

Federal Reserve Bank of Minneapolis
Research Department Staff Report 544

February 2018

Firm Entry and Exit and Aggregate Growth*

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ABSTRACT

Applying the Foster, Haltiwanger, and Krizan (FHK) (2001) decomposition to plant-level manufacturing data from Chile and Korea, we find that a larger fraction of aggregate productivity growth is due to entry and exit during periods of fast GDP growth. Studies of other countries confirm this empirical relationship. To analyze this relationship, we develop a simple model of firm entry and exit based on Hopenhayn (1992) in which there are analytical expressions for the FHK decomposition. When we introduce reforms that reduce entry costs or reduce barriers to technology adoption into a calibrated model, we find that the entry and exit terms in the FHK decomposition become more important as GDP grows rapidly, just as in the data from Chile and Korea.

Keywords: Entry, Exit, Productivity, Entry costs, Barriers to technology adoption.

JEL Codes: E22, O10, O38, O47

*This paper has benefited from helpful discussions at numerous conference and seminar presentations. We thank Paco Buera, V.V. Chari, Hal Cole, John Haltiwanger, Boyan Jovanovic, Joseph Kaboski, Pete Klenow, Erzo Luttmer, Ezra Oberfield, B. Ravikumar, Felipe Saffie, and Juan Sanchez for helpful discussions. We also thank James Tybout, the Instituto Nacional de Estadística of Chile, and the Korean National Statistical Office for their assistance in acquiring data. All of the publically available data used in this paper can be found at <http://users.econ.umn.edu/~tkehoe/>. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

1. Introduction

Findings in empirical studies vary widely on the importance of the entry and exit of plants in accounting for aggregate productivity growth. Consider, for example, two widely-cited studies: Foster, Haltiwanger, and Krizan (FHK) (2001) find that the entry and exit of plants accounts for 25 percent of U.S. manufacturing productivity growth, while Brandt, Van Biesebroeck, and Zhang (2012), using the same decomposition, find that entry and exit account for 72 percent of Chinese manufacturing productivity growth.¹ In this paper, we account for the stark differences in the U.S. and Chinese data both by examining data from other countries and by developing a simple model in which we can understand the driving forces behind those differences.

The first contribution of this paper is empirical. We apply the FHK decomposition to manufacturing plant-level data from Chile and Korea. We find that plant entry and exit accounts for a larger fraction of aggregate manufacturing productivity growth during periods of fast growth in GDP per working-age person. A meta-analysis of the productivity literature, spanning a number of countries and time periods, supports this empirical regularity. We summarize our findings in Figure 3, in which we plot growth in GDP per working-age person against the contribution of the entry and exit of plants to growth in aggregate manufacturing productivity. This empirical relationship is novel to the literature and suggests that the entry and exit of plants plays an important role in explaining periods of fast growth.

Our second contribution is theoretical. We develop a dynamic general equilibrium model with endogenous entry and exit, based on Hopenhayn (1992), that can quantitatively account for the patterns we document in the data. Our model is simple enough that there are analytical expressions that correspond to terms in the FHK decomposition. When we introduce reforms that reduce entry costs or reduce barriers to technology adoption into a calibrated model, we find that the entry and exit terms in the FHK decomposition become more important as GDP grows rapidly, just as in the data. Our simple model, meant to highlight the forces driving productivity growth, performs surprisingly well in quantitatively matching the behavior we observe in the data.

Our general equilibrium model is of the entire economy, but the productivity decompositions in both the existing literature and our own work cover only the manufacturing sector. If we could

¹ To calculate that entry and exit accounts for 25 percent of U.S. manufacturing productivity growth, see Table 8.7 in FHK and find the average net entry share for the 1977-82, 1982-87, and 1987-92 windows. To find the contribution of entry and exit in China, see Figure 7 in Brandt, Van Biesebroeck, and Zhang (2012).

compute the FHK decompositions using economy-wide data for Chile and Korea and we could find comparable results for other countries in the literature, then we would not need to restrict ourselves to the manufacturing sector. Due to the availability of data, we assume that the FHK decomposition for aggregate manufacturing productivity growth assigns the same proportions to entry and exit of plants as would a decomposition of aggregate productivity growth for the whole economy. This assumption allows us to make comparisons between the model and the data.

In our empirical work, Chile and South Korea are good candidates for our analysis because both countries have experienced periods of fast and slow growth. Real GDP per working-age person in Chile grew 4.0 percent per year during 1995–1998, slowing to 2.7 percent per year during 2001–2006. In South Korea, real GDP per working-age person grew by 6.1 percent per year in 1992–1997 and by 4.3 percent per year in 2001–2006 and slowed to 3.0 percent per year in 2009–2014. Studying periods of slow and fast growth in the same country allows us to avoid cross-country differences and use consistent datasets through time, which reduces issues of measurement.

We use the FHK decomposition to measure the contribution of net entry. In this decomposition, the net entry term is higher if entering plants are relatively productive compared to the overall industry, and exiting plants are relatively unproductive. The continuing plant contribution consists of both within-plant productivity dynamics and the reallocation of market shares across continuing plants. We find that, in both countries, net entry plays a more important role during periods of fast GDP growth. During periods of slow growth, when GDP per working-age person grows at less than 4 percent per year, entry and exit account for less than 25 percent of aggregate manufacturing productivity growth on average, similar to the average contribution of entry and exit in the United States. During periods of fast GDP growth, however, entry and exit account for a larger fraction of aggregate manufacturing productivity growth, ranging from 37 to 58 percent. We also find that the increasing importance of entry and exit is mainly driven by the change in the relative productivity of entering and exiting plants, rather than differences in their market shares. Our findings are robust to using alternative decompositions.

