology and how this decision interacts with the mode of foreign expansion by the service firm.

5 Choice of Transport Technology

The decision of the shipper depends upon the monopolist's choice of foreign expansion. In particular, as can be seen from figure 1, the decision of the shipper is:

- If Exit (0): Traditional (T)

²⁰The thick dashed curve depicts the monopolist service firm's decision between the strategies E -0. In turn, the thick solid curve for $m < \tilde{m}$ and $m > \tilde{m}$ represents the monopolist service firm's decision between the strategies D - E and D -0, respectively.

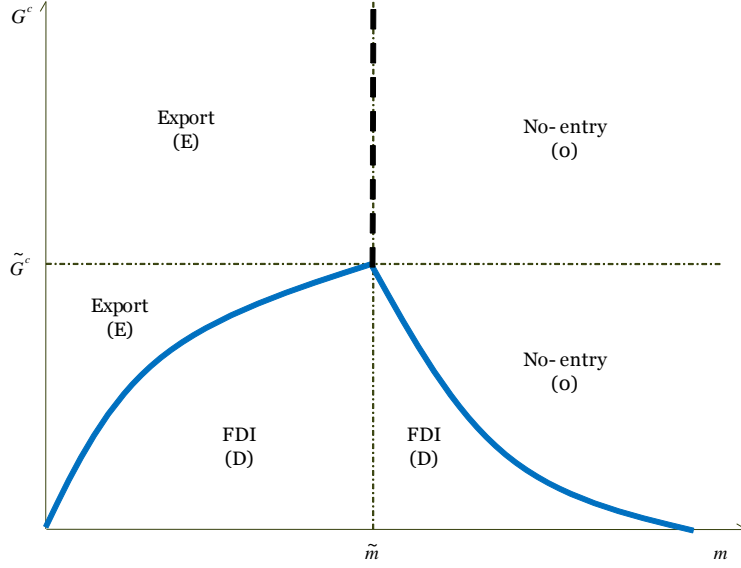


Figure 2: Location of the monopolist in space (G^c, m)

- If Export (E): Modern (M) iff $f(p)m - F^c \geq 0$; Traditional (T) iff $f(p)m - F^c < 0$
- If FDI (D): Modern (M) iff $\alpha f(p)m - F^c \geq 0$; Traditional (T) iff $\alpha f(p)m - F^c < 0$

It is evident that the best reply by the shipper to exit (0) is the traditional (T) transport technology, since the demand for transport services is then zero. Therefore, the modern technology (M) can only be chosen in equilibrium if the monopolist decides to supply the foreign market through exports (E) or FDI (D).

Define $Q_D^c \equiv$ per capita transport demand under FDI (with trade in intermediate goods) and $Q_E^c \equiv$ per capita transport demand under Export. It then follows:

$$\begin{aligned} Q_E^c &= f(p(\alpha w + m)) \\ Q_D^c &= \alpha f(p(\alpha(w + m))). \end{aligned} \quad (15)$$

Let $\Delta Q^c = Q_E^c - Q_D^c$. Generally, ΔQ^c has an indeterminate sign once $\alpha < 1$, as $(p(\alpha w + m)) > (p(\alpha(w + m))) \Rightarrow f(p(\alpha w + m)) < f(p(\alpha(w + m)))$.

Without loss of generality assume that $w = 0$. The relation between $L_E(m) = f(p(m))m$ and $L_D(m) = f(p(\alpha m))\alpha m$ is therefore undetermined.

