Multinational Expansion in Time and Space*

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Abstract

This paper studies the expansion in time and space of the multinational enterprise (MNE). Using a long panel of US MNEs, we document that: MNE affiliates grow by exporting to new markets, and not on the intensive margin within a market; MNE affiliates' activities persist during the affiliate's life, usually starting with sales to the local market and eventually adding exports later in life; and MNE affiliates' entry into new locations does not depend on the location of preexisting affiliates. Informed by these facts, we develop a quantitative dynamic model of the MNE that features heterogeneity in productivity, persistent aggregate shocks, and a rich structure of costs that affect MNE expansion. Importantly, MNE affiliates can decouple their location of production from the one of sales, and endogenously choose to enter or exit both the host and the export markets. We retain the tractability of the model by introducing a compound option formulation, which allows us to calibrate the model and quantify the costs to MNE expansion. Our quantitative application reveals that export platforms are important to understand the reallocation of MNE activity in time and space after a shock, and that the nature of the frictions to MNE activities affects the timing of these responses.

JEL Codes: F1.

Key Words: Multinational firms, Foreign direct investment, Firm dynamics, Sunk costs.

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1 Introduction

Many important questions in international economics involve the complex activities of multinational enterprises (MNEs) in time and space. Consider the recent rise in protectionist sentiments that have been expressed around the world. Understanding how these protectionist forces will affect the global allocation of production and consumption in the years to come requires an understanding of the dynamics of multinational firms. The recent debate about the United Kingdom abandoning the European Union, "Brexit", is one example. If Brexit happened, would MNEs pull out of the United Kingdom and reallocate toward other countries? How would trade flows linked to MNEs be affected over time? How long would this reallocation process take? Studying the expansion patterns of MNEs and understanding the nature of their costs are key to providing sound answers to these important questions.

Despite its importance, the dynamic behavior of MNEs and their affiliates in space has received little attention in the literature. On the empirical side, this is primarily due to data limitations. On the theoretical side, dissecting the nature of the costs of MNE activity –whether variable, fixed, or sunk, and whether host- or destination-country specific– poses challenges to tractability.[1] This paper provides a new set of facts and a new quantitative dynamic framework aimed at answering counterfactual questions about MNE behavior and its effect on the global economy.

Our analysis uses a long panel of US MNEs and their foreign affiliates, from the Bureau of Economic Analysis (BEA). Studying the behavior of US MNEs and their affiliates is a relevant setup because not only the United States is the main source of MNEs in the world, but also MNE affiliates are the main channel through which US firms reach foreign consumers. Majority-owned affiliates of US MNEs abroad accounted, in 2009, for 75 percent of US sales to foreign customers; forty percent of those sales were affiliates' exports, i.e., sales to customers outside the affiliate's host market.

We start by documenting three facts about the life-cycle dynamics of US MNEs and their affiliates. First, MNE expansion happens mainly at the extensive, rather than intensive, margin: MNEs expand by entering new markets, either opening new affiliates or starting exporting from existing ones. We do not observe significant intensive margin growth within a country: the ratio of affiliate-to-parent sales is relatively flat over the affiliate life cycle. Second, the activities of MNE affiliates are persistent over the affiliate life cycle: at birth, most affiliates serve only their host market (horizontal sales). Only later in life they start also exporting to third countries (export platform). Third, the location choice of a MNE's new affiliate does not appear to depend on the location of pre-existing affiliates—in other words, the pattern of affiliate opening does not display extended

[1] See Antrás and Yeaple (2014) for a detailed survey of the main facts and theories about MNEs.

gravity, in contrast with the facts that Morales et al. (2015) document for exporters.

Informed by these facts, we build a quantitative multi-country dynamic model of MNE expansion. Home-based firms decide whether, when and where to open foreign affiliates. Affiliates, in turn, can sell both to their host market and to any other market. Affiliate operations, both in the host and in the export markets, entail sunk, fixed, and variable costs. The decisions of whether to set up an affiliate and export from it are shaped by the interaction of firm characteristics, persistent aggregate productivity shocks, and demand conditions in foreign markets.

We make two key assumptions. First, guided by the observation that almost all affiliates in the data have some horizontal sales at birth, while almost no affiliates are pure exporters, we assume that firms that decide to do foreign direct investment (FDI) must first set up an affiliate and sell to the local market, and only then they can consider exporting from that affiliate. Since the model is set up in continuous time, the decisions of opening an affiliate and exporting from it can be made virtually simultaneously, generating both pure horizontal affiliates and affiliates that are born with both sales to the host market and exports, like the data show. Second, consistent with the lack of extended gravity in the data, we assume that the decision of opening an affiliate —and eventually exporting from it— is independent across markets (e.g., whether a firm decides to open an affiliate in Germany and from it export to France is independent of having an affiliate in France). Interdependence in location choices across countries is featured into the model by allowing the decision to open an affiliate in a country to depend on the set of countries where the affiliate can export to. For this reason, the problem of a MNE in the model takes the form of a *compound option*: opening an affiliate in a country is an option which, when exercised, gives access to a set of additional options: exporting from the affiliate to any other location.

These assumptions lend tractability to the model and allow us to preserve the rich heterogeneity necessary for quantitative analysis. In particular, separating the decisions about performing affiliate activities in different countries significantly simplifies the dynamic problem of the firm. Coupled with the continuous time specification, value functions can be solved in closed-form (up to constants) as simple additive functions of the firm's realized profit flow plus the option values of further expansion and of exit. The independence assumption and the compound option structure imply dynamic interdependence of location decisions but static independence. These features allows us to avoid the complex permutational problem present in (static) models of export-platforms, which would be unmanageable to solve and quantify in a dynamic setup.

The way we formulate the dynamic problem applies insights from the real options literature in finance, and more precisely from the formulation that Dixit and Pindyck (1994) propose to solve general models of investment under uncertainty. The application to the complex decisions of the

the MNEs appears natural, since MNEs location and export decisions happen over time, and they are likely to be affected by uncertainty in demand and other market characteristics. Conversely, the static components of our model are standard and follow Melitz (2003). As a result, a simple version of the model, which we can solve entirely in close form, has stark predictions regarding the selection patterns of MNE affiliates within and across host markets. We contrast these predictions with the data and find that exporting affiliates have larger horizontal sales than affiliates that only serve the host market, and affiliates that export at birth have larger horizontal sales than affiliates that start exporting later in life. Moreover, MNEs open first their largest affiliates, and subsequently their smaller affiliates. Finally, MNEs establish affiliates first in host markets that are larger and easier to access, while later in life they open affiliates in smaller and costlier markets.

The ability of the model to generate predictions that are consistent with the data gives us the confidence to use the framework for quantitative analysis. We calibrate the model to match static and dynamics moments from US MNE affiliates located in the top ten host countries, over thirty years. The moments that we choose are informative about the different costs that the MNE faces when it decides to expand. In this regard, it is very valuable that the model delivers simple closed-form solutions.

Armed with the calibrated model, we perform various counterfactuals to evaluate the importance of the nature of the frictions to multinational expansion. Since our sample includes affiliates located in the United Kingdom, Ireland, Germany, and France, it is natural to use the context of Brexit as our main exercise. Different proposed implementations of Brexit have the common qualitative effect of increasing export costs between the UK and other European countries. This drives a decline in the incentive to open affiliates in the UK (so that export platform sales from the UK decline) but also in other European countries whose affiliates had a large export share to the UK.

We relate to the existing literature in several ways. First, most contributions in the literature have analyzed MNE expansion in space, but not in time. As evident in the static models in Tintelnot (2017), Fan (2017), Arkolakis et al. (2018), and Head and Mayer (2018), allowing firms to set up affiliates in countries that differ from the destinations of their sales can result in a complex problem when fixed costs of production are taken into account. The sharp patterns that we document from observing affiliates over time help to simplify this problem by reducing the choice set of firms in a way that is consistent with the data.

Second, there is a small, but growing, literature that analyzes different aspects of the dynamics of the MNE. Papers in this literature limit, however, the spatial dimension of the problem. In a model with firm-level shocks, Gumpert et al. (2016) focus on the life-cycle dynamics of the proximity-concentration tradeoff—i.e., sales of MNE affiliates are only horizontal and an alternative to (Home) exports—and assess the role of MNEs on new exporters' dynamics, using rich firm-level data from various countries. In contrast, Fillat and Garetto (2015) build a dynamic two-country model of the proximity-concentration tradeoff with aggregate shocks. Importantly, they introduce the idea that MNE activities can be treated as a real option that gets exercised once an affiliate is opened abroad. Fillat et al. (2015) extend this idea further to a multi-country setup, but they get rid of the proximity-concentration tradeoff. Both papers focus on the link between the MNEs' expansion decisions and asset prices, and both assume that the activities of affiliates are restricted to the market of operations.[2] Our model treats MNE activities as a compound, rather than a simple, option. In this way, we are able to preserve the dynamic dimension of the problem in a multi-country setup, expand on the spatial dimension by separating activities of MNE affiliates between the locations of production and sales, and capture the rich heterogeneity of MNE activities present in the data.

Third, our paper is naturally related to the large literature on export dynamics, which has been primarily concerned with quantifying the various costs of export activities and their welfare implications.[3] In particular, we adopt a shock structure that combines insights from the one in Ghironi and Melitz (2005) and Impullitti et al. (2013). By analyzing the dynamics of MNEs and quantifying the frictions to their expansion, our work complements this literature on exporters dynamics and makes useful comparisons between the barriers to the two modes of market entry.

Finally, our paper relates to the large literature that analyzes the dynamics of domestic firms, which goes back to Davis et al. (1996), and more recently Decker et al. (2014, 2015). Our facts suggest that the dynamics of MNE affiliates are starkly different from the dynamics of domestic firms. We interpret the difference between the behavior of new US firms in the domestic and foreign markets as indicative of the fact that they face very different sets of costs.

[2] Additionally, Ramondo et al. (2013) study the implications of the proximity-concentration tradeoff under uncertainty and use BEA data to assess the predictions of the model. Conconi et al. (2016) couple a model of the proximity-concentration tradeoff with learning and test it using detailed data for Belgium. Focusing only on MNEs, Egger et al. (2014) propose a learning model to explain the sequential entry into markets of German MNEs. All these papers limit both the spatial dimension of their analysis, by considering only horizontal FDI sales, and the dynamic dimension, as they are featuring two-period models.

[3] Earlier contributions by Baldwin and Krugman (1989), Roberts and Tybout (1997), Das et al. (2007), and Alessandria and Choi (2007) find evidence for substantial sunk costs of exporting by focusing on observed patterns of export entry and exit. Subsequent analyses, such as Eaton et al. (2008) and Ruhl and Willis (2017), incorporate facts related to the life-cycle dynamics of new exporters and find that those costs are much lower. Alessandria et al. (2015) take a further step and also calculate the welfare gains from trade in a dynamic setting that matches well the life-cycle export facts. Arkolakis (2016) presents rich micro evidence on firm selection and export growth that supports dynamic theories of endogenous entry costs *vis-a-vis* standard export sunk costs.

2 Establishing the Facts

We document three novel facts on the dynamic behavior of foreign affiliates of US MNEs. First, MNE expansion happens at the extensive, rather than intensive, margin. Second, affiliates are born specialized in their life-long main activity which, for the vast majority, consists of sales to the host market, while export activities start later in life and are performed at a low intensity. Finally, the location choice of new affiliates does not depend on the location of pre-existing affiliates.

2.1 Data

Our empirical analysis uses the firm-level data on the operations of US multinational enterprises (MNEs), from the US Bureau of Economic Analysis (BEA). The data include detailed information on the operations of MNEs in the United States and their affiliates abroad, for the period 1987-2011. We restrict the sample to majority-owned affiliates that do not operate in tax haven countries, with primary activity in manufacturing, and belonging to a US parent operating in any sector.[4] We further consolidate affiliates belonging to the same parent and operating in the same country and 3-digit industry. We also remove from our sample affiliates and parents with zero total sales. Finally, since we are interested in firms' life-cycle behavior, we focus on affiliates that open during our sample period and that survive for at least ten consecutive years in the market.[5] We end up with a sample that covers 23 percent of all new affiliates in manufacturing as well as 38 percent of their total sales.

Crucially, the BEA data break down affiliate sales by destination: the host market of operation (horizontal sales), and other markets (exports). The data further distinguish between exports to the United States and to third markets, but this distinction does not make any substantial difference for the facts documented below. Additionally, benchmark year surveys also contain information about affiliates' exports to Canada, the United Kingdom, and Japan.[6] We exploit the distinction among different export destinations, including the US, in the calibration.

Table 1 shows the break down of observations in our sample in horizontal and export sales. Almost 95 percent of our affiliate-year observations have some horizontal sales, while more than two thirds

[4]Our sample is primarily composed of affiliates that are majority owned during their whole life. Only about one percent of affiliates go from majority to minority owned and less than two percent go from minority to majority owned.

[5]Our sample selection implies that we exclude affiliates that open in 2003 or later, as well as observations for affiliates in their eleventh year of life, or greater.

[6]The BEA data, however, do not provide detailed information on the parent's direct exports, except for intra-firm exports.

Table 1: Summary statistics: number of observations, by sale type.

	Horizontal sales	Export sales
No. of observations	38,080	38,080
with positive sales	36,135 (94.9%)	25,958 (68.2%)
of pure type	14,035 (36.9%)	2,418 (6.3%)
of pure type at birth	19,910 (52.3%)	3,590 (9.4%)
Sales accounted by pure-type	15.6%	7.7%

Note: Observations are at the affiliate-year level, for new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. A pure-type affiliate is an affiliate for which at least 99 percent of sales are either only horizontal or only export sales.

of them have some exports. More than one third of the observations correspond to pure horizontal affiliates (i.e., affiliates with at least 99 percent of sales directed to the host market), while the share of pure exporting affiliates is only six percent. These shares go up to 52 and nine percent if one considers all observations belonging to affiliates that were pure type at birth.

Appendix A provides more details on the data coverage, sample construction, and summary statistics.

2.2 Life-cycle expansion of MNE affiliates

The three panels of Figure 1 show the ratio of affiliate-to-parent sales, by affiliate age, for all, horizontal, and export sales, respectively. We plot the coefficients on the age dummies from estimating, by Ordinary Least Squares (OLS),

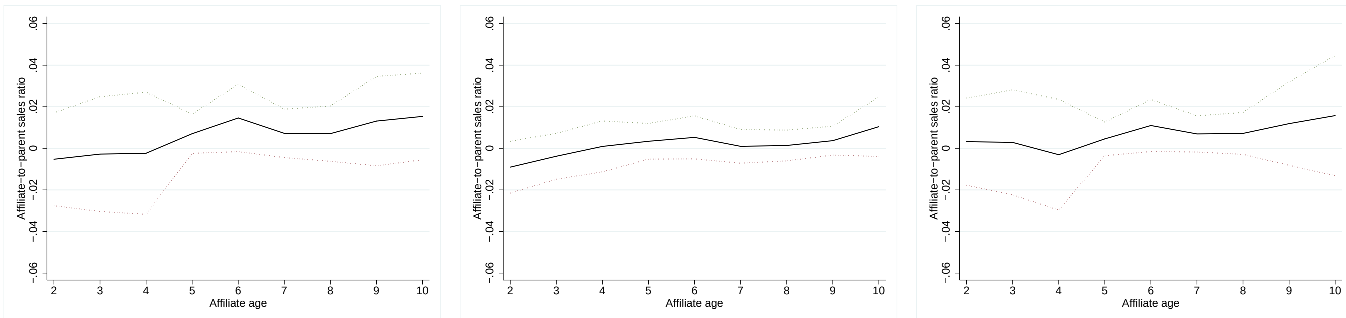
$$\log Y_{iap} = \sum_{a=2}^{10} D_{iap} + \beta_1 \log \text{affiliate emp}_{iap} + \beta_2 \log \text{global emp}_{iap} + u_{iap}. \quad (1)$$

The dependent variable Y_{iap} denotes the ratio of affiliate-to-parent sales for affiliate i belonging to parent p at age a, while D_{iap} is an affiliate i age dummy. We control for the affiliate's employment and for the global employment of the MNE, and we include country-year and affiliate fixed effects.

The affiliate-to-parent sales ratio is flat: at all ages, this ratio is not significantly different from the ratio in the entry year. A similar lack of life-cycle growth is observed not only for all affiliate

Figure 1: Affiliate-to-parent sales ratio, intensive margin.

(a) All sales (b) Horizontal sales (c) Export sales



Notes: OLS coefficients on age dummies (relative to the entry year) from estimating (1), with affiliate fixed effects and country-year fixed effects. Five-percent confidence intervals are shown with dashed lines. Sample of new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. Each panel includes affiliates with positive sales in the given category.

sales, but also for horizontal and export sales, separately.[7] Moreover, this flatness is not only observed within affiliates—i.e., including affiliate fixed effects—but also across affiliates of different ages—i.e., including industry fixed effects—as shown in Appendix Figure C.1.

MNE affiliates do not grow at the intensive margin, however they do expand at the extensive margin—that is, adding sales to markets other than the host market. Table 2 illustrates the results of estimating

$$\log Y_{iap} = \sum_{\delta \in \{-5,1\} \cup \{1,5\}} D_{i\delta p} + \beta_1 \log \text{affiliate emp}_{iap} + \beta_2 \log \text{global emp}_{iap} + u_{iap} \tag{2}$$

where $D_{i\delta p}$ assumes value one when affiliate i is δ years away from starting exporting. Also in this regression we control for the affiliate's employment and for the global employment of the MNE, and we include country-year and affiliate fixed effects.

Because the year in which an affiliate starts exporting is the omitted category, all results in Table 2 show sales relative to export entry. In the five years preceding export entry, the ratio of affiliate-to-parent sales is significantly lower than when the affiliate starts exporting. However, affiliate-to-parent sales don't grow significantly after export entry. This patterns indicates that growth happens at the extensive margin as affiliates begin selling to customers outside the host country.

Robustness. One could argue that the lack of life-cycle growth of MNE affiliates' sales may be due to the fact that the affiliate "inherits" the age of the parent so that, *de facto*, it is a much older firm,

[7] The same lack of life-cycle growth is observed for horizontal sales among the group of affiliates that never export, that always export, and that start exporting at some point in their life.

Table 2: Affiliate-to-parent sales ratio, extensive margin.