Our own analysis is limited by the availability of establishment-level data. Fortunately, the FHK decomposition is widely used in the productivity literature. To get a broader understanding of the empirical relationship between growth and the role of net entry, we survey papers in the literature that use the FHK decomposition. We find that continuing establishments — plants in

four of the papers, firms in the other papers — consistently account for the bulk of aggregate manufacturing productivity growth when GDP per working-age person grows slowly. During episodes of fast GDP growth, the entry and exit of plants play a more important role.

Motivated by our empirical work with the FHK decomposition, we build a simple model that has three sources of productivity growth. First, in each period, potential entrants draw efficiencies from a distribution with a mean that grows at rate $g_e - 1$. Second, continuing firm efficiencies improve with age. This efficiency growth depends on an exogenous growth factor and spillovers from average efficiency growth. Finally, firms optimally choose when to exit production, which induces a selection effect in which inefficient firms exit.

The economy is subject to three types of policy distortions. First, a potential entrant must pay an entry cost to draw an efficiency. Second, a successful entrant must pay a fixed cost to continue production in each period. These two costs are partly technological and partly the result of policy. We think of these policy-related costs as distortions that can be reduced through economic reform. Third, new firms face barriers to technology adoption in the spirit of Parente and Prescott (1994). Better technologies exist but are not used because of policies that restrict their adoption.

We show that the model has a balanced growth path on which income grows at the same rate regardless of the severity of the policy distortions. Income levels on the balanced growth path, however, are determined by the distortions: More severe distortions yield lower balanced growth paths. These results are consistent with the data from the United States and other industrialized economies. These economies have grown at about 2 percent per year for several decades, despite persistent differences in income levels. Kehoe and Prescott (2002) provide an in-depth discussion of these empirical regularities. Similarly, Jones (1995) discusses the stable growth rates shown by the United States over extended periods of time.

The simplicity of our model allows us to analytically characterize the FHK decompositions of the model on the balanced growth path. The decompositions highlight the ways that firm turnover, selection, and the efficiency advantage of entrants affects the contribution of net entry to aggregate productivity growth. These forces are present in many of the growth models in the literature and our model allows us to understand how they map into empirical decompositions.

We further show that, in the balanced growth path, the contribution of entry and exit to productivity growth, just like GDP growth rates, is the same for all economies on the balanced

growth path regardless of the level of distortions in the model. We also show that, under certain parameters, the importance of entry and exit is decreasing in the efficiency growth of continuing firms, a fact that we use in our calibration strategy.

After enacting a reform, the economy grows quickly and eventually converges to a higher balanced growth path. This overall pattern is also consistent with empirical evidence of episodes of fast growth. For example, Eichengreen et al. (2012) study episodes of fast growth followed by economic slowdowns. Using data that starts in 1957, they consider a slowdown to have occurred if: the seven-year average GDP per capita growth rate is at least 3.5 percent for seven years prior to the slowdown, and the growth rate exhibited a decline of at least 2 percentage points in the subsequent seven years after the slowdown. The authors restrict the sample to countries with GDP per capita of at least \$10,000 in 2005 constant dollars at the time of the slowdown. They find that, in the average country that experienced a slowdown, the growth rate slowed from 5.6 to 2.1 percent per year.

We calibrate the model to establishment-level data for the entire U.S. economy. The major exception to using economy-wide data in the calibration of our model is that we target the fact that entry and exit account for 25 percent of U.S. aggregate manufacturing productivity growth according to FHK, which we assume to be the fraction of growth due to entry and exit in the entire economy. Our model also includes spillovers from growth of entering firms to continuing firms. In estimating these spillovers, we rely on manufacturing data from Chile and Mexico, which also is an exception to calibrating to establishment-level data of the entire U.S. economy.

After calibrating the model, we document the reforms that took place in Chile and Korea during the periods of fast GDP growth. We find that the majority of reforms during these periods can be interpreted as the lowering of entry costs and the barriers to technology adoption in the context of our model.

We create three separate distorted economies to evaluate reforms to entry costs, barriers to technology adoption, and fixed continuation costs. The spirit of the exercise is that these distorted economies are exactly the same as the U.S. economy except for the policy distortion that we are studying. We raise one of the distortions in each economy so that the balanced growth path income level is 15 percent below that of the United States. It is important to note that, in the balanced growth path, these distorted economies grow at 2 percent per year and net entry accounts for 25 percent of aggregate productivity growth.

We then remove the distortion in each economy and study the transition to the higher balanced growth path. When we lower entry costs, the GDP growth rate rises to 4.6 percent per year for five years, and entry and exit account for 60 percent of productivity growth. In that sense, the model matches the increasing importance of firm entry and exit during periods of fast GDP growth, even though the model is calibrated so that entry and exit are relatively unimportant in the balanced growth path. We also find that the model has patterns that are similar to the neoclassical growth model. For example, immediately after a reform there is an increase in interest rates due to a boom in investment from more potential entrants paying the entry cost. The increase in interest rates discourages consumption and consumption growth temporarily declines immediately after the reform. Decreasing barriers to technology adoption in the model is quantitatively similar.

Not all reforms, however, generate the dynamics consistent with the data. When we lower fixed continuation costs in this economy, the economy experiences GDP growth, but this fast growth is accompanied by a decline in aggregate productivity. Lowering the fixed continuation cost allows less productive firms to enter and prevents less productive firms from exiting, which results in a decline in aggregate productivity during periods of fast growth in GDP. The reform also results in capital deepening: GDP increases, labor input remains fixed, and aggregate productivity falls, which implies that there are increases in the capital stock. The increase in the capital stock is due to the increased number of firms in the economy.