In the export case, the following condition ensures both that the modern technology is feasible for the shipper and that it is preferred to the traditional one:

$$f(p(m))m - F^c \geq 0 \quad (16)$$

or:

$$F^c \leq L_E(m) = f(p(m))m. \quad (17)$$

Function $L_E(m)$ is defined in $[0, \tilde{m}]$ for high enough values of G^c , so that the monopolist chooses to supply the foreign market through exports. According to the definition of \tilde{m} , function $L_E(m)$ has the following properties:

1. $L_E(0) = 0$
2. $L_E(m)$ is increasing in the neighborhood of 0 since:

$$\text{sign} \frac{dL_E(m)}{dm} = \text{sign} \left[\underset{(+)}{f(p(m))} + m \underset{(-)}{f'(p(m))} \frac{dp}{dm} \right], \quad (18)$$

whose sign is ambiguous. However, since the derivative is continuous by assumption, and $\frac{dL_E}{dm} \big|_{m=0} = 0$, it follows that it is also positive for m in the neighborhood of 0.

3. $L_E(\tilde{m}) = f(p(\tilde{m}))\tilde{m} = f(p(\tilde{m}))p(\tilde{m}) = \tilde{F}_E^c > 0$.

In the FDI case, the condition for the adoption of the modern technology is:

$$\alpha f(p(\alpha m))m - F^c \geq 0 \quad (19)$$

or:

$$F^c \leq L_D(m) = \alpha f(p(\alpha m))m. \quad (20)$$

The function $L_D(m)$ has the following properties:

1. $L_D(0) = 0$
2. $L_D(m)$ is increasing in the neighborhood of 0 since:

$$\text{sign} \frac{dL_D(m)}{dm} = \text{sign} \left[\underset{(+)}{f(p(\alpha m))} + \alpha m \underset{(-)}{f'(p)} \frac{dp}{d(\alpha m)} \right], \quad (21)$$

whose sign is ambiguous. However, since the derivative is continuous by assumption, and $\frac{dL_D}{dm} |_{m=0} > 0$, it follows that it is also positive for m in the neighborhood of 0.

3. $L_D(\tilde{m}) = f(p(\alpha\tilde{m})) (\alpha\tilde{m}) = \tilde{F}_D^c > 0$, since $f(p(\alpha\tilde{m})) > 0$.

4. $L_D(m)$ is decreasing for arbitrary high values of m . This is so because: (i) $f(p(\alpha m)) \rightarrow 0$ when $m \rightarrow \infty$ (note that $\alpha m \rightarrow \infty$ when $m \rightarrow \infty$ and $p(\alpha m)$ increases without bound with αm); (ii) $\alpha m f'(p) \frac{dp}{d(\alpha m)} \rightarrow -\infty$ when $m \rightarrow \infty$, once the assumptions on the demand function ensure that $f'(p) < 0$ and $\frac{dp}{d(\alpha m)} > 0$ for all p .

The fact that $L_D(m)$ is eventually decreasing with the transport rate (m) in the FDI region, together with the observation that the rise of m determines a switch from FDI to exit, makes the adoption of the modern technology less likely for high variable transport rates. This means that the increase of the variable transport rate (proxied by distance) reduces the demand for transport services, thus preventing the modern transport technology to break even. In this sense, the adoption of modern transport technology tends to occur in the vicinity of \tilde{m} .

We then need to analyze the relations between:

$$\begin{aligned} \tilde{F}_E^c &= L_E(\tilde{m}) = f(p(\tilde{m})) \tilde{m} = f(p(\tilde{m})) p(\tilde{m}) \\ \tilde{F}_D^c &= L_D(\tilde{m}) = f(p(\alpha\tilde{m})) (\alpha\tilde{m}) < f(p(\alpha\tilde{m})) p(\alpha\tilde{m}) \\ \tilde{G}^c &= (p(\alpha\tilde{m}) - \alpha\tilde{m}) f(p(\alpha\tilde{m})). \end{aligned} \quad (22)$$

Start by looking at the total revenue function, $pf(p)$. The total revenue function is concave and has a unique maximum (see figure 3). Then we clearly see that the relations between \tilde{F}_E^c , \tilde{F}_D^c , and \tilde{G}^c are undetermined.