D(years to export entry = -5)	-0.013*
	(0.007)
D(years to export entry = -4)	-0.021***
	(0.006)
D(years to export entry = -3)	-0.017**
	(0.007)
D(years to export entry = -2)	-0.014*
	(0.008)
D(years to export entry = -1)	-0.016**
	(0.007)
D(years to export entry = 1)	-0.0057
	(0.009)
D(years to export entry = 2)	-0.001
	(0.009)
D(years to export entry = 3)	0.002
	(0.011)
D(years to export entry = 4)	0.003
	(0.013)
D(years to export entry = 5)	0.006
	(0.013)
log global employment	-0.040***
	(0.014)
log affiliate employment	0.042***
	(0.011)
Obs	38,080
R^2	0.030

Note: Results from estimating (2) by OLS. Observations at the affiliate-year level, for new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. The dependent variable *affiliate to parent sales* refers to affiliate sales relative to the domestic sales of the US parent. We run this specification including only affiliates that start exporting during our sample period. All specifications include affiliate and country-year fixed effects. Standard errors, clustered at the parent level, are in parenthesis. Levels of significance are denoted $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$.

and hence, larger and with lower growth rates. This may well be happening, as documented for multi-plant versus single-plant firms in the United States by Kueng et al. (2016).[8] Unfortunately, the BEA data do not record the age of the parent firm. However, we can look at the affiliate position in the opening sequence of the MNE—i.e., first affiliates versus subsequent affiliates. In this way, we compare affiliates belonging to younger MNEs with affiliates belonging to older MNEs (or to the same MNE at older ages). Columns 1-4 in Appendix Table B.1 show that first affiliates do not appear to grow faster than subsequent affiliates.

A second argument can be that, as global value chains (GVCs) have been growing very fast in the last decades, affiliates linked to them might be the ones also growing faster. In columns 5-8 in Appendix Table B.1, we define as GVC affiliates the ones with positive intra-firm trade (either exports or imports, or both), and as non-GVC affiliates the ones with zero intra-firm trade. We show that both groups have flat affiliate-to-parent sales ratios.

A third argument is related to the mode of FDI entry. If MNEs establish foreign affiliates mostly through mergers and acquisitions (M&A), one could argue that "new" foreign affiliates are in reality pre-existing plants that likely grew before their acquisition. The BEA asks to a sub-set of affiliates whether they were created through a merger with or an acquisition by an existing firm, or through a greenfield project. Because this question applies only to firms that opened mid-year—and thus the reported information about sales covers only part of the entry year—we compute the ratio of affiliate-to-parent sales for this subset starting at age two. Columns 9-12 in Appendix Table B.1 show that, relative to age two (the first year for which sales are recorded for the whole year), the sales ratio is flat, regardless of the mode of FDI entry.

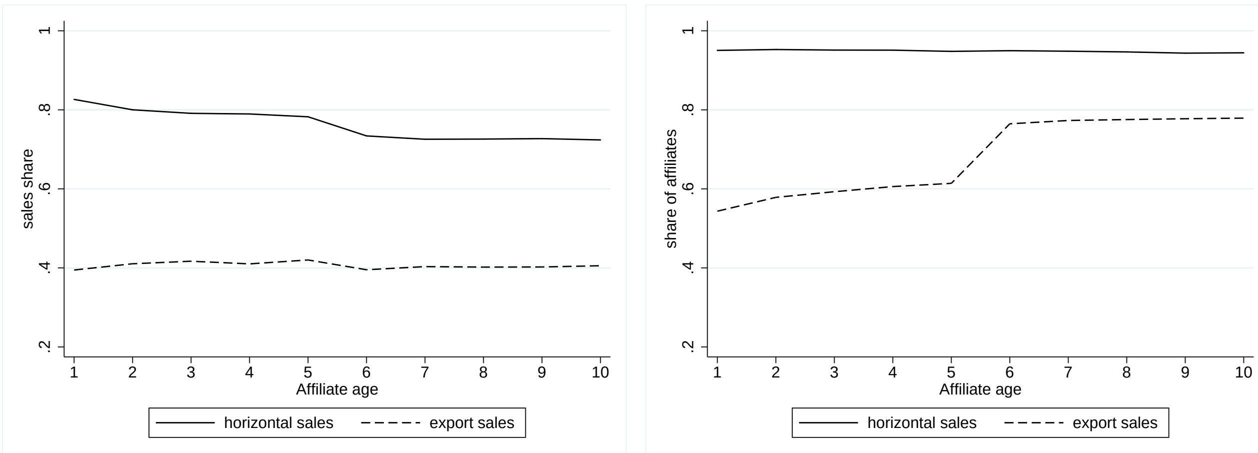
A final concern is that the flat sales profiles observed for new affiliates may be due to the fact that firms acquire experience and grow in a foreign market first through exports, and only subsequently open affiliates at their optimum long-run size. The BEA data do not include information about parent direct exports by destination market, thus making the analysis in that respect impossible. Gumpert et al. (2016), however, report that for Norway and France, the difference in growth profiles for MNEs with previous export experience into a market and those without it is not significant, except for the first year of the affiliate's life.

The fact documented in this section suggests that the expansion of MNE affiliates happens at the extensive margin—i.e., adding new export markets—and not at the intensive margin—i.e., within a market. For this reason, the model we present below exhibits MNE growth at the extensive margin

[8] Kueng et al. (2016) document a stark difference in the life-cycle employment profiles of establishments belonging to single- versus multi-unit firms in manufacturing: while establishments in single-unit firms grow steeply, the ones in multi-unit firms do not grow.

Figure 2: Intensive and extensive margins of sales, by activity type.

(a) Affiliate sales shares (b) Share of affiliates



Notes: Sample of new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. Horizontal and export sales refer, respectively, to sales to the market where the affiliate is located, and to sales to markets outside the local market. (2a): average sales, as a share of total affiliate sales, include affiliates with positive horizontal and export sales, respectively. (2b): number of affiliates, as a share of the total number of affiliates, include affiliates with positive horizontal and export sales, respectively.

only.

2.3 Life-cycle activities of MNE affiliates

We now present evidence on the specialization patterns of affiliates in terms of horizontal and export activities. We show that affiliates are born specialized in a core activity, typically horizontal sales, that persists as their main activity in life, even though affiliates may incorporate exports as a secondary activity later on.

Figure 2 shows the evolution of the intensive and extensive margins of horizontal and export sales, as shares of total sales of the affiliate. In particular, Figure 2a shows the evolution of the horizontal and export sales share, computed as an average over affiliates reporting, respectively, positive horizontal and positive export sales.

On average, horizontal sales account for about 80 percent of affiliate sales at birth and decrease by ten percentage points over the first ten years of life of the affiliate, while the export share is flat at 40 percent. To capture the extensive margin of horizontal and export sales, Figure 2b plots the percentage of affiliates with non-zero horizontal sales and non-zero export sales, respectively. While the share of affiliates with horizontal sales is stable at more than 95 percent, the share of exporting affiliates increases from 50 to 70 percent during the affiliates' life cycle. In other words, for horizontal activities, changes in sales shares are due to the intensive margin, while export shares increase only because of pure type horizontal affiliates that start exporting. Hence, the data suggest that, over time, affiliates incorporate export sales into their activities, but they never stop selling in their host market.

The patterns in Figure 2 are confirmed by OLS regressions that include a battery of fixed effects, as shown in Appendix Table B.2. Estimates that include affiliate fixed effects suggest that, on average, horizontal (export) sales shares decrease (increase) during the life of an affiliate, and the share of affiliates with exports is higher among older affiliates.

For robustness, Appendix B reports analogous figures and regression tables for the subset of affiliates that are pure-type at birth—i.e., firms that in their first year of life either sell exclusively to the host market or only export. The results on pure-type affiliates reinforce the patterns in Figure 2: pure-type affiliates diversify their activities over the life cycle, moving from exclusively horizontal affiliates to export activities at some point in their life. Relatedly, Appendix Figure C.3 shows a more general relation between the intensity at which an activity is performed and the time at which the affiliate first starts such activity: the older the affiliate is when it starts a new activity (e.g., export sales), the lower the intensity at which that activity is performed.

The fact documented in Figure 2 motivates an important assumption of our model: all affiliates start foreign operations with some horizontal sales and endogenously they may expand into export markets. Standard iceberg trade costs imply that exports, the activities that most affiliates start later in life, are performed at lower intensity.

2.4 MNE affiliates' entry and (the lack of) extended gravity

We now present facts related to the sequencing of location decisions of the MNE. In particular, we document the lack of extended gravity—i.e., the order in which MNEs open affiliates is not necessarily related to standard "gravity" variables.[9] Table 3 shows that, for a given US parent, the unconditional probability of opening an affiliate in a country is very similar to the probability of opening an affiliate conditional on already having an affiliate in a "similar" country. Following Morales et al. (2015), we define "similarity" in a variety of ways: similar countries may be ones that are located in the same continent, share a border, share a language, have similar income per

[9] Egger et al. (2014) study the sequential opening of MNE affiliates using German data. They present evidence showing that, for example, affiliates second in the opening sequence of the MNE are closer to affiliates that are first in the sequence.

Table 3: Unconditional and conditional probability of affiliates' opening.

	Unconditional	Continent	Border	Language	Income	All
	(1)	(2)	(3)	(4)	(5)	(6)
Canada	0.021	***0.021***	–	0.023	***0.021***	–
		(0.525)	–	(0.000)	(0.553)	–
United Kingdom	0.025	0.027	***0.030***	***0.026***	0.026	***0.030***
		(0.000)	(0.143)	(0.292)	(0.008)	(0.143)
Germany	0.023	0.026	0.029	0.028	0.024	0.028
		(0.000)	(0.000)	(0.010)	(0.000)	(0.010)
Ireland	0.010	0.010	0.011	0.010	0.010	0.011
		(0.001)	(0.010)	(0.000)	(0.005)	(0.011)
China	0.027	0.037	0.050	0.048	0.051	0.057
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
France	0.021	0.024	0.028	0.023	0.022	0.029
		(0.000)	(0.000)	(0.018)	(0.000)	(0.000)
Brazil	0.016	0.022	0.027	***0.025***	0.023	***0.019***
		(0.000)	(0.000)	(0.063)	(0.000)	(0.614)
Singapore	0.016	0.023	0.044	0.017	***0.016***	0.045
		(0.000)	(0.000)	(0.000)	(0.300)	(0.000)
Mexico	0.024	0.029	***0.028***	0.034	0.031	***0.024***
		(0.000)	(0.620)	(0.000)	(0.000)	(0.961)
Japan	0.016	0.021	–	–	***0.016***	–
		(0.000)	(0.000)	(0.000)	(0.224)	(0.000)

Note: Probabilities of opening affiliates in the top-ten most popular destinations. Conditional probabilities refer to the probability of observing a MNE opening an affiliate in country i given that the parent already has an affiliate in a "similar" country. Column 6 refers to similarity in all the dimensions in columns 2-5. The sample is restricted to parents with at least two affiliates worldwide. P-values from tests of equality of the conditional and unconditional probabilities are in parentheses. Conditional probabilities in ***bold*** are not significantly different from the relevant unconditional probability.

capita, or all of the above.[10] Of course, this comparison is only possible for US parents with at least two foreign affiliates. Host countries are restricted to the ten most popular location choices for US MNE affiliates, which cover about 60% of all sales by majority-owned affiliates of US firms.

The table shows that conditional and unconditional probabilities are strikingly similar. The largest differences are observed for countries such as China that are typically part of global supply chains. Differences become even smaller if we restrict the sample to MNEs with more than five, or more than ten, affiliates (see Appendix Table B.4).

[10] We use the World Bank classification and divide countries into four groups according to their GDP per capita. We refer to two countries belonging to the same income group as similar in terms of income per capita.

Extended gravity is much less pronounced for MNEs opening affiliates than for domestic firms entering export destinations. Morales et al. (2015) find that the probability of exporting to a given country is 12.7, 5.3, 3, and 2.9 *times* higher if the firm already exports, respectively, to an adjacent country, to a country in the same continent, to a country where the same language is spoken, and to a similar country in terms of per capita income. In contrast, we find that the probability to opening an affiliate in the United Kingdom, for example, is 17.5, 8.7, 2.8, and 2.4 *percent* higher if the firm already has an affiliate, respectively, in an adjacent country, a country in the same continent, a country that speaks the same language, and a country in the same income group. The lack of extended gravity that we observe in the data motivates a key assumption of our model: the choice of whether to open an affiliate in a country is independent of the location of pre-existing affiliates.

The evidence reported in Table 3 sheds light on the dynamics of affiliate entry. At the affiliate export level, we report suggestive evidence that an affiliate's decision to export to a country is independent on whether its parent already has an affiliate in that country. With the BEA data, we are able to examine the coexistence of affiliates' exports to three countries (Canada, the United Kingdom, and Japan) with the presence of affiliates owned by the same parents in those countries, for the benchmark year 2004. Of the 20,359 affiliates that export to Canada, 64 percent belong to a US parent that also has affiliates located in Canada. Similarly, of the 5,017 affiliates that export to the United Kingdom, 70 percent belong to a US parent that also has affiliates located in that country. Finally, of the 5,224 affiliates that export to Japan, 47 percent belong to a US parent that also has affiliates located in Japan. This finding motivates an independence assumption at the export level: we assume that an affiliate choice of whether to export to a country is independent across countries. We also assume that products are origin-location-destination specific, so that the choice of an affiliate export destination is independent on the location of other affiliates of the same parent, and there is no cannibalization of sales when a MNE enters a country directly by opening an affiliate *and* by exporting there.

3 A Quantitative Model of MNE Expansion

We build a quantitative dynamic model where MNEs open affiliates across countries over time, and affiliates sell in their host markets and also choose which markets to serve from there (export platforms), if any. We impose assumptions that are guided by the facts documented in Section 2 and are key for the tractability of the model.[11]

[11] Similarly to Tintelnot (2017), our model does not feature the proximity-concentration tradeoff whereby exports and FDI *in the same good* are alternative ways of serving a given foreign market, as in Helpman et al. (2004). Our

The static components of our model are standard and follow Melitz (2003). As a result, the model has stark predictions—that we contrast with the data—regarding the selection patterns of MNE affiliates within a host market, and of MNEs across host markets. Embedding the Melitz-type components into a dynamic setup further allows us to relate such selection patterns to the life cycle of firms.

We introduce the model with a compound option formulation that allows us to capture the richness of the dynamic decisions of the MNE. This formulation is novel to the international trade literature, and it is the key element that makes the model amenable to quantitative analysis. We then present a special case of our model which has the advantage of being solvable entirely in closed form, to illustrate its predictions via a simple comparative statics analysis.

3.1 Preferences and technology

The economy is composed by $N+1$ countries: the Home country (the United States in our data) and N foreign countries. Time is continuous. In each country k, consumers have preferences over a composite good,

$$U_k = \int_0^\infty e^{-\rho t} Q_k(t) dt, \tag{3}$$

with ρ denoting the subjective time discount rate. $Q_k(t)$ aggregates a continuum of varieties, indexed by v, with constant elasticity of substitution (CES), $\eta > 1$,

$$Q_k(t) \quad = \quad \left[\sum_i \sum_j \int_{\Omega_{ijk}(t)} q_{ijk}(v,t)^{\frac{\eta-1}{\eta}} dv \right]^{\frac{\eta}{\eta-1}}, \tag{4}$$

where $q_{ijk}(v,t)$ denotes consumption of variety $v \in \Omega_{ijk}(t)$, and $\Omega_{ijk}(t)$ denotes the set of varieties sold to country k and produced by affiliates located in j belonging to firms from i, at time t.

Assumption 1. *Varieties consumed and produced are origin-location-destination-specific.*

Because of Assumption 1, consumers perceive differently varieties produced in different locations by the same firm. For example, consumers in a given destination perceive differently Möet Chandon champagne produced in France and Chandon sparkling wine produced by the same firm in California.

Each country is populated by a continuum of firms. The Home country is the source of MNEs: Home firms decide whether to operate only in their home market or to establish affiliates abroad.

choice is also driven by a data limitation: the BEA surveys do not distinguish parent (arm's length) exports by destination market.

For simplicity (and lack of correspondent MNE data) we assume that firms from the other countries sell only domestically. In the following, since we focus our attention on the decision problem of Home firms, we remove the i index (denoting a variety's origin country) from the analysis.

Labor is the only factor of production. Each firm produces with a linear technology and operates under monopolistic competition. As in Melitz (2003), each firm is characterized by a productivity parameter φ that determines the unit labor cost of the goods it produces. Each firm sets prices to maximize profits from sales to each destination, $p_{jk}(\varphi) = \widetilde{\eta} c_{jk}(\varphi)$, with $\widetilde{\eta} \equiv \eta/(\eta-1)$, $c_{jk}(\varphi) \equiv w_j \tau_{jk}/\varphi$, w_j denotes the wage in the country j where production takes place, and τ_{jk} denotes the iceberg trade cost to ship goods from production location j to destination k, with $\tau_{jk} > 1$, $\forall j \neq k$, and $\tau_{jj} = 1$. This structure also imply that a firm domestic profits are given by: $\pi_d(\varphi) = H(w_d/\varphi)^{1-\eta} P_d^{\eta} Q_d$ and the variable profits from sales to k of an affiliate in j are given by: $\pi_{jk}(\varphi) = H(\tau_{jk} w_j/\varphi)^{1-\eta} P_k^{\eta} Q_k$, where $H \equiv \eta^{-\eta}(\eta-1)^{\eta-1}$ and P_j denotes the price index in country j. These correspond to profits from horizontal sales for $j = k$, and profits from affiliate export sales otherwise.

When a firm establishes an affiliate in a foreign country j, it has to pay a sunk entry cost, $F_j^h > 0$. The affiliate starts by selling locally (horizontal sales), incurring a per-period fixed cost, $f_j^h > 0$. Once the affiliate is in place, it can expand its operations to sell in other markets (export sales). An affiliate located in country j has to pay a sunk entry cost $F_{jk}^e > 0$ to start exporting to country k, and a per-period fixed export cost $f_{jk}^e > 0$. For simplicity, we assume that there are no per-period fixed costs associated with domestic production, so that all firms produce in their Home market.