What do we learn from comparing the different simulations? Consider the results from the experiment in which we lower entry costs and the results of the experiment in which we lower barriers to technology adoption. Except for an increase in potential entry, the transitions in the two experiments are the same. The reason is that the increasing number of firms that try to enter and fail when entry costs are lowered push up the efficiency cutoff for successful firms to operate. This mechanism is very much in the spirit of Schumpeter (1942). Thus, we find that lowering entry costs is almost equivalent to improving the potential technology from which firms draw. Results from the experiment in which we lower the fixed continuation cost shows that reforms that increase GDP do not always increase aggregate productivity. Our result that the drop in aggregate productivity is mostly due to an increase in the net entry term of the FHK decomposition still holds even in this experiment. The experiment in which we lower fixed continuation costs is not as interesting as the other two, however, because it results in aggregate

productivity falling at the same time that GDP is rising. This is not the case in any of the episodes we study in Chile and Korea. Nor is it the case in any of the episodes we study in the literature.

Our empirical analysis is broadly related to the productivity decomposition literature, including Baily et al. (1992), Griliches and Regev (1995), Olley and Pakes (1996), Petrin and Levinsohn (2012), and Melitz and Polanec (2015), which develops methodologies for decomposing aggregate productivity. These types of decompositions are often used to study the effect of policy reform (Olley and Pakes 1996; Pavcnik 2002; Eslava et al. 2004; Bollard et al. 2013). Our work is the first to document the relationship between the importance of plant entry and exit and aggregate GDP per working-age person growth. These empirical results suggest that the entry and exit of firms is an important ingredient if we want to explain fast economic growth. It also provides empirical facts that can be used to discipline models that study productivity growth in fast growing countries. In a related paper, Garcia-Macia et al. (2016) use a calibrated model to determine that the bulk of aggregate productivity growth in the United States is due to incumbents rather than entering firms.

Our model is related to other works that attempt to understand how the FHK decomposition is related to structural models of firm entry and exit. For example, we are the first to analytically characterize the FHK productivity decomposition along the balanced growth path of a general equilibrium model with firm entry and exit. The characterizations show how the parameters of the model are related to the FHK decompositions. In other papers, such as Acemoglu et al. (2013), Arkolakis (2015), and Lentz and Mortensen (2008), the authors numerically compute the FHK decomposition using a calibrated model and compare it to the data.

Our modelling approach builds on the endogenous growth literature in which productivities are drawn from a distribution that improves over time (see Alvarez et al. 2017; Buera and Oberfield 2016; Lucas and Moll 2014; Perla and Tonetti 2014; Sampson 2016). Relative to these papers, we take a simplified approach where the productivity distribution that entrants draw from improves at an exogenous rate, which is similar to Luttmer (2007). The idea that potential entrants in any economy can draw their productivity from the frontier productivity distribution is related to the literature on technology diffusion and adoption (see Parente and Prescott 1999; Eaton and Kortum 1999; Alvarez et al. 2017).

Finally, our paper is also related to a series of papers that use quantitative models to study the extent to which entry costs can account for cross-country income differences, such as Herrendorf and Teixeira (2011), Poschke (2010), Barseghyan and DiCecio (2011), Bergoeing et al. (2011), D’Erasmus and Moscoso Boedo (2012), Moscoso Boedo and Mukoyama (2012), D’Erasmus et al. (2014), Bah and Fang (2016), and Asturias et al. (2016). Distortions in our model also drive differences in balanced growth path income levels, but our focus is on the behavior of productivity and entry and exit dynamics during the transition between balanced growth paths.

In Section 2, we use productivity decompositions to document the positive relationship between the importance of entry and exit in aggregate manufacturing productivity growth and the growth in GDP per working-age person in the economy. Section 3 lays out our dynamic general equilibrium model, and Section 4 discusses the existence and characteristics of the model’s balanced growth path. In Section 5, we discuss the measurement of productivity in the model. In Section 6, we present analytical characterizations of the FHK decomposition of the model on the balanced growth path. In Section 7, we conduct quantitative exercises to show that the calibrated model replicates the empirical relationship that we find in Section 2. Section 8 concludes and provides directions for future research.

2. Productivity Decompositions

In this section, we use Chilean and Korean manufacturing data to decompose changes in aggregate manufacturing productivity into the contribution of entering and exiting plants and the contribution of continuing plants. We find that, compared to periods of slow growth in GDP per working-age person, the entry and exit of plants accounts for a larger share of aggregate manufacturing productivity growth during years of fast growth in GDP per working-age person. We then analyze previous work on plant entry and exit and aggregate manufacturing productivity. This literature was not explicitly focused on the role of entry and exit during different kinds of growth experiences. We find, however, that previous studies support our finding that countries with fast-growing GDP per working-age person also tend to have a larger share of aggregate manufacturing productivity growth accounted for by the entry and exit of plants.

We use manufacturing data because it is more widely available than data for services. For example, we are not aware of any plant-level panel data on the service sector for Chile and Korea. Furthermore, the wider availability of manufacturing data allows us to conduct a survey of the literature to expand the analysis to a greater set of countries.

We consider a country to be in fast growth if it has a GDP per working-age person growth rate of at least 4 percent per year. To be clear, we use the terms *fast growth* and *slow growth* only in a descriptive sense to ease exposition. We find it illustrative to categorize countries as relatively fast- or slow-growing and make comparisons across the groups. In our final analysis, we regard both GDP per working-age person growth rates and the contribution of entry and exit as continuous (see Figure 3). In our model, we consider a country to be slow-growing if it is on a balanced growth path and to be fast-growing if it is in transition to a higher growth balanced growth path.