We therefore need to examine how the equilibrium of the game changes for different relations between \tilde{F}_E^c , \tilde{F}_D^c , and \tilde{G}^c . Six cases are possible:

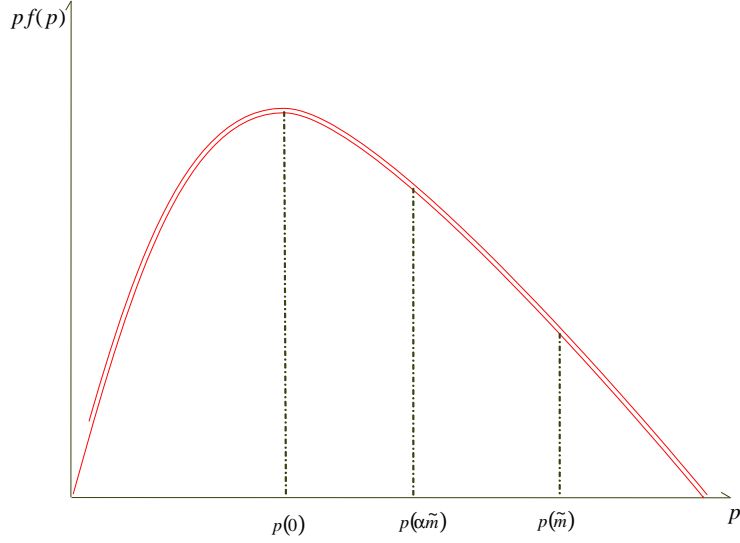


Figure 3: Total revenue function

$$\begin{aligned}
 (1) \quad \tilde{G}^c &> \tilde{F}_E^c > \tilde{F}_D^c \\
 (2) \quad \tilde{G}^c &> \tilde{F}_D^c > \tilde{F}_E^c \\
 (3) \quad \tilde{F}_E^c &> \tilde{G}^c > \tilde{F}_D^c \\
 (4) \quad \tilde{F}_E^c &> \tilde{F}_D^c > \tilde{G}^c \\
 (5) \quad \tilde{F}_D^c &> \tilde{G}^c > \tilde{F}_E^c \\
 (6) \quad \tilde{F}_D^c &> \tilde{F}_E^c > \tilde{G}^c.
 \end{aligned} \tag{23}$$

Figures 4 to 9 show the equilibrium choice of transport technology for the cases in equation 23 as a function of the monopolist's mode of foreign expansion (exit, export, FDI)²¹. From figures 4 to 9, we can observe three patterns related to the choice of transport technology by the shipper alone

²¹In figures 4 to 9, $G = F$, i.e.: the fixed costs of the monopolist equal the fixed costs of the modern technology. We make this assumption in order to be able to make a graphical representation of the equilibrium of the game. However, note that even so \tilde{G}^c , \tilde{F}_E^c and \tilde{F}_D^c differ. The $L_E(m)$ and $L_M(m)$ curves are signed with their respective names. The $L_E(m)$ curve, though, is easy to identify since it is truncated for $m > \tilde{m}$, i.e.: for $m > \tilde{m}$ exports become prohibitive and therefore the demand for transportation is canceled. In turn, from the properties of $L_D(m)$, we know that $L_D(m)$ is decreasing for arbitrary

and two patterns that concern how the choice of the shipper interacts with the decision on the mode of foreign expansion by the service firm. Start with the former. First, we have that as market size increases (low G^c and low F^c) the modern technology is promoted. Accordingly, larger market size allows the shipper to explore the economies of scale of the modern technology.