3.2 The MNE dynamic problem: the compound option

We now present the MNE dynamic problem. At each point in time, a firm endogenously decides whether to open an affiliate in each host market, and whether and where to export from its existing affiliates, including back to the Home market. A firm may also decide to shut down affiliates or to exit any of its affiliate export markets.[12]

We use the notion of a *compound option* to model the dynamic problem of the MNE. The decision to open an affiliate in country j depends on the set of countries where the affiliate can export to. Opening an affiliate in a country is an option that, when exercised, gives access to another set of options, the possibility to expand to each export destination. The compound option structure allows us to easily solve backwards the firm's problem, as suggested by Dixit and Pindyck (1994,

[12] Appendix Table B.6 shows, empirically, that exit rates are not random: they decline with affiliate age and size, but are independent of whether the affiliate exports or not. Quantitatively, modeling exit as endogenous allows us to separately identify sunk entry costs from per-period fixed costs.

chap. 10). Conditional on the MNE having an affiliate in country j, one can solve for the value of exports to each destination, and determine the thresholds that induce the affiliate to export, or stop exporting, to each country $k \neq j$. Once the value of an affiliate in country j has been determined, one can solve for the thresholds that induce the firm to open, or shut down, that affiliate. Quantitatively, this formulation allows us to separately identify sunk and fixed costs of affiliate opening and of exporting from the affiliate to the United States (Home) and to each of the other destination markets.

The two assumptions we present next, together with the compound-option formulation, make the model tractable and allow us to make headway toward a rich quantitative analysis. Both assumptions are guided by the empirical observations in Section 2.

Assumption 2. *The decision to open an affiliate in a country and export from there is independent from the decision to open affiliates in any other countries.*

This assumption is equivalent to imposing that the profits of an affiliate in a country's are independent on the number of affiliates that the firm has. Together with Assumption 1, it implies that the same firm can serve a market through affiliates operating there and through exports from affiliates located elsewhere.[13]

Assumption 3. *A firm needs to first establish an affiliate with horizontal sales before it eventually starts to export.*

The separation in time of the decisions to enter a market and export from it is a mere artifact to gain tractability: because the model is specified in continuous time, opening an affiliate and exporting from it can happen almost simultaneously, allowing for affiliates to export from birth.

Shock structure. Following Ghironi and Melitz (2005), we define the firm-level productivity φ to be the product of a constant firm-specific component, z, and of a stochastic Home country-specific component, Z $\varphi \equiv z \cdot Z$. The term z is a firm-specific draw from a distribution $G(z)$ which is constant over time, as in Melitz (2003). As in Impullitti et al. (2013), we assume that $Z = e^X$, where X is a Brownian motion with drift,

$$dX = \mu dt + \sigma dW, \tag{5}$$

for $\mu \in \Re$ and $\sigma > 0$, and dW denoting a standard Wiener process. This specification is equivalent to assuming that aggregate Home productivity behaves like a random walk, and that productivity

[13] Note that this assumption is different from the assumptions in Tintelnot (2017) and Arkolakis et al. (2018) where each firm only uses the lowest cost production location to reach final consumers in a country, for each good.

growth is independently and identically distributed. This is a convenient functional form assumption, which guarantees tractability to the model. We assume that when a firm operates an affiliate in a foreign country, it transfers both the aggregate and the idiosyncratic components of the productivity shock to the host market, so that MNEs operations contribute to the transmission of productivity shocks across countries, in the spirit of Cravino and Levchenko (2017).

Besides the domestic aggregate productivity shock X, we assume that aggregate demand in destination country k evolves according to a geometric Brownian motion,

$$dQ_k = \mu_k Q_k dt + \sigma_k Q_k dW_k, \tag{6}$$

where $\mu_k \in \Re$, $\sigma_k > 0$, and dW_k denotes a standard Wiener process, possibly correlated with the Home aggregate productivity shock. We denote with γ_k the correlation between e^X and Q_k. Affiliate profits from sales to country k are linear in the term $e^{(\eta-1)X}Q_k$. Thus, it is convenient to define the "composite" shock $Y_k \equiv e^{(\eta-1)X}Q_k$, which captures the effect of both source- and destination-country aggregate shocks on affiliates' profits. The shock Y_k is also a geometric Brownian motion with drift $\tilde{\mu}_k$ and variance $\tilde{\sigma}_k^2$,

$$\tilde{\mu}_k = \mu_k + \mu(\eta - 1) + \frac{\sigma^2}{2}(\eta - 1)^2 + \gamma_k \sigma_k \sigma, \tag{7}$$

$$\tilde{\sigma}_k^2 = \sigma_k^2 + \sigma^2(\eta - 1)^2 + 2\gamma_k(\eta - 1)\sigma\sigma_k. \tag{8}$$

We show below that the model can be then solved in terms of realizations of the composite shock. Together with the independence assumption, this shock structure ensures that only Home- and destination-country shocks are important for the (dynamic) decision of a firm to serve a market.

We introduce host-country demand shocks to match affiliate growth in different host countries. This shock structure is also supported by the data: Appendix Table B.5 shows that most of the variation in MNE affiliates' sales is explained by aggregate, rather than parent- and affiliate-level, time-varying shocks.[14]

Bellman equations. The state of the economy is described by the $(N + 1)$-tuple $(X, \mathbf{Q})$, where $\mathbf{Q} = [Q_1, \ldots, Q_N]$. Let $\mathcal{V}(z, X, \mathbf{Q})$ denote the expected net present value of a Home country firm with productivity z that follows an optimal policy when the state of the economy is $(X, \mathbf{Q})$. Thanks

[14] Our shock structure shares with Cravino and Levchenko (2017) the fact that both home-country and host-country specific shocks affect affiliate sales. Source-country productivity shocks get transferred to the host country, while host country shocks affect affiliate operations through aggregate demand.

to the independence assumption, we can write such value as

$$\mathcal{V}(z, X, \mathbf{Q}) = V_d(z, X) + \sum_{j=1}^{N} \max \left\{ V_j^o(z, X, \mathbf{Q}), V_j^a(z, X, \mathbf{Q}) \right\}. \tag{9}$$

The function $V_d(z, X)$ is the value of domestic sales, $V_j^o(z, X, \mathbf{Q})$ is the option value of opening an affiliate in country j, and $V_j^a(z, X, \mathbf{Q})$ is the value of an affiliate in country j, regardless of the destination of its sales. In turn, the value of an affiliate in country j is given by

$$V_j^a(z, X, \mathbf{Q}) = V_j^h(z, X, \mathbf{Q}) + \sum_{k \neq j} \max \left\{ V_{jk}^o(z, X, \mathbf{Q}), V_{jk}^e(z, X, \mathbf{Q}) \right\}. \tag{10}$$

$V_j^h(z, X, \mathbf{Q})$ is the value of horizontal sales in country j, $V_{jk}^o(z, X, \mathbf{Q})$ is the option value of exporting to country k for an affiliate located in j, and $V_{jk}^e(z, X, \mathbf{Q})$ is the value of exports to country k for an affiliate located in j. The problem is thus formulated as a compound option because opening an affiliate in a country is equivalent to exercising an option that gives access to another set of options: the options to export to any other country.

Since all firms operate in the domestic market, the value of domestic operations is simply given by the evolution of domestic profits over time, and hence depends only on the domestic shock X. Over a generic time interval Δt,

$$V^d(z, X) = \frac{1}{1 + (\rho + \delta)\Delta t} \left[\pi_d(z, X)\Delta t + E[V^d(z, X')|X] \right], \tag{11}$$

where X' denotes the next period realization of the aggregate state.

If a domestic firm does not yet have an affiliate in country j, all the value from its potential operations in j is option value—i.e., the value of the possibility of entering j in the future,

$$V_j^o(z, X, \mathbf{Q}) = \max \left\{ \frac{1}{1 + (\rho + \delta)\Delta t} E[V_j^o(z, X', \mathbf{Q}')|(X, \mathbf{Q})]; V_j^a(z, X, \mathbf{Q}) - F_j^h \right\}. \tag{12}$$

This equation describes the fact that a firm may keep the option of entering market j, or may enter country j by opening a horizontal affiliate there, in which case it pays the entry cost F_j^h and gets the value of an affiliate in country j, $V_j^a(z, X, \mathbf{Q})$.

Since we assume that all affiliates sell in the market where they are located, the value of horizontal sales for an affiliate in country j is given by

$$V_j^h(z,X,\mathbf{Q}) = \max\left\{\frac{1}{1+(\rho+\delta)\Delta t}\left[(\pi_j^h(z,X,\mathbf{Q}) - f_j^h)\Delta t + E[V_j^h(z,X',\mathbf{Q}')|X,\mathbf{Q}]\right]; V_j^o(z,X,\mathbf{Q})\right\}. \tag{13}$$

This equation captures the fact that the affiliate may survive and make profits from horizontal sales in j, or may shut down, in which case the firm gets the value of the option of opening an affiliate in j, $V_j^o(z,X,\mathbf{Q})$.

As indicated in equation (10), the value of an affiliate is given by the value of its horizontal sales plus the value of its export sales. The Bellman equation describing the value of the option to export to country k for a firm with an affiliate in country j is given by

$$V_{jk}^o(z,X,\mathbf{Q}) = \max\left\{\frac{1}{1+(\rho+\delta)\Delta t}E[V_{jk}^o(z,X',\mathbf{Q}')|(X,\mathbf{Q})]; V_{jk}^e(z,X,\mathbf{Q}) - F_{jk}^e\right\}. \tag{14}$$

This equation captures the fact that the affiliate may keep the option of exporting to country k—and get the continuation value of that option—or may start exporting to country k, in which case it pays the entry cost F_{jk}^e and gets the value of exporting to k from j, $V_{jk}^e(z,X,\mathbf{Q})$, which in turn is given by

$$V_{jk}^e(z,X,\mathbf{Q}) = \max\left\{\frac{1}{1+(\rho+\delta)\Delta t}\left[(\pi_{jk}^e(z,X,\mathbf{Q}) - f_{jk}^e)\Delta t + E[V_{jk}^e(z,X',\mathbf{Q}')|(X,\mathbf{Q})]\right]; V_{jk}^o(z,X,\mathbf{Q})\right\}. \tag{15}$$

This expression captures the fact that the affiliate may keep exporting to country k—and get the continuation value of that option—or may stop exporting to country k, in which case it gets the value of the option of exporting to k from j, $V_{jk}^o(z,X,\mathbf{Q})$.

Value functions. The problem can be solved backwards by first solving for $V_{jk}^o(z,X,\mathbf{Q})$ and $V_{jk}^e(z,X,\mathbf{Q})$, conditional on the firm having an affiliate in country j. Once the location of the affiliate is determined, the only country j-specific variables in the firm problem are wages and iceberg costs, which are time invariant. For this reason, together with the independence assumption, the value functions only depend on the Home productivity shock and on the destination country k demand shocks. Because these shocks enter linearly the profit functions, we can replace them with the composite shock $Y_j \equiv e^{(\eta-1)X}Q_j$, with $\mathbf{Y} = [Y_1,\ldots,Y_N]$.

Solving for the value of exports conditional on affiliate location is a simple case of interlinked options (see Dixit and Pindyck 1994, ch. 7), with solution given by

$$V_{jk}^{o}(z,Y_k) = B_{jk}^{o}(z)Y_k^{\beta_k}, \tag{16}$$

$$V_{jk}^{e}(z,Y_k) = \frac{\pi_{jk}^{e}(z,Y_k)}{\rho+\delta-\tilde{\mu}_k} - \frac{f_{jk}^{e}}{\rho+\delta} + A_{jk}^{e}(z)Y_k^{\alpha_k}, \tag{17}$$

where $B_{jk}^{o}(z) > 0$ and $A_{jk}^{e}(z) > 0$ are firm-specific parameters, and $\alpha_k < 0$, $\beta_k > 1$ are the roots of $\tilde{\sigma}_k^2\xi^2/2 + \left(\tilde{\mu}_k - \tilde{\sigma}_k^2/2\right)\xi - (\rho+\delta) = 0$. $B_{jk}^{o}(z)e^{\beta X}$ represents the option value of exporting to country k and it is increasing in the realization of the aggregate Home productivity shock. Similarly, $A_{jk}^{e}(z)e^{\alpha X}$ is the option value of quitting export market k and it is decreasing in the realization of the aggregate Home productivity shock (i.e., the option of exiting an export market has a larger value in "bad times"). For each country pair (j,k) and for each firm with productivity z, the parameters $B_{jk}^{o}(z) > 0$, $A_{jk}^{e}(z) > 0$, and the aggregate productivity thresholds that induce the affiliate to start and stop exporting, denoted by Y_{jk}^{OE} and Y_{jk}^{EO}, respectively, can be recovered from the appropriate system of value-matching and smooth-pasting conditions.

Following a similar procedure, one can show that the value of horizontal sales, conditional on having an affiliate in country j, is given by the present discounted value of profits from horizontal sales plus the option value of shutting down the affiliate,

$$V_j^h(z,Y_j) = \frac{\pi_j^h(z,Y_j)}{\rho+\delta-\tilde{\mu}_j} - \frac{f_j^h}{\rho+\delta} + A_j^h(z)Y_j^{\alpha_j}, \tag{18}$$

where $A_j^h(z) > 0$ is a firm-specific parameter.

As a result, the value of an affiliate in country j can be written as

$$\begin{aligned} V_j^a(z,\mathbf{Y}) = {} & A_j^h(z)Y_j^{\alpha_j} + \frac{\pi_j^h(z,Y_j)}{\rho+\delta-\tilde{\mu}_j} - \frac{f_j^h}{\rho+\delta} + ... \\ & \sum_{k\in\mathcal{A}_j(z)} \left[\frac{\pi_{jk}^{e}(z,Y_k)}{\rho+\delta-\tilde{\mu}_k} - \frac{f_{jk}^{e}}{\rho+\delta} + A_{jk}^{e}(z)Y_k^{\alpha_k}\right] + ... \\ & \sum_{k\notin\mathcal{A}_j(z)} \left[B_{jk}^{o}(z)Y_k^{\beta_k}\right], \end{aligned} \tag{19}$$

where $\mathcal{A}_j(z)$ is the subset of countries where an affiliate of firm z located in j exports to. The implications of the independence assumption are clearly captured by (19): the value of an affiliate does not depend on the sales, or on the value of the firm's affiliates in other countries; it does depend, however, on the set of potential export destinations from the affiliate's host country.

It remains to solve for the decision of a firm to set up an affiliate in country j. The option value of opening an affiliate in j is

$$V_j^o(z, Y_j) = B_j^o(z) Y_j^{\beta_j}. \tag{20}$$

Hence, for each host country j and for each firm with productivity z, the parameters $B_j^o(z) > 0$, $A_j^h(z) > 0$, and the aggregate productivity thresholds that induce the firm to open and shut down an affiliate, denoted by Y_j^{OH}, Y_j^{HO}, respectively, can be recovered from the appropriate system of value-matching and smooth-pasting conditions.

Lastly, the value of domestic sales is simply given by the present discounted value of profits from domestic sales,

$$V_d(z, X) = \frac{\pi_d(z, X)}{\rho + \delta - \hat{\mu}}. \tag{21}$$

Details about the solution of the dynamic problem of the firm are shown in Appendix D.

Industry Equilibrium. To close the model, we solve for an industry equilibrium in each country. This amounts to solve for the price index in each country, by keeping track of the evolution of the number of affiliates located in each host country j and serving each destination country k. This part of the model is standard and is illustrated in Appendix F.

By construction, the model captures the three facts presented in Section 2. First, the presence of aggregate country shocks with a common component (given by the assumption that the MNE transfers its productivity to its affiliates abroad) imply that a firm's domestic and foreign sales positively co-move (conditional on entry). Second, the specification of aggregate shocks as a unit root process drives persistence in the affiliate's type, as observed in the data. If aggregate productivity grows over time ($\mu \geq 0$), firms tend to expand internationally, giving rise to the life-cycle pattern that we document. Finally, the independence assumption is motivated by the observation that the decision of where to open an affiliate is barely affected by the location of previous affiliates.

3.3 The MNE dynamic problem: special case

We now present a special case of the dynamic problem of the MNE in which exit is exogenous, foreign demand is fixed, and we do not distinguish among the different export destinations of the affiliate, but we treat export sales as directed to an aggregate market. This special case admits closed-form solutions and sharp comparative static results that clearly illustrate the workings of the (full) model.

Bellman equations. The state of the economy is now simply given by the Home-country shock, X. Let $\mathcal{V}(z,X)$ denote the expected net present value of a Home country firm with productivity z that follows an optimal policy when the state of the economy is X. The value of the firm is given by the value of its domestic and foreign operations,

$$\mathcal{V}(z,X) = V_d(z,X) + \sum_{j=1}^{N} \max\left\{V_j^o(z,X), V_j^h(z,X), V_j^e(z,X)\right\}. \tag{22}$$

Indeed, this expression in different from the one in (9) since we remove the possibility of choosing individual export markets and hence we do not need a compound option. Similar to the full model, $V_j^o(z,X)$ denotes the option value of opening an affiliate in country j, and $V_j^h(z,X)$ and $V_j^e(z,X)$ denote, respectively, the value of an affiliate in country j that only serves its host market (horizontal), and the value of an affiliate in country j that also exports.

Since now exit is exogenous, the only decisions that a firm can take in a host country are whether or not to open an affiliate and whether or not to start exporting from an existing affiliate. These possibilities are reflected in the following Bellman equations.

If a domestic firm does not yet have an affiliate in country j, all the value from operations in j is an option value,

$$V_j^o(z,X) = \max\left\{\frac{1}{1+(\rho+\delta)\Delta t} E[V_j^o(z,X')|X]; V_j^h(z,X) - F_j^h\right\}. \tag{23}$$

A firm may keep the option of entering market j, or may enter that country by opening a horizontal affiliate there, in which case it pays the entry cost F_j^h and gets $V_j^h(z,X)$.

A firm that already has an affiliate in country j may decide to export from j, in which case the the Bellman equation is given by

$$V_j^h(z,X) = \max\left\{\frac{1}{1+(\rho+\delta)\Delta t}\left[(\pi_j^h(z,X) - f_j^h)\Delta t + E[V_j^h(z,X')|X]\right]; V_j^e(z,X) - F_j^e\right\}. \tag{24}$$

The affiliate makes profits from horizontal sales and gets the continuation value of those sales in the future, or can expand into export markets by paying the entry cost F_j^e.[15] The value of an affiliate that serves the host and other foreign markets is given by the expected value over time of

[15] Since we consider one aggregate export market, the fixed and sunk export costs do not depend on the destination of exports.

its profits from horizontal and export sales,

$$V_j^e(z,X) = \frac{1}{1+(\rho+\delta)\Delta t}\left[(\pi_j^h(z,X) - f_j^h + \pi_j^e(z,X) - f_j^e)\Delta t + E[V_j^e(z,X')|X]\right]. \tag{25}$$

Lastly, since all firms operate in the domestic market, the value of domestic operations is given by the evolution of domestic profits over time, as in (11).