2.1. Decomposing Changes in Aggregate Productivity Growth

Our aggregate productivity decomposition follows FHK. We define the industry-level productivity of industry i at time t , Z_{it} , to be

$$\log Z_{it} = \sum_{e \in i_t} s_{eit} \log z_{et}, \quad (1)$$

where s_{eit} is the share of plant e 's gross output in industry i and z_{et} is the plant's productivity.

The industry's productivity change during the *window* of $t-1$ to t is

$$\Delta \log Z_{it} = \log Z_{it} - \log Z_{i,t-1}. \quad (2)$$

The industry-level productivity change can be written as the sum of two components,

$$\Delta \log Z_{it} = \Delta \log Z_{it}^{NE} + \Delta \log Z_{it}^C, \quad (3)$$

where $\Delta \log Z_{it}^{NE}$ is the change in industry-level productivity attributed to the entry and exit of plants and $\Delta \log Z_{it}^C$ is the change attributed to continuing plants.

The first component in (3), $\Delta \log Z_{it}^{NE}$, is

$$\Delta \log Z_{it}^{NE} = \underbrace{\sum_{e \in N_{it}} s_{eit} (\log z_{et} - \log Z_{i,t-1})}_{\text{entering}} - \underbrace{\sum_{e \in X_{it}} s_{ei,t-1} (\log z_{e,t-1} - \log Z_{i,t-1})}_{\text{exiting}}, \quad (4)$$

where N_{it} is the set of entering plants and X_{it} is the set of exiting plants. We define a plant as *entering* if it is only active at t , and *exiting* if it is only active at $t-1$. The first term, the entering plant component, positively contributes to aggregate productivity growth if entering plants' productivity levels are greater than the initial industry average. The second term, the exiting plant component, positively contributes to aggregate productivity growth if the exiting plants' productivity levels are less than the initial industry average.

The second component in (4), $\Delta \log Z_{it}^C$, is

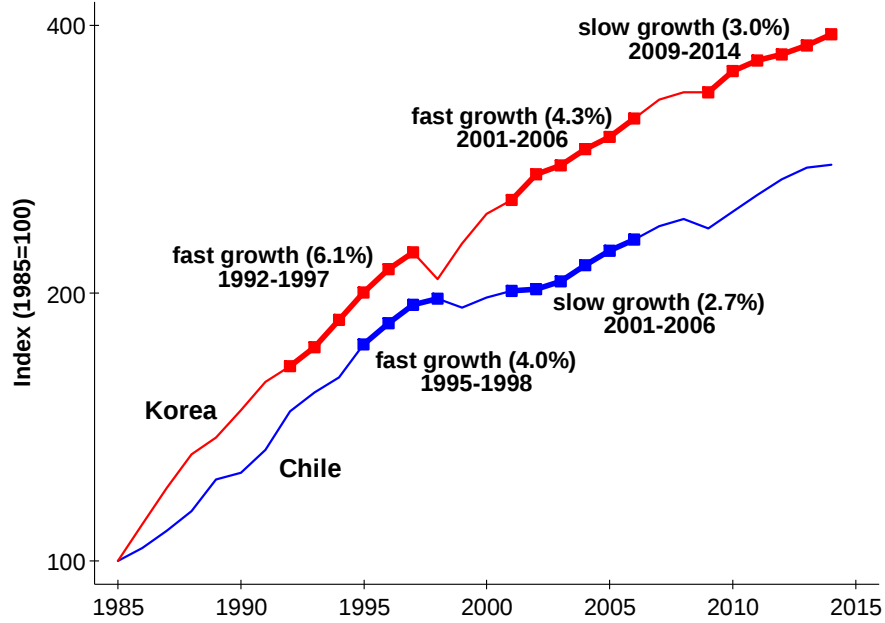
$$\Delta \log Z_{it}^C = \underbrace{\sum_{e \in C_{it}} s_{ei,t-1} \Delta \log z_{et}}_{\text{within}} + \underbrace{\sum_{e \in C_{it}} (\log z_{et} - \log Z_{i,t-1}) \Delta s_{et}}_{\text{reallocation}}, \quad (5)$$

where C_{it} is the set of continuing plants. We define a plant as *continuing* if it is active in both $t-1$ and t . The first term in (5), the within-plant component, measures productivity growth that is due to changes in the productivity of existing plants. The second term in (5), the reallocation component, measures productivity growth that is due to the reallocation of output shares among existing plants.

2.2. The Role of Net Entry in Chile and Korea

We decompose aggregate manufacturing productivity in two countries that experienced fast growth in the 1990s followed by a slowdown in the 2000s: Chile and Korea. We plot real GDP per working-age person in Chile and Korea in Figure 1. GDP per working-age person in Chile grew at an annualized rate of 4.0 percent during 1995–1998 and, in Korea, GDP per working-age person grew at 6.1 percent during 1992–1997 and 4.3 percent during 2001–2006. GDP growth in Chile slowed to 2.7 percent during 2001–2006 and, in Korea, GDP growth declined to 3.0 percent during 2009–2014. Using plant-level data from these periods, we examine how the importance of net entry in aggregate manufacturing productivity growth evolves in an economy that has fast growth in GDP per working-age person and then experiences a slowdown. The benefit of looking across multiple periods in the same country is that we can avoid cross-country differences and use consistent datasets.

Figure 1: Real GDP per working-age person in Chile and Korea.



The Chilean data is drawn from the *Encuesta Nacional Industrial Anual* dataset provided by the Chilean statistical agency, the *Instituto Nacional de Estadística*. The panel dataset covers all manufacturing establishments in Chile with more than 10 employees for the years 1995–2006. For Korea, we use the Mining and Manufacturing Surveys provided by the Korean National Statistical Office. This panel dataset covers all manufacturing establishments in Korea with at least 10 workers. We have three panels: 1992–1997, 2001–2006, and 2009–2014. The full details of the data preparation can be found in Appendix A.