Furthermore, the relation between market size and modern technology adoption tends to be monotonic. There is, however, one exception: case (3), where $\tilde{F}_E^c > \tilde{G}^c > \tilde{F}_D^c$. When this occurs as market size increases, the modern technology is only monotonically adopted in relation to the same mode of foreign expansion, but not when export gives place to FDI, i.e.: $(E, T) \rightarrow (E, M) \rightarrow (D, T) \rightarrow (D, M)$. Note however, that the non-monotonic relation only arises for intermediate levels of m (lower than \tilde{m} , but in its vicinity), for lower and higher levels of m the relation is always monotonic, as it takes place in the other cases (case (1), (2), (4), (5) and (6)). The reason for the non monotonicity is that in case (3) there is a large difference between the level of fixed costs that leads to the adoption of the modern technology under exports and under FDI, i.e.: $\tilde{F}_E^c \gg \tilde{F}_D^c$. This can occur for example when trade in intermediate goods is small under FDI, and therefore the level of fixed costs that makes the modern technology profitable under FDI is also low.

Second, decreasing transport costs (m) can encourage the adoption of the modern technology. The rationale for this is that as trade costs decrease, the demand for transportation increases, making the modern technology more profitable than the traditional one. The previous result indicates that further economic integration creates a good environment for the introduction of modern transportation technologies.

Third, the relation between transport costs (as proxied by distance) and the modern technology adoption is non-monotonic. In particular, as discussed above, the modern technology tends to be chosen by the shipper in the vicinity of \tilde{m} (i.e.: for intermediate levels of transport costs and in the limits of the export strategy). For either high or low transport costs the traditional technology is preferred. The reason for this is that with high

high values of m . In the figures below, we have depicted that $L_D(m)$ starts to decrease for $m = \tilde{m}$. However, the results are not changed qualitatively if $L_D(m)$ is decreasing only for $m > \tilde{m}$. As in figure 2, the thick dashed curve depicts the monopolist service firm's decision between the strategies $E-0$. The thick solid curves for $m < \tilde{m}$ and $m > \tilde{m}$ represents the monopolist service firm's decision between the strategies $D-E$ and $D-0$, respectively.

variable transport costs, demand for transportation is very low, and therefore the modern technology is not appealing for the shipper since economies of scale in transportation are also low. In turn, for low trade costs (i.e.: over short distance), while the demand for transportation is high, the returns from transportation are so low that the shipper finds it difficult to pay the fixed costs of the modern technology.

In terms of the relation between the choice of the service firm and of the shipper, we have the following. First, and as already mentioned above, if the service firm does not enter the market, then it is also not profitable for the shipper to adopt the modern technology. This is so, since in this scenario, there are no trade exchanges.

Second, the modern technology tends to arise together with the FDI strategy. The reason for this is that both the modern technology and the FDI strategy are more likely to emerge when market size is large and trade costs intermediate. However, the modern transport technology can also occur jointly with the export strategy. This is only the case, though, when $\tilde{F}_E^c > \tilde{G}^c$ (figures 6, 7 and 9), i.e.: when the modern technology is profitable for relatively high levels of fixed costs and the export strategy is profitable for relatively low levels of plant-specific fixed costs.

Given that the export strategy is relatively more intensive in transportation (since $\alpha \in [0, 1]$), it might seem a counter intuitive outcome that the modern transport technology is more likely to arise when the service firm chooses the FDI strategy than with the export strategy (although, as we have just seen the modern technology can also arises together with the export technology, see figure 6, 7 and 9). In other words, we would expect *à priori* that the modern technology would potentially be more attractive under the export strategy than under the FDI strategy. However, this is not the case, because in the end what is more important for the shipper's decision is not only the intensity of transportation under a given mode of foreign expansion by the service firm, but also the profitability of a given transport technology as determined by market size. And as we have just seen, it comes out that when market size is large the decisions of the shipper and of the service firm converge for the modern technology and the FDI strategy, respectively.