Value functions. In this simpler case of the model we can fully solve for the value functions. Derivations are shown in Appendix E.

The value of domestic sales is given by the present discounted value of profits from domestic sales,

$$V^d(z,X) = \frac{\pi_d(z,X)}{\rho+\delta-\hat{\mu}}, \tag{26}$$

where $\hat{\mu} \equiv \mu(\eta-1) - \frac{1}{2}\sigma^2(\eta-1)^2$ is the drift of the stochastic process for the profit flow, and the discount rate $(\rho+\delta-\hat{\mu})$ takes into account the exogenous exit rate and the effect of the evolution of aggregate productivity on profits. The option value of opening an affiliate in country j is

$$V_j^o(z,X) = B_j^o(z)e^{\beta X}, \tag{27}$$

where $B_j^o(z) > 0$ is a firm-specific parameter, and $\beta > 1$ is the positive root of $\sigma^2\beta^2/2+\mu\beta-(\rho+\delta) = 0$. The value of an affiliate with only horizontal sales in country j is

$$V_j^h(z,X) = \frac{\pi_j^h(z,X)}{\rho+\delta-\hat{\mu}} - \frac{f_j^h}{\rho+\delta} + B_j^h(z)e^{\beta X}, \tag{28}$$

where $B_j^h(z) > 0$ is a firm-specific parameter. The value of a horizontal affiliate is given by the sum of discounted profits from sales in the host country plus the option value of expanding to export markets. Finally, the value of an affiliate located in country j who sells locally and also exports is given by the present discounted value of its profits,

$$V_j^e(z,X) = \frac{\pi_j^h(z,X) + \pi_j^e(z,X)}{\rho+\delta-\hat{\mu}} - \frac{f_j^h + f_j^e}{\rho+\delta}. \tag{29}$$

By imposing value-matching and smooth pasting conditions, for each firm and each host market, we can solve for the two firm-specific parameters $B_j^o(z)$, $B_j^h(z)$, and for the aggregate productivity thresholds to open an affiliate ($X_j^h(z)$) and to export from it ($X_j^e(z)$):[16]

$$X_j^h(z) = \frac{1}{\eta-1}\log\left[\left(\frac{\beta}{\beta-\eta+1}\right)\cdot\left(\frac{\rho+\delta-\hat{\mu}}{k_j^h(z)}\right)\cdot\left(\frac{f_j^h+(\rho+\delta)F_j^h}{\rho+\delta}\right)\right], \tag{30}$$

$$X_j^e(z) = \frac{1}{\eta-1}\log\left[\left(\frac{\beta}{\beta-\eta+1}\right)\cdot\left(\frac{\rho+\delta-\hat{\mu}}{k_j^e(z)}\right)\cdot\left(\frac{f_j^e+(\rho+\delta)F_j^e}{\rho+\delta}\right)\right]. \tag{31}$$

where $k_j^h(z)$ and $k_j^e(z)$ are firm-specific revenue terms.[17] Under the parameter restriction that $\beta > \eta - 1$, the threshold $X_j^h(z)$ ($X_j^e(z)$) is increasing in the fixed and sunk costs of opening (exporting from) the affiliate in country j. Both thresholds are decreasing in firm productivity z, indicating that more productive firms need smaller (positive) aggregate productivity shocks to start and expand affiliate operations compared to less productive firms.

3.4 Testable Implications and Additional Evidence.

For the special case of the model described above, we can derive sharp comparative statics results regarding the relation between firm-level productivity, host market characteristics, and both entry and exporting thresholds. There are two sets of implications: within a host market, across affiliates of different MNEs; and within an MNE, across host markets.

We make the following assumption to ensure that the productivity threshold to open a horizontal affiliate is lower than the productivity threshold to open an exporting affiliate, $X_j^h(z) < X_j^e(z)$, $\forall z$.

Assumption 4. $\frac{f_j^h+(\rho+\delta)F_j^h}{P_j^\eta Q_j} < \frac{(f_j^e+(\rho+\delta)F_j^e)\tau^{\eta-1}}{\sum_{k\neq j} P_k^\eta Q_k}$.

Under Assumption 4, exporting affiliates are on average more productive than horizontal affiliates and the model generates the following predictions.

First, given a host market j, more productive firms have lower affiliate entry and affiliate export thresholds: $\partial X_j^h(z)/\partial z \leq 0$ and $\partial X_j^e(z)/\partial z \leq 0$. Then: 1) affiliates that are exporters from birth have larger horizontal sales than affiliates born with exclusively horizontal sales; and 2) conditional on aggregate productivity increasing over time ($\mu \geq 0$), affiliates that start exporting later in life have lower horizontal sales than affiliates that start exporting earlier in their life cycle.[18] The

[16] We report the solution of the parameters $B_j^h(z)$ and $B_j^o(z)$ and the system of value matching and smooth pasting conditions in Appendix E.

[17] $k_j^h(z) \equiv H\left(w_j/z\right)^{1-\eta} P_j^\eta Q_j$, and $k_j^e(z) \equiv H\left(\tau_j w_j/z\right)^{1-\eta} \left(\sum_{k\neq j} P_k^\eta Q_k\right)$.

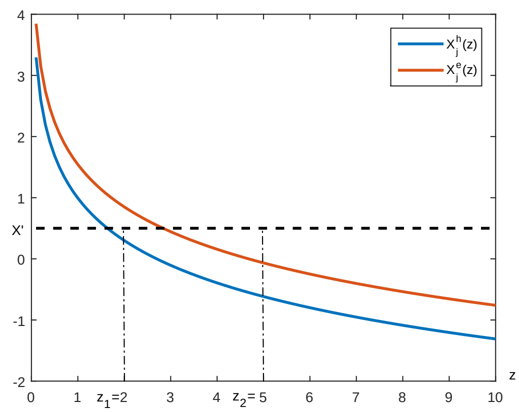
[18] These predictions hold both in the special case and in the full model as long as there are no idiosyncratic, time-varying firm-level or affiliate-level shocks. The fact that these predictions find support in the data is further evidence in support of the shock structure we impose into the model.

upper panels of Figure 3 illustrate these predictions. The red and blue lines denote, respectively, the threshold for opening an affiliate in j, $X_j^h(z)$, and the threshold for exporting from there, $X_j^e(z)$. They are a decreasing function of the firm's productivity z (and hence, invertible).

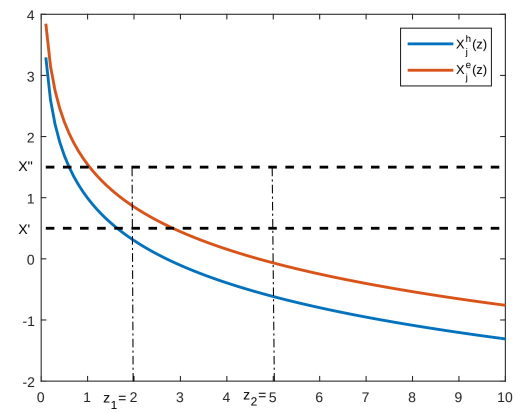
Figure 3: Model's predictions: special case.

Affiliate size, export status, and the timing of entry.

(a) Exporters vs non-exporters

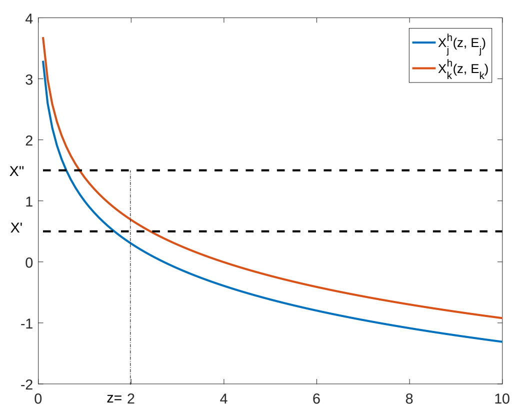


(b) Early vs late exporters

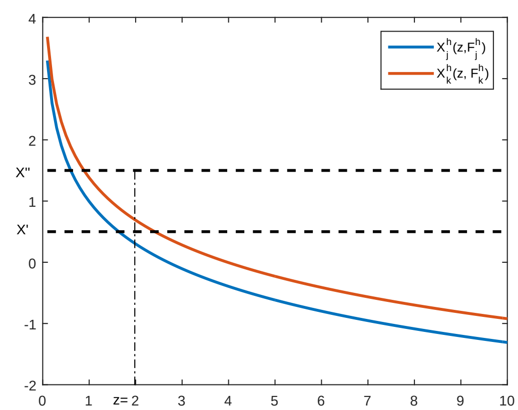


Host market characteristics and the timing of entry.

(c) Market size



(d) Entry costs



As Figure 3a indicates, suppose that the realization of the aggregate shock is X' and we observe two firms having affiliates in the same host country j. Firm 1 with productivity z_1 has an affiliate in j with only horizontal sales, while firm 2 with productivity z_2 has an affiliate in j that also exports, so that $z_2 \geq z_j^e(X') \geq z_1$. Since $z_2 \geq z_1$, the horizontal sales of the affiliate of firm 2 must be larger than the horizontal sales of the affiliate of firm 1. Now, suppose that aggregate productivity grows to $X'' > X'$. As illustrated in Figure 3b, $z_1 \geq z_j^e(X'')$ and firm 1 will start exporting from its foreign affiliate in j. Hence, within a host country, affiliates that export earlier in life are more productive and exhibit larger horizontal sales than late exporters.

Regarding the expansion strategies of a MNE across countries, the model predicts that: 1) since entry thresholds are decreasing in the size of the host market, $\partial X_j^h(z)/\partial Q_j \leq 0$, a MNE opens first affiliates located in larger countries, and subsequently, affiliates located in smaller countries; 2) a MNE opens first its largest affiliates and subsequently its smaller affiliates; and 3) since entry thresholds are increasing in entry costs, $\partial X_j^h(z)/\partial F_j^h \geq 0$, a MNE opens first affiliates in markets with lower entry costs. The lower panels of Figure 3 illustrates these predictions.

Figure 3c plots entry thresholds in two host countries of different size, $Q_k < Q_j$, so that $X_k^h(z, E_k) \geq X_j^h(z, E_j)$ (where $E_j \equiv P_j^\eta Q_j, \forall j$). Firm z only opens an affiliate in country j when the realization of the aggregate shock is X'. When aggregate productivity grows to $X'' > X'$, the firm can afford to open an affiliate also in country k. Since affiliate sales are positively correlated with host country size, the same figure also illustrates that, controlling for factor costs, a MNEs opens first its largest affiliates. Figure 3d plots entry thresholds in two host countries with different entry costs, $F_k^h > F_j^h$, so that $X_k^h(z, F_k^h) \geq X_j^h(z, F_j^h)$. Firm z opens an affiliate in country j when the realization of the aggregate shock is X'. When aggregate productivity grows to $X'' > X'$, the firm can afford to open an affiliate also in country k.

The model's predictions about affiliate size, export status, and timing of exports, as well as the predictions about the expansion patterns of a MNE across countries, hold both in the special case and in the full model. Moreover, these predictions can be contrasted with the data, and lend further support to our model's structure. First, Figure 4a shows strong support for the model's implication stating that affiliates that export from birth are on average larger than affiliates with no exports at birth. Second, Figure 4b shows that affiliates that start exporting earlier in life have larger sales directed to their host country than affiliates that start exporting later in life.[19] Third, the data show that the first affiliate of a MNE is systematically larger, in terms of horizontal sales, than subsequent affiliates (see column 1 in Table 4). And fourth, on average, the first affiliates of a MNE are located in larger and easier-to-access host markets compared to subsequent affiliates (see columns 2-4 in Table 4).[20]

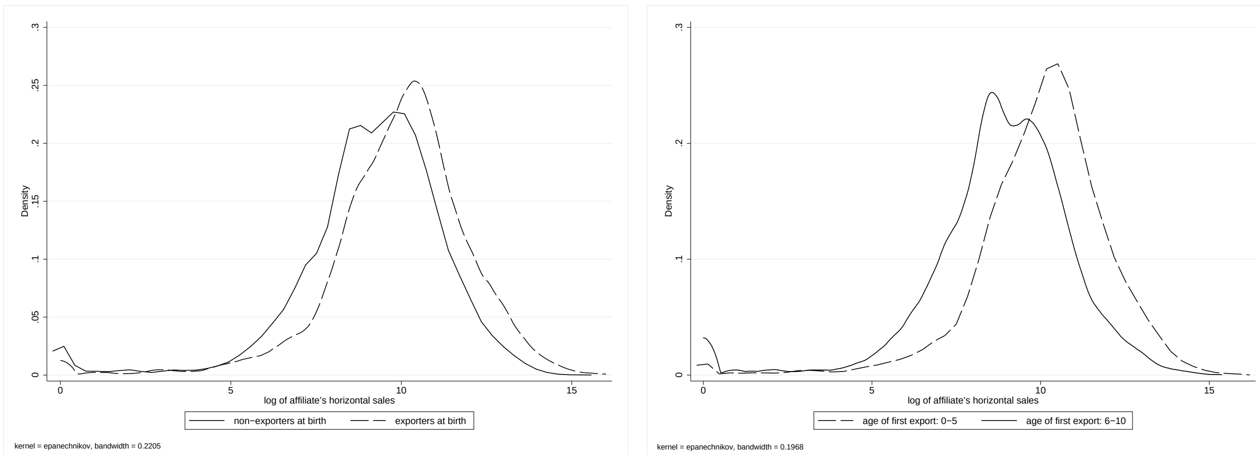
[19] In Figure 4b, start exporting "earlier in life" is defined as before age five. The pattern is robust to the choice of this age cutoff as well as to a battery of fixed effects and other controls (not shown).

[20] Appendix Table B.7 provides additional summary statistics.

Figure 4: Affiliate size, export status, and the timing of export entry.

(a) Exporters vs non-exporters

(b) Early vs late exporters



Notes: Sample of new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. Kernel density of log horizontal sales for affiliates that: are born with exclusively horizontal sales (non-exporters) and those with exports (exporters), in (4a); start exporting in their first five years of life and those that start after five years of life, in (4b).

Table 4: Affiliate size, host market characteristics, and the expansion pattern of a MNE, OLS.

Dep var	probability of being the first affiliate of a MNE			
	(1)	(2)	(3)	(4)
Log of horizontal sales	0.013***	0.012***	0.012***	0.011***
	(0.003)	(0.003)	(0.003)	(0.003)
Host country GDP	0.011*	0.013**	0.008	0.014**
	(0.006)	(0.006)	(0.006)	(0.006)
Number of business procedures		-0.006***		-0.008***
		(0.001)		(0.002)
Cost of starting business			-0.006***	-0.0004*
(% of GDP p.c.)			(0.0002)	(0.0002)
Obs	36,127	36,127	36,127	36,127
R-squared	0.291	0.295	0.293	0.297

Note: Observations at the affiliate-year level, for new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. The variables "Number of business procedures" and "Cost of starting business" are from the World Bank's Doing Business dataset. Host country GDP is from Penn World Tables (9.0). All specifications include year fixed effects and parent fixed effects. Standard errors, clustered at the parent level, are in parenthesis. Levels of significance are denoted $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$.

While the evidence provided in Section 2 guided us in choosing the model's dynamic structure, this additional evidence supports our modeling of the cross-section of MNE affiliates along the lines of a Melitz model. Next, we proceed to calibrate the full version of the model to match static and dynamic moments of MNEs expansion in space.

4 Quantitative Analysis

We calibrate the model to match the expansion of US MNEs during the period 1987-2011 in the top-ten host countries for US FDI: Brazil, Canada, China, France, United Kingdom, Germany, Ireland, Japan, Mexico, and Singapore. We choose the values of preference and technology parameters using estimates from the literature and direct observations from the data. Then, we jointly calibrate the rich set of barriers to MNE expansion included in the model to match static and dynamic moments from the BEA data.

4.1 Calibration Procedure

We set the elasticity of substitution $\eta = 5$, in line with estimates in the literature (see Broda and Weinstein, 2006). We set the exogenous death rate to $\delta = 0.05$ and the time preference rate to $\rho = 0.05$ so that we do not violate the technical condition $\rho + \delta > \tilde{\mu}_j$, $\forall j$, which ensures that the present discounted value of profits in market j does not diverge. We assume that the distribution of firm productivities is Pareto, with location parameter normalized to $b = 1$ and shape parameter $\vartheta = 4.5$, consistent with estimates in the literature (see Simonovska and Waugh, 2014).

We use data on real (expenditure-based) GDP growth across countries, from the Penn World Tables (9.0), to calibrate the composite shock process, for each country in our sample. The composite shock Y_j captures the effect on profits of both US aggregate productivity and aggregate demand in the destination country j. We set the drift of the process, $\tilde{\mu}_j$, to match the growth rate of real GDP in country j. Matching $\tilde{\sigma}_j$ to the standard deviation of real GDP growth, however, would generate too little volatility to induce reasonable firm dynamics. For this reason, we first set σ to match the standard deviation of labor productivity among US firms, and σ_j and γ_j to match, respectively, country j's standard deviation of real GDP growth and correlation with US GDP growth. We then use (8) to recover values for $\tilde{\sigma}_j$. Finally, we take wages as exogenous and calculate them as real GDP per unit of equipped labor from Klenow and Rodríguez-Clare (2005), an average over the period 1995-2000. Appendix Table G.1 reports the results of this procedure for each of the top ten host countries.

It remains to initialize the shock process–i.e., to choose values for $Q_j(0)$, for$j = 1, ...10$–, and to calibrate the parameters related to the costs of MNE expansion: the fixed and sunk costs of affiliate opening, f_j^h and F_j^h, for $j = 1, ...10$, respectively; the fixed and sunk costs of affiliate exports, f_{jk}^e and F_{jk}^e, for $j = 1, ...10$, $k \neq j$, and $k = US$, respectively; and the iceberg costs of affiliate exports, τ_{jk}, for $j = 1, ...10$, $k \neq j$, and $k = US$. Due to data limitations, however, we need to make some symmetry assumptions.[21] First, we assume that the fixed and sunk costs of affiliate exports are symmetric across all destination countries, other than the United States: $f_{jk}^e = f_j^e$ and $F_{jk}^e = F_j^e$, for $j = 1, ...10$ and $k \neq j, US$. Second, we assume that iceberg trade costs for destinations for which we do not have any bilateral affiliate export data are proportional to bilateral distance and to an exporter-specific dummy which is chosen to exactly match the aggregate export share from country j to the destinations for which we do not have any micro data.[22]

We are left with 116 parameters to calibrate for which we choose the values that jointly fit best the data moments listed in Table 5 (an average across years in our sample period). For this exercise, we simulate 1000 firms for 30 years.