The first step in the decomposition is to compute plant-level productivity. For plant e in industry i , we assume the production function is

$$\log y_{eit} = \log z_{eit} + \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit}, \quad (6)$$

where y_{eit} is gross output, z_{eit} is the plant's productivity, k_{eit} is capital, ℓ_{eit} is labor, m_{eit} is intermediate inputs, and β_j^i is the industry-specific coefficient of input j in industry i .

To define an industry, we use the most disaggregated classification possible. For the Chilean data, this is 4-digit International Standard Industrial Classification (ISIC) Revision 3. For the Korean data, depending upon the sample window, this is a Korean national system that is based

on 4-digit ISIC Revision 3 or Revision 4. To get a sense of the level of disaggregation, note that ISIC Revisions 3 and 4 have, respectively, 127 and 137 industries.

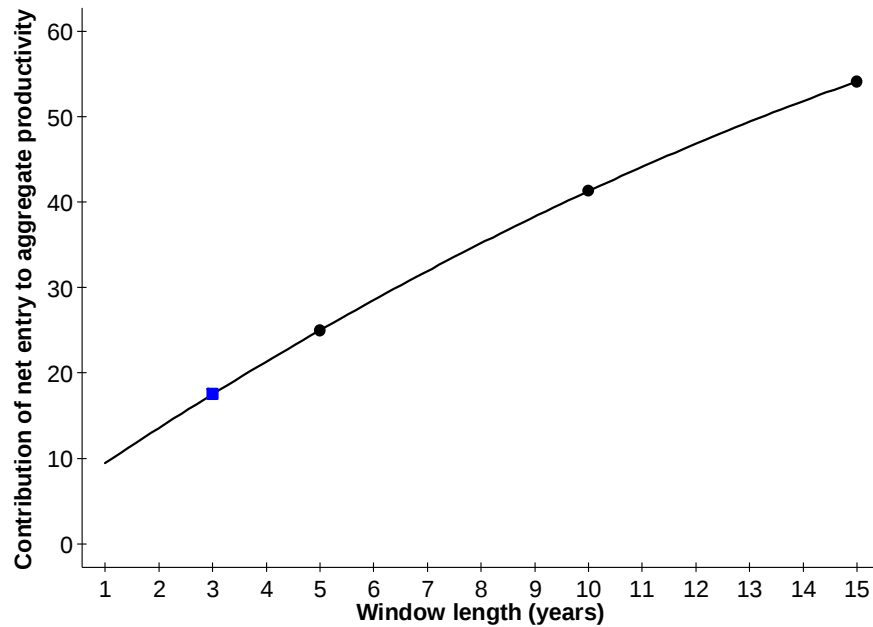
We construct measures of real factor inputs for each plant. Gross output, intermediate inputs, and capital are measured in local currencies, and we use price deflators to build the real series. For labor, we use man-years in the Chilean data and number of employees in the Korean data. Following FHK, the coefficients β_j^i are the industry-level factor cost shares, averaged over the beginning and end of each time window.

We calculate the industry-level productivity, $\log Z_{it}$, for industry i in each year using (1), and decompose these changes into net entry and continuing terms using (4) and (5). To compute the aggregate manufacturing-wide productivity change, $\Delta \log Z_t$, we weight the productivity change of each industry by the fraction of nominal gross output accounted for by that industry, averaged over the beginning and end of each time window. We follow the same process to compute the aggregate entering, exiting, and continuing terms.

Before we compare the results, we must make an adjustment for the varying lengths of the time windows considered. We face the constraint that our data for Chile that covers the fast growth period is three years: The data begin in 1995, and the period of fast growth ends in 1998. Furthermore, in Section 2.3 we describe how we supplement our own work with studies from the literature, which also use windows of varying lengths. The length of the sample window is important because longer sample windows increase the importance of net entry in productivity growth.

We use our calibrated model (discussed in Sections 3–7) to convert each measurement into 5-year equivalent windows. To do so, we compute the contribution of net entry generated by the model (on the balanced growth path) using window lengths of 5, 10, and 15 years. The contribution of net entry to aggregate productivity growth in the model is 25.0 percent when measured over a 5-year window, 41.1 percent when measured over a 10-year window, and 53.9 percent when measured over a 15-year window. Using these points, we fit a quadratic equation that relates the importance of net entry to the window length, which we plot in Figure 2. We use the fitted curve to adjust the measurements that do not use 5-year windows.

Figure 2: Contribution of net entry under various windows in the model.



The contribution of net entry to aggregate manufacturing productivity growth in Chile 1995–1998, for example, is 35.5 percent. To adjust this 3-year measurement to its 5-year equivalent, we divide the model’s net entry contribution to aggregate productivity at five years (25.0 percent) by the net entry contribution at three years (17.6 percent, the square on the curve at 3 years in Figure 2) to arrive at an adjustment factor of 1.42 ($=25.0/17.6$). The 5-year equivalent Chilean measurement is 50.4 ($=1.42 \times 35.5$) percent.

We summarize the Chilean and Korean manufacturing productivity decompositions in Table 1. We find that periods with faster GDP growth are accompanied by faster manufacturing productivity growth, and larger contributions of net entry to aggregate manufacturing productivity growth. From 1995 to 1998, Chilean manufacturing productivity experienced annual growth of 3.3 percent compared to 1.9 percent growth during the 2001–2006 period. During the period of fast growth for Chile, net entry accounts for 50.4 percent of aggregate manufacturing productivity growth, whereas it accounts for only 22.8 percent during the period with slower growth. In Korea, the manufacturing sector experienced annual productivity growth of 3.6 percent during 1992–1997 and 3.3 percent during 2001–2006, compared to 1.5 percent during 2009–2014. During the periods of fast growth, net entry accounts for 48.0 percent of aggregate

manufacturing productivity growth in 1992–1997 and 37.3 percent in 2001–2006, compared to only 25.1 percent in 2009–2014.