In line with what we have discussed in the introduction, the development of the HSR in several countries and regions of the world looks to confirm our results related to adoption of the modern technology by the shipper alone. We cannot, however, provide evidence for the assertions related to

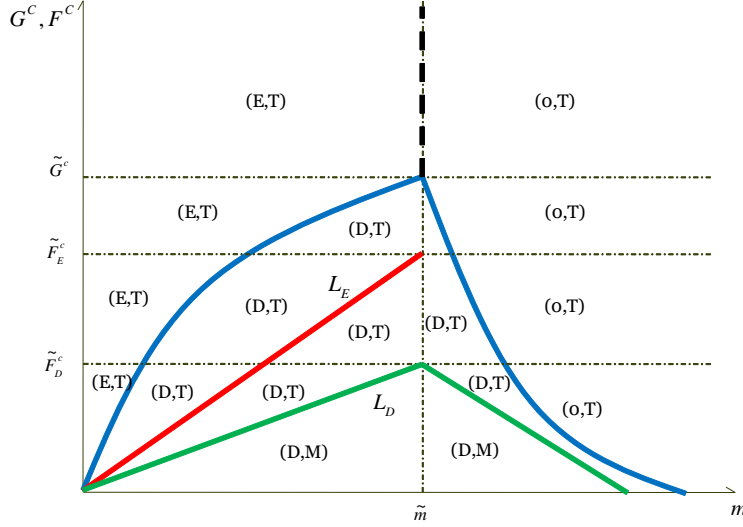


Figure 4: Transport technology in space $((G^c, F^c), m)$: (1) $\tilde{G}^c > \tilde{F}_E^c > \tilde{F}_D^c$

the interactions between the decisions of the shipper and the service firm, since in our case study we do not compare FDI and export data with the introduction of the HSR. For analyzing the relations between the mode of foreign expansion by firms and the adoption of modern transport technologies by shippers, we would need a fully fledged econometric model with data on exports and FDI. In our opinion this is an interesting topic for future empirical research.

6 Discussion

In a set-up with intermediate production, we have analyzed how a shipper's choice of transport technology (traditional *versus* modern) is affected by the mode of foreign expansion by a service firm (export *versus* foreign direct investment).

Concerning the choice of the service firm, we derive the well known proximity-concentration trade-off augmented with trade in intermediate goods. The last feature is central in our model because FDI and trade become complements, and therefore we continue to have demand for transportation under FDI and not only under exports (as is the case in the standard set-up with

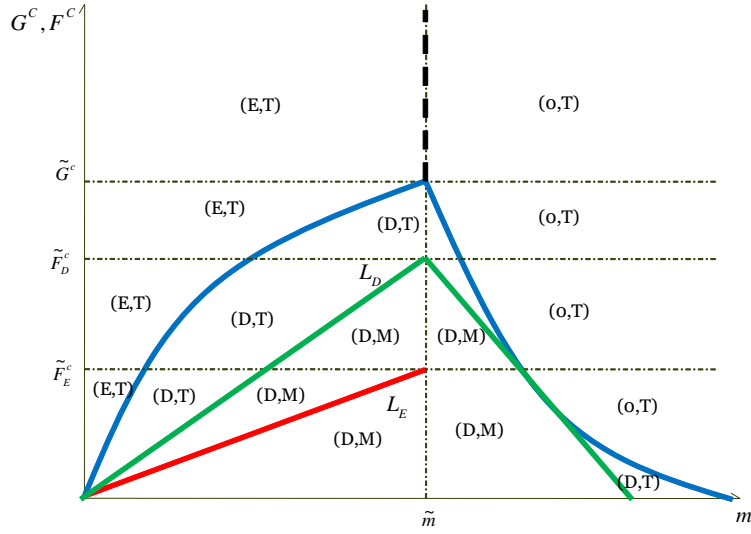


Figure 5: Transport technology in space $((G^c, F^c), m)$: (2) $\tilde{G}^c > \tilde{F}_D^c > \tilde{F}_E^c$