4.2 Results: The Frictions to Multinational Activity

Table 5 illustrates the average fit of the model by reporting averages across the top ten host countries of both model and data moments. Our procedure has the goal of matching the moments at the country level whenever possible: the full set of matched moments is reported in Appendix Tables G.4 - G.8, while the resulting calibrated frictions to the expansion of the MNE, by country, are reported in Appendix Tables G.2 and G.3.

The model does a good job at matching both static and dynamic targeted moments from the data, and we have a good understanding of which data moments help identify which model parameters. More precisely, the intensive margin export shares drive the identification of the iceberg costs τ_{jk}; affiliate entry rates and share of affiliates help identifying F_j^h, f_j^h, and similarly, export entry rates and share of exporting affiliates help identifying F_j^e, f_j^e.[23] Finally, horizontal affiliate sales as a share of parent sales help identifying the initialization of the demand shocks Q_j. Endogenous exit

[21] As mentioned in Section 2.1, the BEA data do not report affiliate exports by destination country, except for the United States and for a handful of countries (Canada, Japan, and the United Kingdom) only in benchmark-year surveys.

[22] The distance elasticity is calculated by running a standard gravity equation with two sets of fixed effects and assuming that the trade elasticity is 4.

[23] Entry rates, exit rates, and shares of affiliates are linearly dependent, hence they can only identify two moments per type of sales (horizontal and export, respectively). For this reason, exit rates appear as non-targeted moments in the calibration.

Table 5: Moments: model versus data, averages.

	data	model
Targeted Moments		
1. Static moments: extensive margin		
1.1 Share of MNEs with affiliates in j	0.287	0.282
1.2 Share of affiliates in j exporting to US	0.566	0.573
1.3 Share of affiliates in j exporting to third countries	0.650	0.652
2. Static moments: intensive margin		
2.1 Affiliate sales share to host country	0.026	0.026
2.2 Affiliate sales share to the US	0.140	0.139
2.3 Affiliate sales share to third countries	0.288	0.288
2.4 Affiliate sales share to Canada	0.015	0.013
2.5 Affiliate sales share to the U.K.	0.069	0.082
2.6 Affiliate sales share to Japan	0.033	0.028
3. Dynamic moments: Entry		
3.1 Share of MNEs opening affiliates in j	0.035	0.027
3.2 Share of affiliates in j that start exporting to the US	0.030	0.028
3.3 Share of affiliates in j that start exporting to third countries	0.031	0.027
Non-Targeted Moments		
4. Dynamic moments: Exit		
4.1 Share of MNEs shutting down affiliates in j	0.113	0.043
4.2 Share of affiliates in j that stop exporting to the US	0.025	0.017
4.3 Share of affiliates in j that stop exporting to third countries	0.027	0.007

Note: Averages across host countries and years. Data moments for Japan, Canada, and the United Kingdom are averages over benchmark-year surveys only. Shares' denominators are: in 1.1, the total number of MNEs; in 1.2 and 1.3, the total number of affiliates in j; in 2.1, US parent's sales; and in 2.2-2.6, total horizontal sales of affiliates in j; in 3.1, total number of MNEs in period before entry; in 3.2 (3.3), total number of affiliates in j in period before export entry into US (third countries); in 4.1, total number of affiliates in j in period before exit; and in 4.2 (4.3), the total number affiliate in j that export to the US (third countries) in the period before stopping the activity. Exit rates do not include the exogenous exit rate.

appears low when compared to the data, but total affiliate exit rates are of similar magnitude as in the data (0.113 versus 0.093) once we add the exogenous exit rate of 0.05.

The relative magnitudes of different fixed and sunk costs of affiliate opening and affiliate exports are instructive about the heterogeneity in the frictions to multinational production, both by country and by type of affiliate sales. In particular, we observe that for most host countries, opening affiliates is more costly than exporting from them: the calibrated F_j^h/F_j^e range from 0.28 for Singapore to extremely high numbers for Canada and Mexico. These numbers make sense if one thinks that favorable, "tax-heaven"-like policies attract investment in Singapore, while reaching affiliate export markets from there reasonably entails high transportation costs. Similarly, NAFTA basically reduces to zero the export costs from Canada and Mexico to their main export partners (which are likely within NAFTA itself) so affiliate opening costs are much higher than sunk affiliate export costs. For fixed costs, the calibrated f_j^h/f_j^e range from 1.43 for Ireland to 6.53 for Brazil, indicating that for all the top host countries, the fixed costs of affiliates' horizontal operations are higher than the fixed costs of affiliate exports.

The calibration also confirms that "vertical" sales of foreign affiliates back to the US are usually less costly than export sales to third countries. Again with the exception of Canada and Mexico, whose calibrated affiliate export costs are close to zero (presumably because of NAFTA), the ratio F_j^e/F_{US}^e ranges from 2.43 (Singapore) to 164 (France), indicating how the cost of starting a vertical affiliate export relationship is negligible compared to the cost of starting exporting to third countries. Relative fixed costs f_j^e/f_{US}^e exhibit less variation, ranging from 0.57 (China) to 1.97 (Germany).

Next, we evaluate the ability of the model to quantitatively replicate the life-cycle patterns observed in the first two facts presented in Section 2. Figures 5 and 6 replicate the facts illustrated in Section 2 with simulated data.

Figure 5 illustrates that in the calibrated model, like in the data, affiliate-to-parent sales ratio grow little if at all during the affiliate life-cycle. Figure 6a shows that the horizontal sale share of an affiliate declines during the affiliate life-cycle, while the export sale share is flat. Figure 6b shows that the decline in the horizontal sale share is due to more affiliates starting exporting during their life cycle, while no affiliate stops selling in the market where it is located.

Figure 5: Affiliate-to-parent sales ratio, intensive margin. Simulated data.

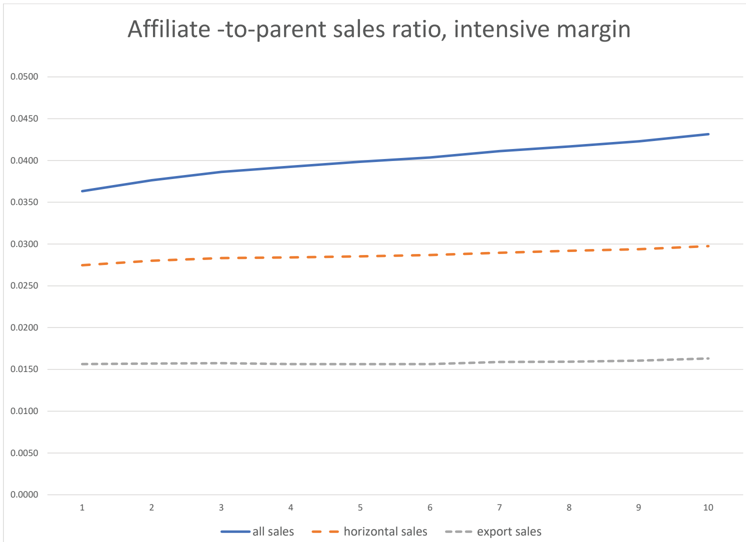
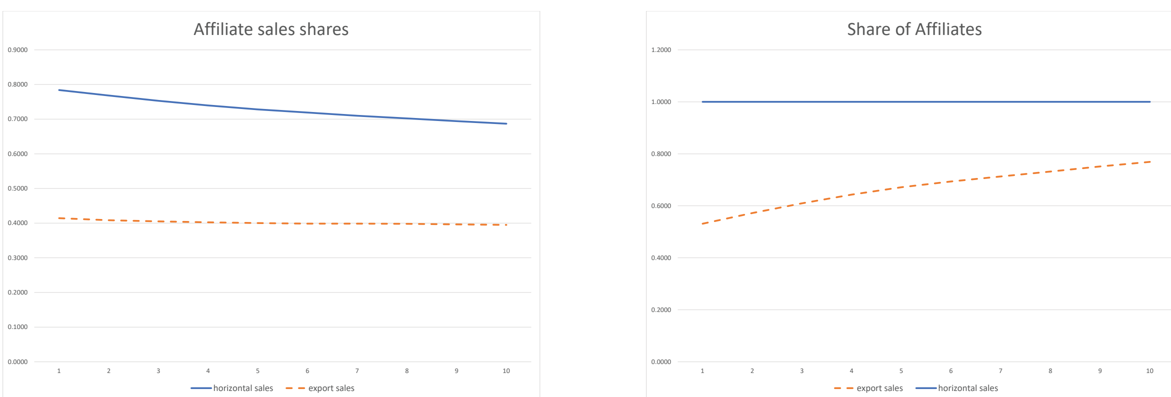


Figure 6: Intensive and extensive margins of sales, by activity type. Simulated data

(a) Affiliate sales shares (intensive margin)

(b) Share of affiliates (extensive margin)



4.3 Counterfactual Analysis

Armed with the quantitative model, we explore the implications of counterfactual scenarios on aggregate firm dynamics and on affiliates' life-cycle dynamics. Since the top ten host countries in our sample include the United Kingdom, Ireland, Germany, and France, it is natural to use, as a motivation for our counterfactual scenarios, the recent debate about the United Kingdom abandoning the European Union, "Brexit". Different proposed implementations of Brexit have the common qualitative effect of increasing export costs between the UK and other European countries. Quantitatively, in our model, this can be represented as an increase in the iceberg export cost, $\tau_{UK,j}$, and/or an increase in the fixed export cost, $f^e_{UK,j}$, and/or an increase in the sunk export cost, $F^e_{UK,j}$, for $j =$ France, Germany, Ireland. We can think about "shallow" Brexit scenarios, where only one type of friction is affected, or "deep" Brexit scenarios, where all the export barriers increase.

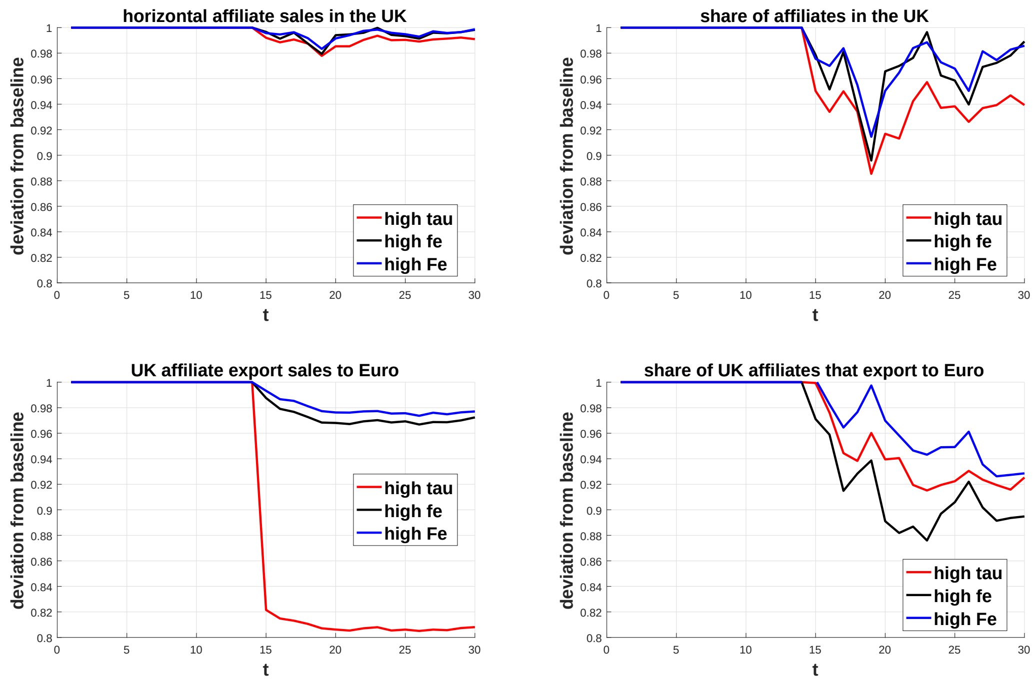
Intuitively, increasing trade barriers between the UK and other European countries has two main implications, which are qualitatively equivalent for any form of Brexit. First, exporting from the UK to other European countries is more costly, so that export platform sales from UK-based affiliates to other European countries decline, and there is less incentive to open affiliates in the UK because of the smaller/costlier available network of exporting destination. Second, exporting from other European countries to the UK is more costly, so that export platform sales from affiliates in other European countries to the UK decline, and there is less incentive to open affiliates in other European countries.

Shallow Brexit. We simulate our economy for 30 periods. At t=15, we impose a "Brexit shock" in the model, in the form of (alternative) increases in $\tau_{UK,j}$, $f^e_{UK,j}$, or $F^e_{UK,j}$, for $j =$ France, Germany, Ireland. In order to make the results of the three exercises comparable, we increase each friction of an amount such that the total per-period cost of FDI increases of 20%. This is the relevant exercise to illustrate the different impact that different frictions have on FDI flows. A static model, or a dynamic model without sunk costs, would generate exactly the same dynamics for these three exercises.

Figure 7 shows the results, computed as deviations from the baseline scenario. Higher trade costs between the UK and other European countries reduce the share of affiliates based in the UK: before the shock, about half of US MNEs had affiliates located in the UK. The shock causes about 2-5% of UK affiliates to shut down on impact (depending on the trade barriers that increase). Naturally, these are the smallest affiliates, and account for only a few percentages of UK affiliate sales. There are small quantitative differences in affiliate presence depending on which trade barrier is hit. One should interpret the effect of changes in in $f^e_{UK,j}$, $F^e_{UK,j}$, and $\tau_{UK,j}$ as second-order effects on horizontal activities, since none of these frictions affects horizontal activities directly, but only through the compound option components.

The lower left panel of the figure shows the export sales of UK-based affiliates of US firms to

Figure 7: Increases in export frictions between the UK and the EU: effect on UK affiliates.



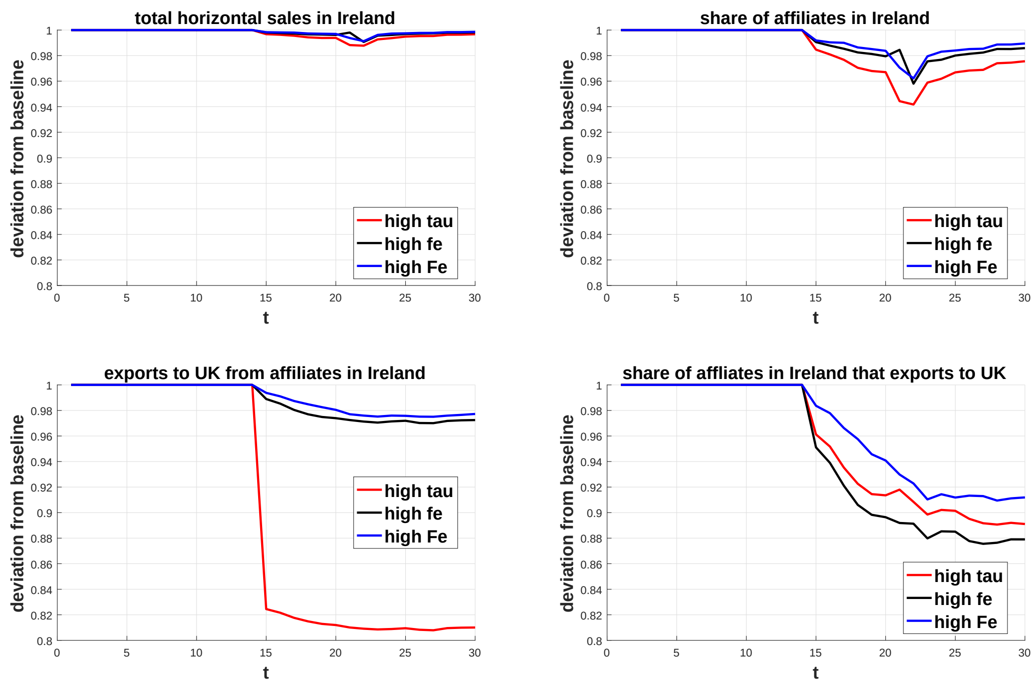
Ireland, Germany, and France. This plot nicely illustrates how different frictions to multinational production have different effects on affiliate sales, even if we set the changes in those frictions to be associated to equivalent increases in per-period costs. More precisely, the observed decline in sales comes from the extensive margin of affiliates stopping exporting for increases in $f^{e}_{UK,j}$ and $F^{e}_{UK,j}$, but incorporates also intensive margin declines for the scenario in which $\tau_{UK,j}$ increases. Consequently, the friction that has the highest impact on affiliate export sales is the per-period iceberg costs: increases in $\tau_{UK,j}$ drive a 20% decline in UK affiliates' export sales, much larger than what is driven by increases in fixed and sunk export costs.

The lower right panel of the figure shows the share of UK-based affiliates that export to France, Germany, and Ireland. As expected, the share of exporting affiliates declines after the shock. When looking at the extensive margin of affiliate exports, the fixed continuation cost of affiliate export drives the largest decline. This makes sense as fixed costs are intimately related to the decision of affiliates to exit.

It is worthy to notice that these results affect the operations of US firms, but no frictions between the US and the UK have changed. As such, they illustrate the need to fully understand the global structure of multinational firm to assess the consequences of proposed policy changes. In a simple model of trade and FDI across countries that doesn't take into account complex FDI strategies, one would be led to conclude that Brexit does not have any impact on the US economy.

The results for affiliates located in France, Germany, and Ireland are qualitatively similar. In the interest of space, we only show in Figure 8 the associated affiliate and sales dynamics for affiliates of US MNEs located in Ireland.

Figure 8: Increases in export frictions between the UK and the EU: effect on Irish affiliates.