Table 1: Contribution of net entry in manufacturing productivity decompositions.

Period	Country	Real GDP per working-age person annual growth (percent)	Aggregate manufacturing productivity annual growth (percent)	Contribution of net entry (percent)
1995–1998	Chile	4.0	3.3	50.4*
2001–2006	Chile	2.7	1.9	22.8
1992–1997	Korea	6.1	3.6	48.0
2001–2006	Korea	4.3	3.3	37.3
2009–2014	Korea	3.0	1.5	25.1

*Measurements adjusted to be comparable with the results from the 5-year windows.

In Appendix B, we consider alternative productivity decompositions described in Griliches and Regev (1995) and Melitz and Polanec (2015). Our finding that net entry is a more important contributor to aggregate manufacturing productivity during periods of fast growth in GDP per working-age person is robust to these alternative methods. We also show that this fact is robust to using the Wooldridge (2009) extension of the Levinsohn and Petrin (2003) methodology (Wooldridge-Levinsohn-Petrin) to estimate the production function. It is also robust to using value added as weights, as opposed to gross output weights.

As a next step, we further decompose both the entering and exiting terms in (4) to investigate whether the increased importance of entry and exit is associated with changes in the relative productivities of entering and exiting plants or their market shares. Appendix C contains additional details regarding this decomposition. Table 2 reports the results. We find that during periods of fast growth in GDP per working-age person, we tend to see both the entering and exiting term contributing more to aggregate manufacturing productivity growth. It is useful to note that, as shown in (4), if the exiting term is negative then it has a positive effect on productivity growth. We find that the relative productivity of entrant and exiting plants, rather than their market shares, tends to be the most consistent driver of changes in both of these terms.

Table 2: Entering and exiting terms decomposed multiplicatively.

Period	Entering term			Exiting term		
	Entering term	Relative productivity of entrants	Entrant market share	Exiting term	Relative productivity of exiters	Exiter market share
Chile						
1995–1998*	6.6	28.1	0.24	−1.1	−5.7	0.20
2001–2006	2.5	6.8	0.36	0.2	0.9	0.23
Korea						
1992–1997	5.6	15.0	0.38	−3.7	−10.5	0.35
2001–2006	2.0	7.3	0.27	−4.6	−18.9	0.24
2009–2014	−0.6	−2.4	0.27	−2.6	−10.5	0.24

*Measurements adjusted to be comparable with the results from the 5-year windows.

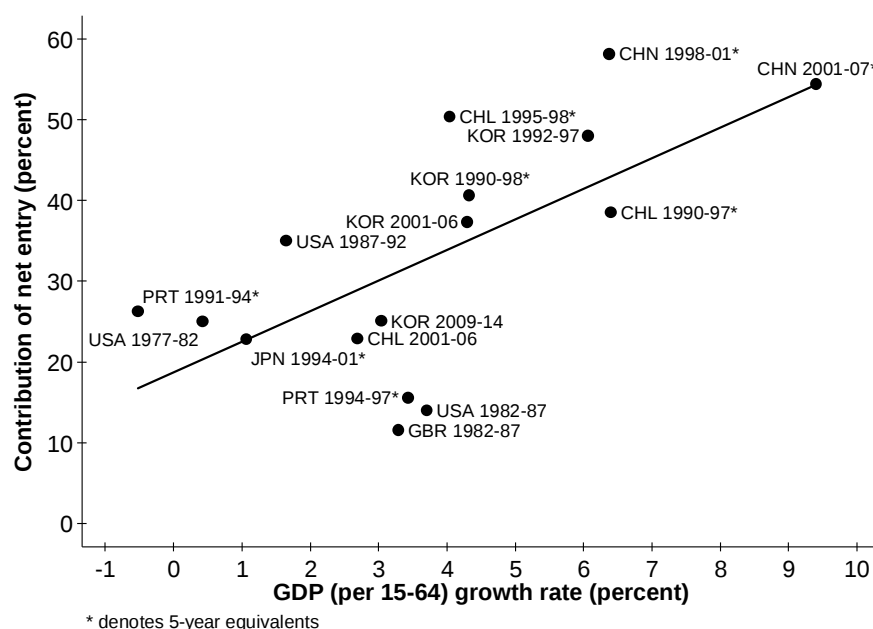
2.3. The Role of Net Entry in the Cross Section

In Section 2.2 we studied the contribution of net entry to aggregate manufacturing productivity growth in Chile and Korea, countries that experienced both fast growth in GDP per working age person and a subsequent slowdown. This is ideal because we eliminate problems that might arise from cross-country differences. We would like to study the determinants of aggregate manufacturing productivity growth in as many countries as possible, but access to plant-level data constrains the set of countries that we are able to consider. Fortunately, several researchers have used the same methodology that we describe in Section 2.1 to study countries that are growing relatively slowly (Japan, Portugal, the United Kingdom, and the United States) and countries that are growing relatively fast (Chile, China, and Korea). As mentioned before, we consider a country to grow relatively fast if it has a GDP per working-age person growth rate of at least 4 percent per year. These studies are not focused on the questions that we ask here, but their use of TFP as the measure of productivity, gross output production functions, gross output as weights, manufacturing data, and the FHK decomposition make their calculations comparable to ours for Chile and Korea.