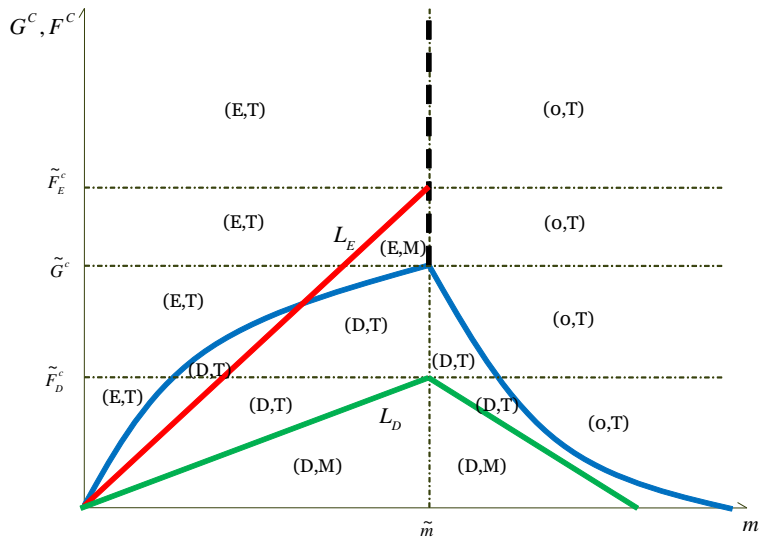


Figure 6: Transport technology in space $((G^c, F^c), m)$: (3) $\tilde{F}_E^c > \tilde{G}^c > \tilde{F}_D^c$

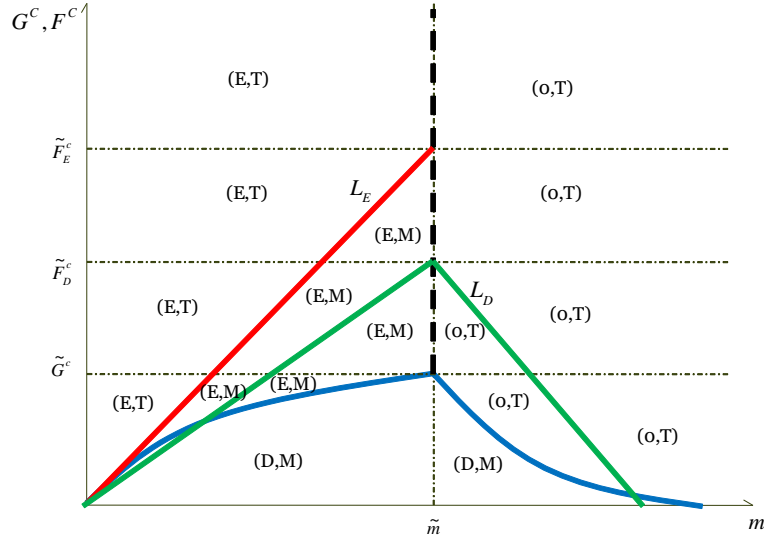


Figure 7: Transport technology in space $((G^c, F^c), m)$: (4) $\tilde{F}_E^c > \tilde{F}_D^c > \tilde{G}^c$

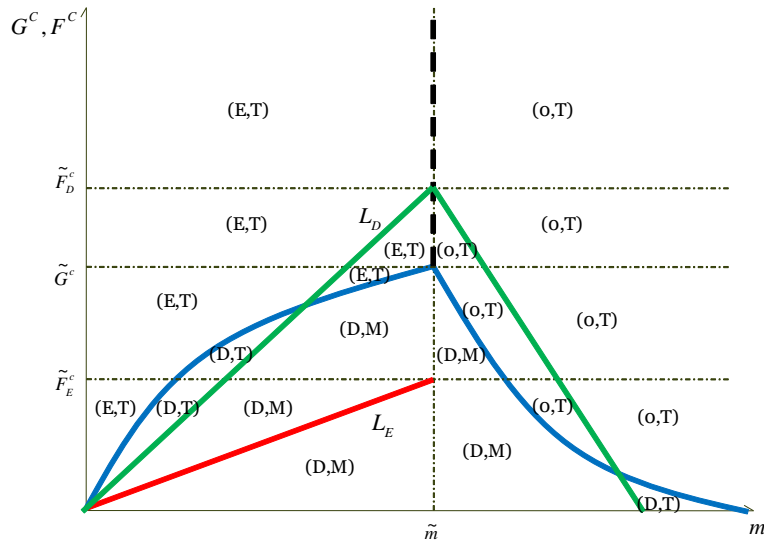


Figure 8: Transport technology in space $((G^c, F^c), m)$: (5) $\tilde{F}_D^c > \tilde{G}^c > \tilde{F}_E^c$