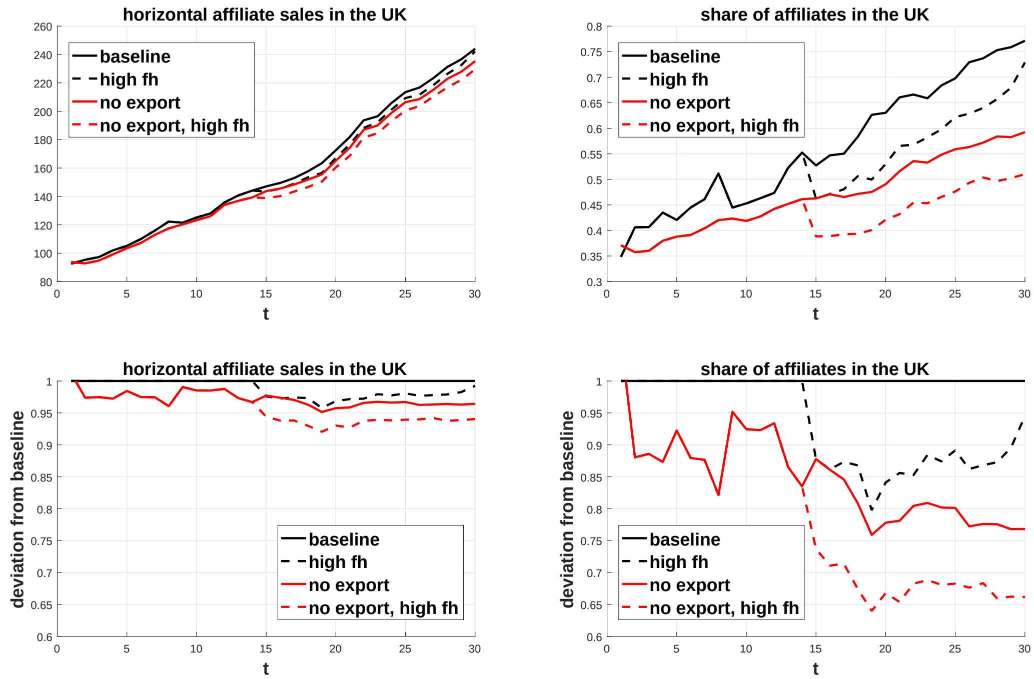
Deep Brexit.

SAME BUT CHANGING ALL BARRIERS AT ONCE - QUANTITATIVE COMPARISON

Increases in the Cost of Affiliate Opening. While most of the discussion about Brexit has revolved around restrictions to trade flows, it is useful to make the thought experiment and analyze the effects of an "extended" Brexit, possibly involving also increases in barriers to FDI. That would amount to increasing F^h_{UK}, f^h_{UK} in our model.

Figure 9 shows the results associated with a 20% increase in f^h_{UK} for horizontal affiliate sales and

Figure 9: Effects of an increase in the cost of operating affiliates: affiliate exports matter.



shares of affiliates in the UK. We show these results both in levels (upper panels) and as deviations from the baseline (lower panels). The black lines show the evolution of sales and affiliates in the baaseline scenario of the model (solid lines) and under a Brexit shock that lowers f^h_{UK} (dashed lines). The increase in the fixed cost of affiliate operations generates exit of about 5-10% of affiliates (depending on the time horizon) and a decrease in sales of about 5%.

We can also use this exercise to compare the predictions of our model with the predictions of standard models of horizontal FDI only. The red lines in Figure 9 represent the same experiment —an increase in f^h_{UK}— performed in a model where affiliates do not export, and the only motive for FDI is horizontal sales. In the "horizontal FDI only" model, MNEs don't have the incentive to open an affiliate in a country because of its possible export network, so the model generates lower affiliate presence and lower affiliate sales compared to the baseline. The "horizontal FDI only" model generates a similar pattern of affiliate exit following the Brexit shock, but re-entry over time is slower because of the "smaller" market that the MNEs considers when taking dynamic decisions of opening and shutting down affiliates.

Figure 9 alerts us about the importance of taking into account affiliate exports in quantitative analyses of the effects of trade policies.

5 Conclusions

TBA

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Appendix

A Data Description

Reporting thresholds. The BEA collects firm-level data on the operations of US multinational enterprises (MNEs) in its annual surveys of US direct investment abroad. All US-located firms that have at least one foreign affiliate and that meet a minimum size threshold are required by law to respond to these surveys. These minimum size thresholds are in terms of affiliate sales and differ over time. In general, reporting thresholds increased in recent years, reaching US$60 millions by 2011. Additionally, benchmark survey years (i.e., years in which the survey is more comprehensive), which occur every 5 years, have lower reporting thresholds. Table A.1 shows the reporting thresholds for the years in our sample.

Tax havens. Our sample contains affiliates that do not operate in tax haven countries. Affiliates in tax haven countries are likely to open for different reasons than production purposes, and to be subject to different cost structures than affiliates in non-tax haven countries. We exclude countries defined as tax havens by Gravelle (2015), except for some countries, such as Ireland, Switzerland, Hong Kong, and Singapore, that meet some of the criteria for tax haven status but also have a substantial amount of US MNE production. Table A.2 reports the list of countries that we exclude from our sample.

Industry classification. Each foreign affiliate is assigned an industry classification based on its primary activity according to the BEA International Surveys Industry (ISI) system, which closely follows the 3-digit Standard Industrial Classification (SIC) system. The BEA uses 3-digit SIC-based ISI codes for years prior to 1999. From 1999 onward, they use 4-digit NAICS-based ISI codes. For consistency, we convert the NAICS-based codes to 3-digit SIC-based ISI codes for the relevant years.

Unit of observation. According to the BEA definition, an affiliate is a business enterprise in a given industry operating in a particular host country; it thus can operate several plants in different locations within the host country. The BEA rules permit consolidated reporting for distinct plants located in the same country that operate in the same narrowly defined industry or otherwise are integral parts of the same business operation. We consolidate observations of enterprises belonging to the same parent company and operating in the same country and 3-digit industry. We group these enterprises' activities together and refer to them as a single affiliate.

Table A.1: BEA minimum survey exemptions levels.

survey year	Minimum exemption levels (in U$ millions)	survey year	Minimum exemption levels (in U$ millions)
1987-88	10	2000-03	30
1989	**3**	**2004**	**25**
1990 -93	15	2005-07	40
1994	**3**	2008	60
1995-98	20	**2009**	**25**
1999	**7**	2010-11	60

Note: Exemption levels are for majority-owned foreign affiliates. Benchmark survey years are highlighted.

Table A.2: Tax haven countries excluded from our sample.

Anguilla	Turks and Caicos	Monaco
Antigua and Barbuda	US Virgin Islands	San Marino
Aruba	Belize	Maldives
Bahamas	Costa Rica	Mauritius
Barbados	Panama	Seychelles
British Virgin Islands	Bermuda	Bahrain
Cayman Islands	Macau	Cook Islands
Dominica	Andorra	Marshall Islands
Grenada	Channel Islands	Samoa
Montserrat	Cyprus	Nauru
Netherlands Antilles	Gibraltar	Niue
St. Kitts and Nevis	Isle of Man	Tonga
St Lucia	Liechtenstein	Vanuatu
St Vincent and Grenadines	Malta	Liberia

Note: From Gravelle (2015).

B Additional Tables

Table B.1: Affiliate-to-parent sales ratio by sales type, robustness. OLS.

	Dep var: affiliate-to-parent sales ratio											
	First affiliate		Subsequent affiliate		Non-GVC affiliate		GVC affiliate		Greenfield affiliate		M&A affiliate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
D(age=2)	-0.0039	0.0011	0.0008	-0.0005	-0.0069	0.0248	0.0004	-0.0024				
	(0.0064)	(0.0052)	(0.0013)	(0.0010)	(0.0081)	(0.0191)	(0.0021)	(0.0019)				
D(age=3)	-0.0023	0.0015	0.0005	-0.0010	-0.0176	-0.0085	0.0022	-0.00004	0.0021	0.0015	0.0039	0.0007
	(0.0076)	(0.0051)	(0.0009)	(0.0008)	(0.0168)	(0.0176)	(0.0016)	(0.0016)	(0.0034)	(0.0023)	(0.0029)	(0.0035)
D(age=4)	-0.0017	0.0033	0.0012	-0.0001	-0.0189	-0.0213	0.0029**	0.0009	0.0057*	0.0041	0.0025	-0.0015
	(0.0076)	(0.0056)	(0.0009)	(0.0007)	(0.0176)	(0.0265)	(0.0014)	(0.0020)	(0.0029)	(0.0031)	(0.0031)	(0.0039)
D(age=5)	0.0019	0.0061	0.0018**	0.0002	0.0100	0.0416	0.0018	-0.0007	0.0047	0.0021	0.0023	-0.0026
	(0.0028)	(0.0041)	(0.0008)	(0.0008)	(0.0115)	(0.0373)	(0.0013)	(0.0014)	(0.0037)	(0.0030)	(0.0031)	(0.0037)
D(age=6)	0.0052	0.0096**	0.0021	0.0000	-0.0039	-0.0039	0.0044**	0.0023	0.0039	0.0022	0.0045	-0.0029
	(0.0045)	(0.0043)	(0.0013)	(0.0007)	(0.0068)	(0.0061)	(0.0020)	(0.0018)	(0.0035)	(0.0032)	(0.0029)	(0.0036)
D(age=7)	0.0007	0.0042	0.0021	-0.0001	-0.0026	0.0069	0.0022	0.0003	0.0019	-0.0005	0.0040	-0.0039
	(0.0036)	(0.0037)	(0.0013)	(0.0008)	(0.0049)	(0.0071)	(0.0015)	(0.0015)	(0.0026)	(0.0034)	(0.0024)	(0.0037)
D(age=8)	0.0002	0.0032	0.0022*	-0.0001	-0.0082	-0.0092	0.0029**	0.0005	0.0030	0.0008	0.0044*	-0.0025
	(0.0042)	(0.0037)	(0.0013)	(0.0008)	(0.0093)	(0.0114)	(0.0013)	(0.0014)	(0.0027)	(0.0027)	(0.0023)	(0.0034)
D(age=9)	0.0026	0.0052*	0.0026	0.0005	-0.0067	-0.0150	0.0041***	0.0018	0.0065	0.0041	0.0055***	-0.0010
	(0.0030)	(0.0031)	(0.0017)	(0.0011)	(0.0066)	(0.0166)	(0.0015)	(0.0016)	(0.0051)	(0.0034)	(0.0021)	(0.0033)
D(age=10)	0.0062	0.0108	0.0027	0.0006	0.0143	0.0504	0.0034**	0.0016	0.0060	0.0037	0.0053***	0.0001
	(0.0051)	(0.0069)	(0.0017)	(0.0016)	(0.0136)	(0.0476)	(0.0014)	(0.0015)	(0.0053)	(0.0039)	(0.0019)	(0.0033)
log global employment	-0.0881**	-0.1510***	-0.0207**	-0.0415***	-0.0913	-0.0656***	-0.0288***	-0.1028***	-0.0056	-0.0684***	-0.0242*	-0.1618***
	(0.0407)	(0.0240)	(0.0084)	(0.0041)	(0.0583)	(0.0157)	(0.0075)	(0.0125)	(0.0176)	(0.0176)	(0.0132)	(0.0451)
log affiliate employment	0.0824**	0.1295***	0.0197***	0.0328***	0.0624	0.0674**	0.0315***	0.0655***	0.0326**	0.0500***	0.0404***	0.1162***
	(0.0337)	(0.0192)	(0.0036)	(0.0032)	(0.0387)	(0.0273)	(0.0044)	(0.0060)	(0.0138)	(0.0125)	(0.0073)	(0.0217)
Observations	17,360	17,360	20,720	20,720	10,320	10,320	27,760	27,760	2,214	2,214	3,564	3,564
R^2 overall	0.034	0.053	0.085	0.182	0.0118	0.0280	0.0558	0.0761	0.0511	0.1900	0.0953	0.2273
Affiliate fe	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Industry fe	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Note: Observations at the affiliate-year level, for new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. The dependent variable *affiliate to parent sales* refers to affiliate sales relative to the domestic sales of the US parent. First affiliate refers to the first foreign affiliate opened by the parent, while subsequent affiliate refers to second or higher. GVC affiliate refers to affiliates with positive intra-firm trade, while non-GVC affiliate refers to affiliates with zero intra-firm trade. M&A affiliate refers to affiliates created through a merger or acquisition of an existing firm, while greenfield affiliate refers to a new firm. All specifications include country-year fixed effects. Standard errors, clustered at the parent level, are in parenthesis. Levels of significance are denoted $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$.

Table B.2: Intensive and extensive margins of sales. OLS.

Dep var	Intensive margin of sale shares				Extensive margin of sale shares			
	horizontal sales		export sales		horizontal sales		export sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
affiliate age	-0.002	-0.012***	-0.005**	0.005***	0.00003	-0.001	0.014***	0.029
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.0006)	(0.003)	(0.002)
country-year fe	yes	yes	yes	yes	yes	yes	yes	yes
industry fe	yes	no	yes	no	yes	no	yes	no
affiliate fe	no	yes	no	yes	no	yes	no	yes
Observations	36,135	36,135	25,958	25,958	38,080	38,080	38,080	38,080
R-square	0.079	0.013	0.092	0.000	0.042	0.0001	0.081	0.036

Note: Observations at the affiliate-year level, for new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. In columns (1)-(4), the dependent variable is horizontal (export) sales, as a share of total affiliate's sales, for affiliates with positive horizontal (export) sales; in columns (5)-(8), the dependent variable is the share of affiliates with positive horizontal (export) sales. Standard errors, clustered at the parent level, are in parenthesis. Levels of significance are denoted $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$.

Table B.3: Intensive and extensive margins of sales, pure-type affiliates at birth. OLS.

Dep var	Intensive margin of sale shares				Extensive margin of sale shares			
	horizontal sales		export sales		horizontal sales		export sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
affiliate age	-0.014***	-0.096***	-0.036**	-0.021***	-0.046***	-0.044***	-0.059***	-0.038***
	(0.001)	(0.001)	(0.004)	(0.003)	(0.004)	(0.002)	(0.005)	(0.004)
country-year fe	yes	yes	yes	yes	yes	yes	yes	yes
industry fe	yes	no	yes	no	yes	no	yes	no
affiliate fe	no	yes	no	yes	no	yes	no	yes
Observations	19,910	19,910	3,590	3,590	19,910	19,910	3,590	3,590
R-square	0.147	0.020	0.288	0.133	0.245	0.099	0.268	0.125

Note: Observations at the affiliate-year level, for new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. In columns (1)-(4), the dependent variable is horizontal (export) sales, as a share of total affiliate's sales, for affiliates born with only horizontal (export) sales; in columns (5)-(8), the dependent variable is the share of affiliates born with only horizontal (export) sales. Standard errors, clustered at the parent level, are in parenthesis. Levels of significance are denoted $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$.

Table B.4: Unconditional and conditional probability of affiliates' opening, robustness.

	Unconditional	Continent	Border	Language	Income	All
			Parents with at least five affiliates worldwide			
Canada	0.0252	***0.0258***	–	0.0258	***0.0250***	–
		(0.724)	–	(0.000)	(0.286)	–
United Kingdom	0.0300	***0.0302***	***0.0324***	***0.0301***	***0.0230***	***0.0324***
		(0.661)	(0.506)	(0.865)	(0.520)	(0.506)
Germany	0.0345	0.0353	***0.0353***	***0.0319***	0.0346	***0.0319***
		(0.000)	(0.284)	(0.210)	(0.000)	(0.210)
Ireland	0.0166	0.0169	***0.0174***	***0.0169***	0.0167	***0.0174***
		(0.025)	(0.311)	(0.163)	(0.000)	(0.311)
China	0.0451	0.0489	0.0568	0.0579	0.0581	0.0599
		(0.000)	(0.000)	(0.000)	(0.000)	(0.004)
France	0.0335	0.0341	0.0364	***0.0322***	0.0335	***0.0339***
		(0.000)	(0.000)	(0.263)	(0.000)	(0.758)
Brazil	0.0273	***0.0290***	***0.0294***	***0.0253***	0.0308	***0.0188***
		(0.212)	(0.413)	(0.674)	(0.001)	(0.091)
Singapore	0.0289	0.0322	0.0507	***0.0293***	0.0290	0.0508
		(0.000)	(0.000)	(0.061)	(0.000)	(0.000)
Mexico	0.0340	***0.0354***	***0.0313***	***0.0367***	***0.0361***	***0.0243***
		(0.351)	(0.739)	(0.121)	(0.107)	(0.247)
Japan	0.0269	0.0288	–	–	***0.0269***	–
		(0.007)	–	–	(0.598)	–
			Parents with at least ten affiliates worldwide			
Canada	0.0291	***0.0291***	–	0.0292	***0.0291***	–
		(0.964)	–	(0.017)	(0.286)	–
United Kingdom	0.0273	0.0275	***0.0264***	***0.0276***	***0.0273***	***0.0264***
		(0.000)	(0.810)	(0.218)	(0.610)	(0.809)
Germany	0.0354	0.0357	***0.0349***	0.0306	0.0354	0.0306
		(0.000)	(0.508)	(0.027)	(0.000)	(0.027)
Ireland	0.0224	***0.0224***	***0.0220***	0.0225	***0.0224***	***0.0220***
		(0.862)	(0.680)	(0.002)	(0.105)	(0.680)
China	0.0587	***0.0600***	***0.0616***	0.0661	***0.0598***	***0.0620***
		(0.069)	(0.382)	(0.007)	(0.687)	(0.515)
France	0.0395	***0.0396***	***0.0401***	***0.0376***	***0.0395***	***0.0382***
		(0.697)	(0.214)	(0.123)	(0.116)	(0.283)
Brazil	0.0321	***0.0299***	***0.0277***	0.0286	***0.0323***	0.0183
		(0.112)	(0.084)	(0.505)	(0.808)	(0.007)
Singapore	0.0432	***0.0439***	0.0564	***0.0431***	***0.0432***	0.0564
		(0.238)	(0.008)	(0.556)	(0.610)	(0.008)
Mexico	0.0423	***0.0412***	***0.0282***	***0.0393***	0.0388	0.0247
		(0.535)	(0.085)	(0.088)	(0.009)	(0.039)
Japan	0.0361	***0.0365***	–	–	***0.0361***	–
		(0.478)	–	–	(0.865)	–

Note: Probability of opening affiliates in the top-ten most popular destinations for US MNEs. Conditional probabilities refer to the probability of observing a MNE opening an affiliate in country i given that the parent already has an affiliate in a "similar" country. The sample is restricted to parents with at least five (ten) affiliates worldwide in the upper (lower) panel.

Table B.5: MNE shock structure, OLS.

Dep var	log of horizontal affiliate sales			
country-industry fixed effect	yes	yes	yes	yes
US GDP	yes	yes	yes	yes
Host country GDP	yes	yes	yes	yes
parent fixed effect	no	yes	yes	no
parent sales	no	no	yes	yes
affiliate fixed effect	no	no	no	yes
Adjusted R-squared	0.24	0.27	0.29	0.79

Notes: Sample of *all* affiliates born during the sample period. Number of observations: 153,773.