Table 3 summarizes our findings as well as those in the literature. The sixth column in the table contains the contributions of net entry to aggregate manufacturing productivity growth as reported in the studies, and the seventh column contains the adjusted 5-year equivalents. In the first panel of Table 3, we gather results from countries with relatively slow growth rates in GDP per working-age person. In this set of countries, the contribution of net entry ranges from 12

percent to 35 percent, with an average of 22 percent. In the second panel of Table 3, we gather the results from countries with relatively high growth rates in GDP per working-age person. In this set of countries, the contribution of net entry to aggregate manufacturing productivity growth ranges between 37 and 58 percent, with an average of 47 percent.

Figure 3: The contribution of net entry and GDP growth.



In Figure 3, we summarize our findings. On the vertical axis, we plot the contribution of net entry to aggregate manufacturing productivity growth and on the horizontal axis we plot the economy's GDP per working-age person growth rate. The figure shows a clear positive correlation: The net entry of plants is more important for aggregate manufacturing productivity growth during periods of fast GDP per working-age person growth. Combining our results with studies from the literature yields a more complete picture of the relationship between GDP per working-age person growth and the contribution of net entry to aggregate manufacturing productivity growth. Note that there is also a positive relationship between aggregate productivity growth in manufacturing and net entry. This is not a surprise as the correlation between GDP per working-age person growth rates and aggregate manufacturing productivity growth rates is 0.73 and if we remove one outlier observation (Portugal 1991–1994) this correlation rises to 0.88.

Table 3: Productivity decompositions.

Country	Period	GDP/WAP growth rate	Aggregate manufacturing productivity growth rate	Window	Net entry contribution	Net entry contribution, 5-year equiv.	Source
Japan	1994–2001	1.1	0.3	7 years	29	23	Fukao and Kwon (2006)
Portugal	1991–1994	-0.5	3.0	3 years	19	26	Carreira and Teixeira (2008)
Portugal	1994–1997	3.4	2.5	3 years	11	16	Carreira and Teixeira (2008)
U.K.	1982–1987	3.3	2.9	5 years	12	12	Disney et al. (2003)
United States	1977–1982	0.4	0.5	5 years	25	25	Foster et al. (2001)
United States	1982–1987	3.7	1.4	5 years	14	14	Foster et al. (2001)
United States	1987–1992	1.6	0.7	5 years	35	35	Foster et al. (2001)
Chile	2001–2006	2.7	1.9	5 years	23	23	Authors' calculations
Korea	2009–2014	3.0	1.5	5 years	25	25	Authors' calculations
Average		2.1	1.6			22	
China	1998–2001	6.4	3.2	3 years	41	58	Brandt et al. (2012)
China	2001–2007	9.4	4.5	6 years	62	54	Brandt et al. (2012)
Chile	1990–1997	6.4	3.4	7 years	49	39	Bergoeing and Repetto (2006)
Korea	1990–1998	4.3	3.5	8 years	57	41	Ahn et al. (2004)
Chile	1995–1998	4.0	3.3	3 years	36	50	Authors' calculations
Korea	1992–1997	6.1	3.6	5 years	48	48	Authors' calculations
Korea	2001–2006	4.3	3.3	5 years	37	37	Authors' calculations
Average		5.8	3.5			47	

Notes: The third column reports annual growth rates of real GDP per working-age person (in percent) over the period of study. The fourth column reports the aggregate manufacturing productivity growth (in percent) in the manufacturing sector as described in (2). The fifth column reports the sample window's length. The sixth column reports the contribution of net entry (in percent) during the sample window using the decomposition described in (3). The seventh column reports the net entry contribution (in percent) normalized to 5-year sample windows. The eighth column reports the source of the information. All studies use TFP as the measure of productivity, use the gross output production function, use gross output shares as weights, and use manufacturing data. All studies use plants except for Brandt et al. (2012), Fukao and Kwon (2006), and Carreira and Teixeira (2008), which use firms.

3. Model

In this section, we develop a simple dynamic general equilibrium model of firm entry and exit based on Hopenhayn (1992). We model a continuum of firms in a closed economy. In the conclusion, we discuss how our model can be extended to an open economy model. Openness was undoubtedly important in the growth experiences of Chile and Korea. In this paper, however, we want to focus on the simplest possible model so that we can understand the economics of the FHK decomposition. Furthermore, when we look at the reforms implemented in both Chile and Korea during the episodes that we study, we do not find major trade reforms. In our model, the firms are heterogeneous in their marginal efficiencies and produce a single good in a perfectly competitive market. Time is discrete and there is no aggregate uncertainty.

In our model, as in Parente and Prescott (1994) and Kehoe and Prescott (2002), all countries grow at the same rate when they are on the balanced growth path, but the level of the balanced growth path depends on the distortions in the economy. We incorporate three distortions, a portion of which we interpret as being the result of government policy. First, potential firms face entry costs. Second, new firms face barriers that prevent them from adopting the most efficient technology. Third, there is a fixed continuation cost that firms must pay to operate each period. When these policy-induced barriers are reduced, the economy transits to a higher balanced growth path.

The model has three key features. First, the distribution from which potential entrants draw their efficiencies exogenously improves each period. Second, the efficiency of existing firms improves both through an exogenous process and through spillovers from the rest of the economy. Finally, firm entry and exit are endogenous, although we also allow for exogenous exit.

In terms of linking the empirical work and the model, we make two points. First, firms in the model are heterogeneous in their efficiencies. These efficiencies are not the same as the productivity that we measure in the data. When we decompose aggregate productivity growth in the model, we must compute a firm's productivity using the same process described in Section 2.2. Second, our plant-level data do not distinguish between single and multi-plant firms. Given this lack of data, we treat a plant in the data as being equivalent to a firm in our model.