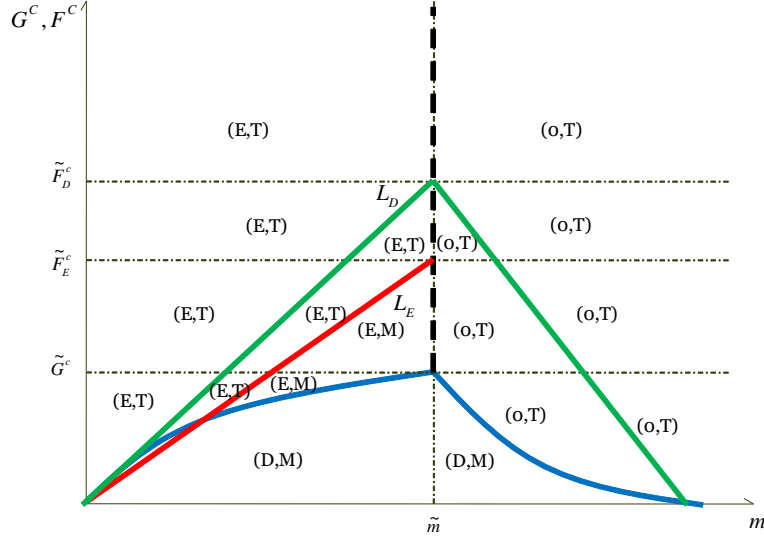


Figure 9: Transport technology in space $((G^c, F^c), m)$: (6) $\tilde{F}_D^c > \tilde{F}_E^c > \tilde{G}^c$

FDI and trade as substitutes).

In what relates to the shipper's choice of transport technology, we obtain the following. First, the modern technology tends to be implemented in larger markets, since the shipper can explore larger economies of scale in the modern technology. Second, economic integration can help to promote the adoption of the modern technology, given that it increases international trade and therefore transport demand. Third, the adoption of modern technology tends to arise for intermediate levels of variable transport costs (as proxied by distance), since for high transport costs the demand for transportation is low and for low transport costs the returns from transportation are small.

The above results seem to fit well with the adoption of modern transport technologies, such as the HSR. In fact, we have observed that the HSR tends to connect large cities that are not too far apart or too close together. Furthermore, the European experience of closer economic integration has triggered the adoption of HSR across European borders.

In turn, in terms of the interaction between the shipper's choice of transport technology and the service firm's mode of foreign expansion, we find two main results. First, the modern technology is only adopted if the service firm enters the market, since only then is there demand for transportation.

Second, the adoption of modern technology tends to take place together with the FDI strategy, once they both emerge for intermediate levels of trade costs and when market size is large.

Given that we have not provided evidence to support the two previous findings, future empirical research could analyze the relation between the adoption of modern transport technologies (such as the HSR) and the dominant mode of foreign entry by firms, such as export and FDI.

In addition, future work could extend our model to introduce competition in the service sector, competition in the transport sector, and endogenize the rate of transportation. Competition in the service sector in principle will not change our main results since the proximity-concentration trade-off still holds in duopoly and oligopoly market structures (see Markusen, 2002). Competition in the service sector, in turn, would only be relevant with imperfect competition between transporting firms (since with perfect competition marginal cost pricing would hold). With imperfect competition in the transport sector, we could also endogenize the rate of transportation. In this way, the mode of foreign expansion in the service sector and the choice of transport technology in the transport sector would be mutually dependent.

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