Table B.6: Affiliate exit, by affiliate type. OLS.

Dep var	D(affiliate exit)		
	all affiliates	pure horizontal affiliates	exporting affiliates
age	-0.001*	-0.001	-0.001**
	(0.0003)	(0.001)	(0.0003)
log affiliate employment	-0.016***	-0.014***	-0.015***
	(0.0007)	(0.001)	(0.001)
log global employment	0.001	0.001	0.001
	(0.001)	(0.002)	(0.001)
Observations	156,446	47,772	102,518
R-squared	0.031	0.033	0.031

Note: Observations at the affiliate-year level, for affiliates in manufacturing. Pure exporters are not included. The variable D(affiliate exit) equals one if the affiliate exits the following year. To ensure that we're not confounding exit from the BEA surveys with actual exit, we limit our sample to affiliates with sales that are consistently above the highest reporting threshold, that is, affiliates with at least $60 million in sales for all years. The variable "global employment" refers to the aggregate MNE employment, both in the United States and abroad. All specifications include country-year and industry fixed effects. Standard errors, clustered at the parent level, are in parenthesis. Levels of significance are denoted $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$.

Table B.7: Affiliate size, host market characteristics, and the expansion pattern of a MNE, averages.

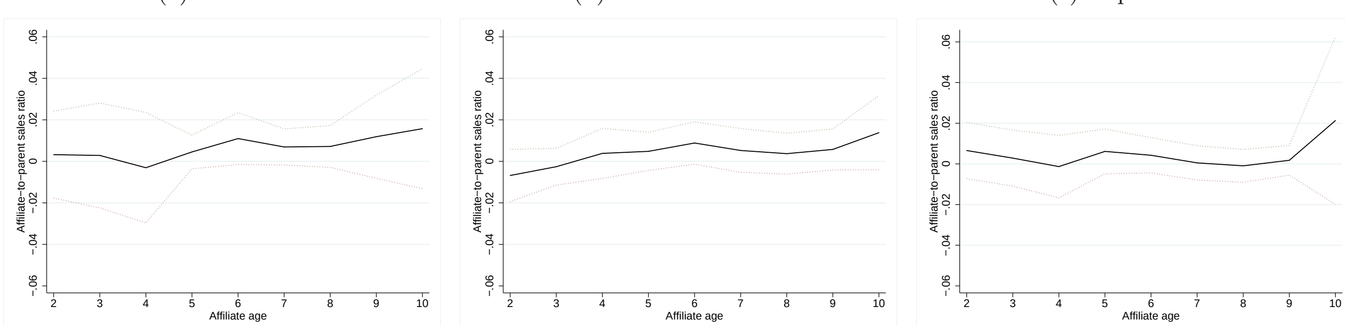
	first affiliates	subsequent affiliates
affiliate employment	709	526
affiliate sales, as % of parent's	20	6.5
affiliate horizontal sales, as % of parent US sales	10	3.8
GDP (billions of US$)	970	868
number of business procedures	6.4	7.6
number of days to start business	20.2	24.6
cost of start business (% of GDPpc)	7.0	11.8
Min K needed to start business (U$)	4,634	6,017

Note: Observations at the affiliate level, for new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. Variables related to entry costs are from the World Bank, Doing Business. GDP is from the Penn World Tables (9.0).

C Additional Figures

Figure C.1: Affiliate-to-parent sales ratio, by sales type, robustness.

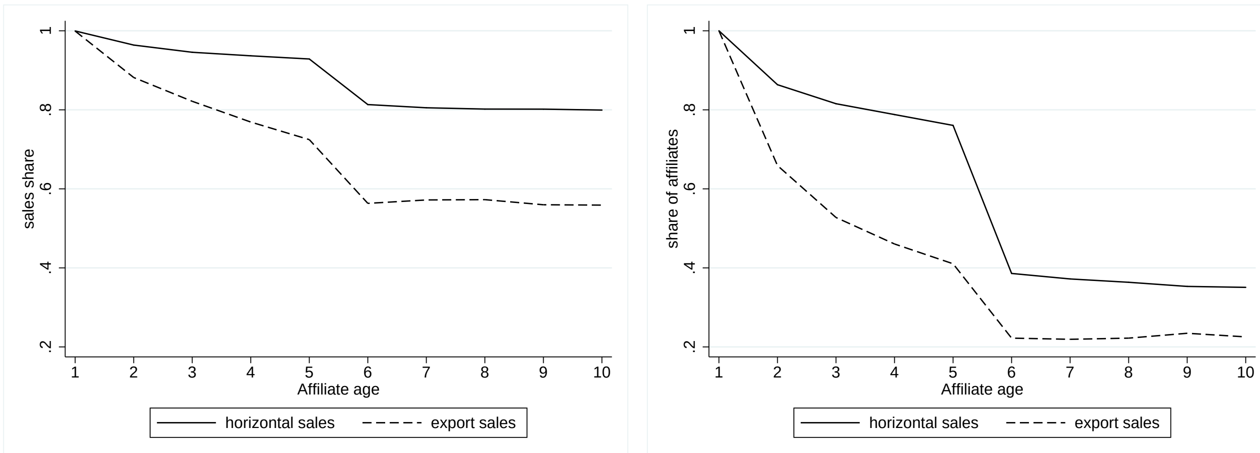
(a) All sales (b) Horizontal sales (c) Export sales



Notes: OLS coefficients on age dummies (relative to the entry year) from estimating (1), with industry fixed effects and country-year fixed effects. Five-percent interval confidences in dash lines. Sample of new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. Each panel includes affiliate with positive sales in the given category.

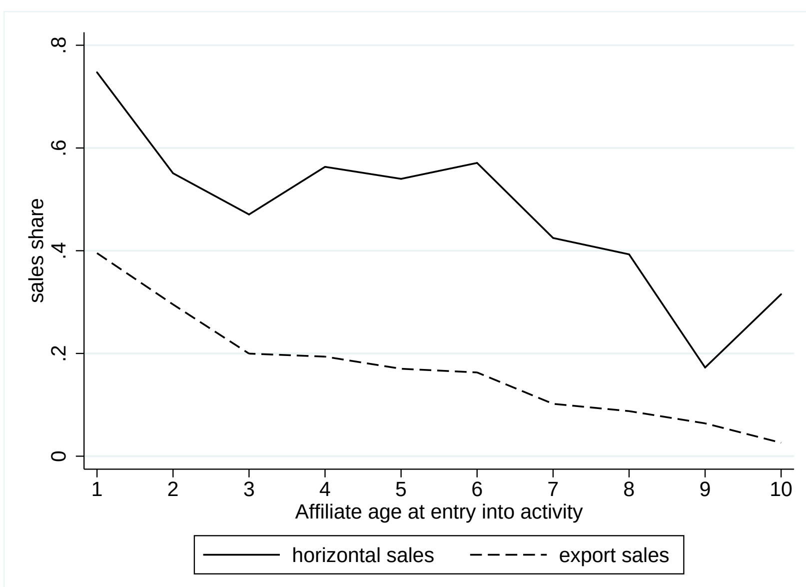
Figure C.2: Intensive and extensive margins of sales, by activity type. Pure-type affiliates at birth.

(a) Affiliate sales shares (intensive margin) (b) Share of affiliates (extensive margin)



Notes: Sample of new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. Horizontal and export sales refer, respectively, to sales to the market where the affiliate is located, and to sales to markets outside the local market. (C.2a): average sales, as a share of total affiliate sales, include affiliates with positive horizontal and export sales, respectively, for the subset of affiliates with only horizontal and only export sales at birth, respectively). (C.2b): number of affiliates, as a share of the total number of affiliates, include affiliates with positive horizontal and export sales, respectively.

Figure C.3: Sales and affiliate entry age, by activity type.



Notes: Sample of new majority-owned affiliates that survive for at least ten consecutive years, in manufacturing. Average horizontal (export) sales shares, by affiliate first age with positive horizontal (export) sales.

D Model's Solution: the Compound Option

With a compound-option structure, the model is solved backwards, starting from the problem of a firm that already has an affiliate in country j and has to decide whether to export to any country $k \neq j$.

The option value of exporting to k only depends on the composite shock Y_k. Hence, writing the Bellman equation describing the value of the option to export to country k for a firm with an affiliate in country j in (14) in the continuation region, taking the limit as $\Delta t \to 0$, and applying Ito's Lemma, yields the non-arbitrage condition

$$(\rho+\delta)V^o_{jk}(z,Y_k) = \tilde{\mu}_k Y_k V'^o_{jk}(z,Y_k) + \frac{\tilde{\sigma}^2_k}{2} Y^2_k V''^o_{jk}(z,Y_k). \tag{D.1}$$

Guessing a solution for the value function and applying the method of undetermined coefficients, the value of the option of exporting to country k for an affiliate in country j has general solution given by

$$V^o_{jk}(z,Y_k) = A^o_{jk}(z)Y_k^{\alpha_k} + B^o_{jk}(z)Y_k^{\beta_k},$$

where $\alpha_k < 0$ and $\beta_k > 1$ are the roots of $\frac{1}{2}\tilde{\sigma}^2_k\xi^2 + \left(\tilde{\mu}_k - \frac{\tilde{\sigma}^2_k}{2}\right)\xi - (\rho+\delta) = 0$. As $Y_k \to 0$, the option of exporting becomes worthless, so it must be that $A^o_{jk}(z) = 0$. Conversely, the option of exporting becomes more attractive as Y_k increases, so it must be that $B^o_{jk}(z) > 0$.

Similarly, writing the Bellman equation describing the value of exporting to country k from an affiliate in country j in (15) in the continuation region, taking the limit as $\Delta t \to 0$, and applying Ito's Lemma, yields the non-arbitrage condition

$$(\rho+\delta)V^e_{jk}(z,Y_k) = \pi^e_{jk}(z,Y_k) - f^e_{jk} + \tilde{\mu}_k V'^e_{jk}(z,Y_k) + \frac{\tilde{\sigma}^2_k}{2} Y^2_k V''^e_{jk}(z,Y_k). \tag{D.2}$$

Guessing a solution for the value function and applying the method of undetermined coefficients, the value of the option of exporting to country k for an affiliate in country j has general solution given by

$$V^e_{jk}(z,Y_k) = A^e_{jk}(z)Y_k^{\alpha_k} + B^e_{jk}(z)Y_k^{\beta_k} + \frac{\pi^e_j(z,Y_k)}{\rho+\delta-\tilde{\mu}_k} - \frac{f^e_j}{\rho+\delta}.$$

Notice that, as $Y_k \to 0$, there is value from the possibility of endogenously stopping to export, so it must be that $A^e_{jk}(z) > 0$. Also, as Y_k increases, the value of exports converges to the discounted profit flow (i.e., there is no further expansion option), so it must be that $B^e_{jk}(z) = 0$.

For each country pair (j,k) and for each firm with productivity z, the parameters $B^o_{jk}(z) > 0$,

$A^e_{jk}(z) > 0$, and the aggregate productivity thresholds that induce the affiliate to start and stop exporting, denoted by Y^{OE}_{jk} and Y^{EO}_{jk}, respectively, can be recovered from the following system of value-matching conditions,

$$V^o_{jk}(z, Y^{OE}_{jk}) = V^e_{jk}(z, Y^{OE}_{jk}) - F^e_{jk} \quad \text{and} \quad V^o_{jk}(z, Y^{EO}_{jk}) = V^e_{jk}(z, Y^{EO}_{jk}),$$

and smooth-pasting conditions,

$$V'^o_{jk}(z, Y^{OE}_{jk}) = V'^e_{jk}(z, Y^{OE}_{jk}) \quad \text{and} \quad V'^o_{jk}(z, Y^{EO}_{jk}) = V'^e_{jk}(z, Y^{EO}_{jk}).$$

Writing the Bellman equation describing the value of horizontal sales for an affiliate in country j in (13) in the continuation region, taking the limit as $\Delta t \to 0$, and applying Ito's Lemma, yields the non-arbitrage condition

$$(\rho + \delta)V^h_j(z, Y_j) = \pi^h_j(z, Y_j) - f^h_j + \tilde{\mu}_j Y_j V'^h_j(z, Y_j) + \frac{\tilde{\sigma}^2_k}{2} Y^2_j V''^h_j(z, Y_j). \tag{D.3}$$

Guessing a solution for the value function and applying the method of undetermined coefficients, the value of horizontal sales for an affiliate in country j has general solution given by

$$V^h_j(z, Y_j) = A^h_j(z) Y^{\alpha_j}_j + B^h_j(z) Y^{\beta_j}_j + \frac{\pi^h_j(z, Y_j)}{\rho + \delta - \tilde{\mu}_j} - \frac{f^h_j}{\rho + \delta}.$$

Notice that, as $Y_j \to 0$, there is value from the possibility of shutting down the affiliate, so it must be that $A^h_j(z) > 0$. As Y_j increases, the value of horizontal sales converges to the discounted profit flow, so it must be that $B^h_j(z) = 0$.

At this point, the value of an affiliate in country j, $V^a_j(z, X, \mathbf{Q})$ is completely characterized up to the option value parameter $A^h_j(z)$,

$$V^a_j(z, \mathbf{Y}) = A^h_j(z) Y^{\alpha_j}_j + \frac{\pi^h_j(z, Y_j)}{\rho + \delta - \tilde{\mu}_j} - \frac{f^h_j}{\rho + \delta} + \sum_{k \in \mathcal{A}_j(z)} \left[\frac{\pi^e_{jk}(z, Y_k)}{\rho + \delta - \tilde{\mu}_k} - \frac{f^e_{jk}}{\rho + \delta} + A^e_{jk}(z) Y^{\alpha_k}_k \right] + \sum_{k \notin \mathcal{A}_j(z)} \left[B^o_{jk}(z) Y^{\beta_k}_k \right], \tag{D.4}$$

where $\mathcal{A}_j(z)$ denotes the set of export markets in which an affiliate of a firm with productivity z located in country j exports.

Lastly, writing the Bellman equation describing the value of the option to open an affiliate in country j in(12) in the continuation region, taking the limit for $\Delta t \to 0$, and applying Ito's Lemma, yields the non-arbitrage condition

$$(\rho+\delta)V_j^o(z,Y_j)=\tilde{\mu}_j Y_j V'^o_j(z,Y_j)+\frac{\tilde{\sigma}_j^2}{2}Y_j^2 V''^o_j(z,Y_j). \tag{D.5}$$

Guessing a solution for the value function and applying the method of undetermined coefficients, the value of the option of exporting to country k for an affiliate in country k has general solution given by

$$V_j^o(z,Y_j)=A_j^o(z)Y_j^{\alpha_j}+B_j^o(z)Y_j^{\beta_j}.$$

As $Y_j\to 0$, the option of opening an affiliate becomes worthless, so it must be that $A_j^o(z)=0$. Conversely, the option of opening an affiliate becomes more attractive as Y_j increases, so it must be that $B_j^o(z)>0$.

Finally, we need to determine the option value parameters. When the firm decides to open an affiliate in a country, it considers not only the value of its horizontal sales, but also the option value of potential export to any destination country. For this reason, the value-matching and smooth-pasting conditions that deliver the parameters $A_j^h(z)$, $B_j^o(z)$, together with the aggregate productivity thresholds that induce the firm to open or shut down the affiliate, Y_j^{OH} and Y_j^{HO}, respectively, are computed using the option value function $V_j^o(z,Y_j)$ and the total value of the affiliate $V_j^a(z,\mathbf{Y})$,

$$V_j^o(z,Y_j^{OH})=V_j^a(z,Y_j^{OH})-F_j^h \quad , \quad V_j^o(z,Y_j^{HO})=V_j^a(z,Y_j^{HO}),$$

$$V'^o_j(z,Y_j^{OH})=V'^a_j(z,Y_j^{OH}) \quad , \quad V'^o_j(z,Y_j^{HO})=V'^a_j(z,Y_j^{HO}).$$

E Model's Solution: Special Case

Writing the Bellman equation for the value of domestic operations in (11) in the continuation region, taking the limit as $\Delta t\to 0$,, and applying the Ito's lemma, yields the non-arbitrage condition

$$(\rho+\delta)V_d(z,X)=\pi_d(z,X)+\mu V_d'(z,X)+\frac{\sigma^2}{2}V_d''(z,X). \tag{E.1}$$

Guessing that the value function takes the form $V_d(z,X)=W_d(z,X)+e^{\xi X}$, and substituting it into (E.1) yields

$$(\rho+\delta)[W_d(z,X)+e^{\xi X}]=\pi_d(z,X)+\mu[W_d'(z,X)+\xi e^{\xi X}]+\frac{\sigma^2}{2}[W_d''(z,X)+\xi^2 e^{\xi X}].$$

Using the method of undetermined coefficients, the general solution for the value of domestic sales is then given by

$$V_d(z,X) = \frac{\pi_d(z,X)}{\rho+\delta-\mu(\eta-1)-\frac{\sigma^2}{2}(\eta-1)^2} + A_d(z)e^{\alpha X} + B_d(z)e^{\beta X},$$

where $\alpha < 0$ and $\beta > 1$ are the two values of ξ. Since all firms always have domestic sales, there is no option value of domestic sales, so that $A_d(z) = B_d(z) = 0$.[1]

We proceed in an analogous way to solve for the other value functions. Following the same steps as above, we obtain a non-arbitrage condition for the option value of an affiliate,

$$(\rho+\delta)V_j^o(z,X) = \mu V'^o_j(z,X) + \frac{\sigma^2}{2}V''^o_j(z,X), \tag{E.2}$$

guess that the value function takes the form $V_j^o(z,X) = e^{\xi X}$, and obtain the general solution,

$$V_j^o(z,X) = A_j^o(z)e^{\alpha X} + B_j^o(z)e^{\beta X},$$

where $\alpha < 0$ and $\beta > 1$ are the two values of ξ. As $X \to 0$, the option of opening an affiliate becomes worthless, so it must be that $A_j^o(z) = 0$. Conversely, the option of opening an affiliate becomes more attractive as X increases, so it must be that $B_j^o(z) > 0$.

The non-arbitrage condition for the value of an affiliate with only horizontal sales is

$$(\rho+\delta)V_j^h(z,X) = \pi_j^h(z,X) - f_j^h + \mu V'^h_j(z,X) + \frac{\sigma^2}{2}V''^h_j(z,X). \tag{E.3}$$

We guess that the value function takes the form $V_j^h(z,X) = W_j^h(z,X) + e^{\xi X}$, apply the method of undetermined coefficients and get the general solution for the value of an affiliate with only horizontal sales,[2]

$$V_j^h(z,X) = A_j^h(z)e^{\alpha X} + B_j^h(z)e^{\beta X} + \frac{\pi_j^h(z,X)}{\rho+\delta-\mu(\eta-1)-\frac{\sigma^2}{2}(\eta-1)^2} - \frac{f_j^h}{\rho+\delta}.$$

As $X \to 0$, the value of horizontal sales also goes to zero (since exit is exogenous and random), so it must be that $A_j^h(z) = 0$. Conversely, as X increases, the value of the affiliate also increases

[1] We first collect the homogeneous terms, $\rho+\delta = \mu\xi + (\sigma^2/2)\xi^2$, where ξ is given by the solution to the quadratic equation $\xi = (-\mu \pm \sqrt{\mu^2+2\sigma^2(\rho+\delta)})/\sigma^2$. We then collect the non-homogeneous terms, $(\rho+\delta)W_d(z,X) = \pi_d(z,X) + \mu W_d'(z,X) + (\sigma^2/2)W_d''(z,X)$, guess that its form is $W_d(z,X) = \pi_d(z,X)/\kappa$, solve for $\kappa = \rho+\delta-\mu(\eta-1)-(\sigma^2/2)(\eta-1)^2$, and get $W_d(z,X) = \pi_d(z,X)/\left[\rho+\delta-\mu(\eta-1)-(\sigma^2/2)(\eta-1)^2\right]$.

[2] The non-homogeneous term takes the form $W_j^h(z,X) = \pi_j^h(z,X)/\kappa_1 + f_j^h/\kappa_2$, and we solve for $\kappa_1 = \rho+\delta-\mu(\eta-1)-(\sigma^2/2)(\eta-1)^2$ and $\kappa_2 = \rho+\delta$.

because of the option of starting export activities, so it must be that $B_j^h(z) > 0$.

Finally, the non-arbitrage condition for the value of an exporting affiliate is

$$(\rho+\delta)V_j^e(z,X) = \pi_j^h(z,X) - f_j^h + \pi_j^e(z,X) - f_j^e + \mu V'^e_j(z,X) + \frac{\sigma^2}{2}V''^e_j(z,X). \tag{E.4}$$

Again, we guess that the value function takes the form $V_j^e(z,X) = W_j^e(z,X) + e^{\xi X}$, apply the method of undetermined coefficients, and get the general solution for the value of an affiliate with both horizontal and exports sales,[3]

$$V_j^e(z,X) = A_j^e(z)e^{\alpha X} + B_j^e(z)e^{\beta X} + \frac{\pi_j^h(z,X) + \pi_j^e(z,X)}{\rho+\delta-\mu(\eta-1)-\frac{\sigma^2}{2}(\eta-1)^2} - \frac{f_j^h + f_j^e}{\rho+\delta}.$$

As $X \to 0$, the value of the affiliate also goes to zero (since exit is exogenous and random), so it must be that $A_j^e(z) = 0$. As X increases, the value of the affiliate converges to the discounted profit flow—i.e, there is no further expansion option, so it must be that $B_j^e(z) = 0$.

It remains to solve for the two firm-specific parameters $B_j^o(z)$, $B_j^h(z)$ and for the aggregate productivity thresholds that induce a firm with productivity z to open an affiliate in j, or to start exporting from it, denoted by $X_j^h(z)$ and $X_j^e(z)$, respectively. For each firm and each foreign market, we impose the following system of value-matching conditions, $V_j^o(z,X_j^h) = V_j^h(z,X_j^h) - F_j^h$, $V_j^h(z,X_j^e) = V_j^e(z,X_j^e) - F_j^e$, and smooth-pasting conditions,$V_j^{o\prime}(z,X_j^h) = V_j^{h\prime}(z,X_j^h)$ $V_j^{h\prime}(z,X_j^e = V_j^{e\prime}(z,X_j^e)$.

The resulting value function parameters $B_j^h(z)$ and $B_j^o(z)$ are given, respectively, by

$$B_j^o(z) = k_B \cdot \left(\frac{k_j^h(z)}{\beta(\rho+\delta-\hat{\mu})}\right)^{\frac{\beta}{\eta-1}} \cdot \left(\frac{f_j^h + (\rho+\delta)F_j^h}{\rho+\delta}\right)^{\frac{\eta-1-\beta}{\eta-1}} + B_j^h(z), \tag{E.5}$$

$$B_j^h(z) = k_B \cdot \left(\frac{k_j^e(z)}{\beta(\rho+\delta-\hat{\mu})}\right)^{\frac{\beta}{\eta-1}} \cdot \left(\frac{f_j^e + (\rho+\delta)F_j^e}{\rho+\delta}\right)^{\frac{\eta-1-\beta}{\eta-1}}, \tag{E.6}$$

where k_B is a constant, and $k_j^h(z)$ and $k_j^e(z)$ are firm-specific revenue terms.[4] With $\beta > \eta - 1$, the expression in (E.5) reveals that the option value of opening an affiliate is decreasing in both the fixed and sunk costs of opening the affiliate and the value of exporting from that affiliate. In turn, the option value of exporting from an affiliate, captured in (E.6), is decreasing in both the fixed and sunk costs of exporting from the affiliate. Both option values are increasing in the firm

[3] The non-homogeneous term takes the form $W_j^e(z,X) = (\pi_j^h(z,X) + \pi_j^e(z,X))/\kappa_1 - (f_j^h + f_j^e)/\kappa_2$, and we solve for $\kappa_1 = \rho + \delta - \mu(\eta-1) - (\sigma^2/2)(\eta-1)^2$ and $\kappa_2 = \rho + \delta$.

[4] $k_B \equiv (\eta-1)(1+\beta-\eta)^{\frac{\eta-1-\beta}{1-\eta}}$, $k_j^h(z) \equiv H\,(w_j/z)^{1-\eta}\,P_j^\eta Q_j$, and $k_j^e(z) \equiv H\,(\tau_j w_j/z)^{1-\eta}\,(\sum_{k\neq j} P_k^\eta Q_k)$.

productivity z. Closed form solutions for the productivity thresholds are reported in Section 3.3.

F Industry Equilibrium

The industry equilibrium in this economy is defined by a vector of price indexes $\{P_k\}$, for $k = 1, ...N$, and by the laws of motion governing the evolution of affiliate operations over time across countries. The price index in country k is

$$P_k^{1-\eta} = \sum_{i=1}^{N} \sum_{j=1}^{N} P_{ijk}^{1-\eta}, \tag{F.1}$$

where P_{ijk} denotes the price index of varieties produced by affiliates of firms from country i located in country j and selling to country k. As we only MNEs from the United States, we compute the price index distinguishing only transactions for US MNEs; domestic firms as well as other MNEs operating in country k are treated all as domestic firms,

$$P_k^{1-\eta} = P_{kkk}^{1-\eta} + P_{US,kk}^{1-\eta} + \sum_{j \neq k} P_{US,j,k}^{1-\eta}, \tag{F.2}$$

with

$$P_{kkk}^{1-\eta} = \int \left(\frac{\eta}{\eta - 1} \frac{w_k}{z_k} \right)^{1-\eta} dz, \tag{F.3}$$

$$P_{US,kk}^{1-\eta} = \int_{\Omega_k^h} \left(\frac{\eta}{\eta - 1} \frac{w_k}{zZ} \right)^{1-\eta} dz, \tag{F.4}$$

$$P_{US,jk}^{1-\eta} = \int_{\Omega_{jk}^e} \left(\frac{\eta}{\eta - 1} \frac{\tau_{jk} w_j}{zZ} \right)^{1-\eta}, dz \tag{F.5}$$

and Ω_k^h (Ω_{jk}^e) denoting the set of US MNEs with horizontal affiliates in k (with affiliates located in j and selling to k). As each firm does not take into consideration the effect of its choices on the price index, we assume that it does not take into consideration the way in which Z, Ω_k^h, and Ω_{jk}^e affect the price index as well. Price indexes fluctuate only because of US productivity shocks and changes in US MNE activity.

Let M_i denote the (exogenous) mass of firms in country i. The endogenous mass of affiliates of firms from i located in j, M_{ij}, is given by continuing plus new affiliates,

$$M'_{ij} = M_{ij} \cdot (1 - G_i(z_{ij}^{HO})) + (M_i - M_{ij}) \cdot (1 - G_i(z_{ij}^{OH})), \tag{F.6}$$

while the mass of affiliates of firms from i located in j that export to k is given by continuing plus new exporters to k,

$$M'_{ijk} \quad = \quad M_{ijk} \cdot (1 - G_i(z_{ijk}^{EO})) + (M_{ij} - M_{ijk}) \cdot (1 - G_i(z_{ijk}^{OE})). \tag{F.7}$$

The variable z_{ij}^{OH} (z_{ij}^{HO}) is the productivity threshold that induces a firm from i to open (shut down) an affiliate in j, while z_{ijk}^{OE} (z_{ijk}^{EO}) is the productivity threshold that induces an affiliate of a firm from i in j to start (stop) exporting from j to k.

Table G.1: Calibrated parameters: aggregate shock and wages, by country.

	$\tilde{\mu}_j$	$\tilde{\sigma}_j$	γ_j	w_j
Brazil	0.051	0.130	0.032	0.711
Canada	0.030	0.136	0.661	0.831
China	0.064	0.122	0.035	0.307
France	0.025	0.127	0.370	0.981
United Kingdom	0.025	0.136	0.314	0.930
Gemany	0.026	0.128	0.648	0.825
Ireland	0.048	0.144	0.560	1.188
Japan	0.027	0.133	0.383	0.719
Mexico	0.036	0.127	0.083	0.699
Singapore	0.080	0.137	0.213	0.950
United States	0.028	0.116	1.000	1.000

Note: $\tilde{\mu}_j$ and $\tilde{\sigma_j}$ refer to the drift and standard deviation, respectively, of the composite shock Y_j. γ_j refers to the correlation between the US aggregate productivity shock and country j's aggregate demand shock. The variable w_j refers to wages for country j (relative to the US).

G Calibration: Additional Tables

Table G.2: Calibrated parameters: fixed and sunk costs of export and horizontal activities, shock initialization.

	f_k^e	F_k^e	f_{US}^e	F_{US}^e	f_j^h	F_j^h	$Q_j(0)$
Brazil	0.0192	0.0010	0.0287	0.0003	0.1254	0.0788	0.115
Canada	0.0056	0.0000	0.0088	0.0062	0.0254	0.0052	0.831
China	0.2207	0.0376	0.3881	0.0031	0.9560	0.1722	0.307
France	0.0189	0.0292	0.0111	0.0002	0.0664	0.0253	0.981
United Kingdom	0.0153	0.0082	0.0087	0.0018	0.0411	0.0029	0.930
Germany	0.0272	0.0319	0.0138	0.0026	0.0770	0.0172	0.825
Ireland	0.0079	0.0066	0.0094	0.0000	0.0113	0.0112	0.188
Japan	0.0356	0.0257	0.0378	0.0001	0.2216	0.0194	0.719
Mexico	0.0100	0.0004	0.0162	0.0065	0.0484	0.0438	0.699
Singapore	0.0116	0.0148	0.0175	0.0061	0.0464	0.0042	0.950

Note: f_k^e (F_k^e) is the fixed (sunk) cost of exporting from j (rows) to a any destination k other than the United States. f_{US}^e (F_{US}^e) is the fixed (sunk) cost of exporting from j (rows) to the United States. f_j^h (F_k^h) is the fixed (sunk) cost of entering market j (rows) with an affiliate.

Table G.3: Calibrated parameters: bilateral iceberg-trade costs.

	BRA	CAN	CHN	FRA	GBR	GER	IRL	JPN	MEX	SGP	USA
Brazil	1.000	1.867	2.466	2.082	2.780	2.108	2.082	2.501	1.955	2.403	3.308
Canada	2.314	1.000	2.481	2.128	2.787	2.142	2.052	2.466	1.806	2.725	2.800
China	3.439	2.998	1.000	2.800	3.979	2.758	2.806	2.683	3.133	2.377	4.284
France	2.783	1.577	2.685	1.000	1.388	1.218	1.421	1.860	2.767	2.887	2.735
United Kingdom	3.203	1.463	3.074	1.307	1.000	1.443	1.415	1.681	3.151	3.322	2.632
Germany	3.198	1.800	3.002	1.382	1.426	1.000	1.686	2.012	3.158	3.243	2.881
Ireland	3.859	1.649	3.730	1.969	1.579	2.060	1.000	1.940	3.753	4.048	2.810
Japan	2.281	1.949	1.266	1.916	2.511	1.893	1.909	1.000	1.996	1.628	3.281
Mexico	2.319	2.209	2.666	2.457	2.823	2.470	2.403	2.597	1.000	2.881	3.333
Singapore	2.162	1.823	1.534	1.942	1.948	1.925	1.965	1.758	2.185	1.000	2.923
United States	3.742	2.849	5.026	2.677	2.616	2.874	3.122	3.362	3.493	3.660	1.000

Note: Iceberg-trade costs from country j (rows) to destination k (columns).

Table G.4: Static moments: participation. Model versus data.

Share of:	MNEs with affiliates in j		Affiliates in j exporting to US		Affiliates in j exporting to third countries	
	data	model	data	model	data	model
Brazil	0.198	0.201	0.515	0.522	0.674	0.675
Canada	0.544	0.540	0.725	0.720	0.478	0.477
China	0.184	0.183	0.382	0.409	0.548	0.539
France	0.312	0.277	0.539	0.545	0.747	0.750
United Kingdom	0.554	0.563	0.605	0.611	0.739	0.743
Germany	0.367	0.349	0.608	0.616	0.760	0.764
Ireland	0.122	0.127	0.575	0.572	0.760	0.768
Japan	0.155	0.150	0.468	0.475	0.578	0.582
Mexico	0.302	0.291	0.647	0.656	0.494	0.494
Singapore	0.129	0.136	0.597	0.607	0.724	0.728
Average	0.287	0.282	0.566	0.573	0.650	0.652

Note: Calculations are conditional on affiliates with positive sales in their host market. Averages across years.

Table G.5: Static moments: sales shares. Model versus data.

Share of:	Affiliate sales to the US		Affiliate sales to third countries		Affiliate sales to host market	
	data	model	data	model	data	model
Brazil	0.072	0.072	0.142	0.142	0.018	0.018
Canada	0.261	0.261	0.113	0.113	0.048	0.048
China	0.099	0.099	0.219	0.219	0.003	0.003
France	0.075	0.075	0.364	0.364	0.038	0.038
United Kingdom	0.111	0.111	0.371	0.371	0.052	0.052
Germany	0.092	0.092	0.413	0.413	0.047	0.047
Ireland	0.242	0.242	0.515	0.515	0.002	0.002
Japan	0.047	0.047	0.130	0.130	0.034	0.034
Mexico	0.173	0.173	0.128	0.129	0.011	0.011
Singapore	0.222	0.222	0.488	0.488	0.003	0.003
Average	0.140	0.139	0.288	0.288	0.026	0.026

Note: Affiliate sales to the US and to third countries are as share of affiliate sales in the host market, while affiliate sales to the host market are as share of parent's US sales. Calculations are conditional on affiliates with positive sales in their host market (but with positive or zero exports). Averages across years.

Table G.6: Static moments: sales to selected destination markets. Model versus data.

Share of:	Affiliate sales to Canada		Affiliate sales to the United Kingdom		Affiliate sales to Japan	
	data	model	data	model	data	model
Brazil	0.008	0.018	0.008	0.005	0.004	0.005
Canada	1.000	1.000	0.006	0.005	0.003	0.006
China	0.008	0.005	0.002	0.002	0.037	0.045
France	0.010	0.005	0.091	0.109	0.006	0.005
United Kingdom	0.012	0.011	1.000	1.000	0.009	0.012
Germany	0.009	0.003	0.079	0.144	0.010	0.004
Ireland	0.053	0.033	0.386	0.360	0.082	0.032
Japan	0.006	0.005	0.001	0.004	1.000	1.000
Mexico	0.007	0.013	0.001	0.011	0.002	0.013
Singapore	0.024	0.024	0.047	0.098	0.147	0.132
Average	0.015	0.013	0.069	0.082	0.033	0.028

Note: Share of affiliate sales in the host market. Calculations are conditional on affiliates with positive sales in their host market (but with positive or zero exports). Averages across (benchmark) years.

Table G.7: Dynamic moments: entry. Model versus data.

Share of:	MNEs opening affiliates in j		Affiliates in j that start exporting to			
			United States		third countries	
	data	model	data	model	data	model
Brazil	0.021	0.025	0.032	0.029	0.037	0.029
Canada	0.060	0.046	0.024	0.026	0.036	0.027
China	0.029	0.015	0.027	0.023	0.040	0.023
France	0.038	0.027	0.033	0.030	0.025	0.030
United Kingdom	0.069	0.046	0.029	0.025	0.027	0.024
Germany	0.046	0.024	0.030	0.028	0.025	0.027
Ireland	0.015	0.018	0.037	0.038	0.030	0.029
Japan	0.020	0.013	0.032	0.030	0.030	0.026
Mexico	0.036	0.040	0.029	0.028	0.033	0.024
Singapore	0.019	0.013	0.026	0.026	0.028	0.032
Average	0.035	0.027	0.030	0.028	0.031	0.027

Note: Calculations are conditional on affiliates with positive sales in their host market. Averages across years.

Table G.8: Dynamic moments: exit. Model versus data.

Share of:	MNEs shutting down affiliates in j		Affiliates in j that stop exporting to United States		third countries	
	data	model	data	model	data	model
Brazil	0.102	0.051	0.027	0.023	0.032	0.011
Canada	0.125	0.037	0.021	0.004	0.028	0.023
China	0.082	0.003	0.020	0.024	0.031	0.008
France	0.117	0.038	0.029	0.021	0.021	0.001
United Kingdom	0.128	0.039	0.026	0.009	0.023	0.005
Germany	0.122	0.014	0.029	0.009	0.024	0.003
Ireland	0.119	0.137	0.030	0.039	0.030	0.004
Japan	0.111	0.034	0.029	0.029	0.029	0.003
Mexico	0.114	0.064	0.021	0.006	0.026	0.011
Singapore	0.115	0.017	0.023	0.006	0.026	0.001
Average	0.113	0.043	0.025	0.017	0.027	0.007

Note: Calculations are conditional on affiliates with positive sales in their host market. Averages across years. The model-generated exit rates rely on endogenous exit only; total exit is given by endogenous plus exogenous ($\delta = 0.05$) exit.