3.1. Households

The representative household inelastically supplies one unit of labor to firms and chooses consumption and bond holdings to solve

$$\begin{aligned} \max \quad & \sum_{t=0}^{\infty} \beta^t \log C_t \\ \text{s.t.} \quad & P_t C_t + q_{t+1} B_{t+1} = w_t + B_t + D_t \\ & C_t \geq 0, \text{ no Ponzi schemes, } B_0 \text{ given,} \end{aligned} \quad (7)$$

where β is the discount factor, C_t is household consumption, P_t is the price of the good, q_{t+1} is the price of the one-period bond, B_{t+1} are the holdings of one-period bonds purchased by the household, w_t is the wage, and D_t are aggregate dividends paid by firms. We normalize $P_t = 1$ for all t .

3.2. Producers

In each period t , potential entrants pay a fixed entry cost, κ_t , to draw a marginal efficiency, x , from the distribution, $F_t(x)$, whose mean grows exogenously by $g_e > 1$. This entry cost is paid by the household, entitling it to the future dividends of firms that operate. After observing their efficiencies, potential entrants choose whether to operate. We refer to potential entrants that draw a high enough efficiency to justify operating as successful entrants. Potential entrants that do not draw a high enough efficiency are failed entrants. Firms that operate may exit for exogenous reasons (with probability δ), or they may endogenously exit when the firm's value is negative.

We first characterize the profit maximization problem of a firm that has chosen to operate. A firm with efficiency x uses a decreasing returns to scale production technology,

$$y = x \ell^\alpha, \quad (8)$$

where ℓ is the amount of labor used by the firm and $0 < \alpha < 1$. Conditional on operating, firms hire labor to maximize dividends, $d_t(x)$,

$$d_t(x) = \max_{\ell} x \ell_t^\alpha(x) - w_t \ell_t(x) - f_t, \quad (9)$$

where f_t is the fixed continuation cost, which is denominated in units of the consumption good.

The solution to (9) is given by

$$\ell_t(x) = \left(\frac{\alpha x}{w_t} \right)^{\frac{1}{1-\alpha}}. \quad (10)$$

Notice that labor demand is increasing in the efficiency of the firm. An important mechanism in our model is the increase in the wage that results from an inflow of relatively productive new firms.

At the beginning of each period, an operating firm chooses whether to produce in the current period or to exit. If the firm chooses to exit, its dividends are zero and the firm cannot reenter in subsequent periods. The value of a firm with efficiency x is

$$V_t(x) = \max \{d_t(x) + q_{t+1}(1 - \delta)V_{t+1}(xg_{c,t+1}), 0\}, \quad (11)$$

where $g_{c,t+1}$ is the continuing firm's efficiency growth factor from t to $t+1$. This efficiency growth factor is characterized by

$$g_{ct} = \bar{g}g_t^\varepsilon, \quad (12)$$

where $\bar{g}$ is a constant, g_t is the growth factor from $t-1$ to t of the unweighted mean efficiency of all firms that operate in each period, and ε measures the degree of spillovers from the aggregate economy to the firm. These spillovers are not important for our theory, but they are important for our quantitative results. We assume that $\bar{g} < g_e^{1-\varepsilon}$, which ensures endogenous exit in the balanced growth path.

Since $d_t(x)$ is increasing in x , $V_t(x)$ is also increasing in x , and firms operate if and only if they have an efficiency above the cutoff threshold, $\hat{x}_t$, which is characterized by

$$V_t(\hat{x}_t) = 0. \quad (13)$$

It is also useful to define the minimum efficiency of firms in a cohort of age j , $\hat{x}_{jt}$. For all firms age $j=1$, we have that $\hat{x}_{1t} = x_t$ since firms only enter if the firm's value is positive. For all firms age $j \geq 2$, $\hat{x}_{jt}$ is characterized by

$$\hat{x}_{jt} = \max \{x_t, \hat{x}_{j-1,t-1}g_{ct}\}. \quad (14)$$

If there are firms in a cohort that choose to exit, then $\bar{x}_{jt}^1 = x_t$. If no firms in the cohort choose to exit, then the minimum efficiency evolves with the efficiency of the least-efficient operating firm adjusted for efficiency growth, $\bar{x}_{jt}^1 = x_{j-1,t-1} g_{ct}$.

3.3. Entry

Upon paying the fixed entry cost, κ_t , a potential entrant draws its efficiency, x , from a Pareto distribution,

$$F_t(x) = 1 - \left(\frac{\varphi x}{g_e^t} \right)^{-\gamma}, \quad (15)$$

for $x \geq g_e^t / \varphi$. The parameter γ governs the shape of the efficiency distribution. We assume that $\gamma(1-\alpha) > 2$, which ensures that the firm size (employment) distribution has a finite variance. In the spirit of Parente and Prescott (1994), the parameter φ characterizes the barriers to technology adoption faced by potential entrants. When $\varphi > 1$, potential entrants draw their efficiencies from a distribution that is stochastically dominated by the frontier efficiency distribution. The mean of (15) is proportional to g_e^t / φ , so increasing barriers to technology adoption lowers the mean efficiency of potential entrants.

We assume that both the entry cost, $\kappa_t = \kappa g_e^t$, and the fixed continuation cost, $f_t = f g_e^t$, grow at the same rate as the potential entrant's average efficiency. In the next section, we show that these assumptions imply that the fixed costs incurred are a constant share of output per capita and thus ensure the existence of a balanced growth path. Our formulation is similar to that of Acemoglu et al. (2003), who assume that fixed costs are proportional to the frontier technology. In Appendix F, we consider an alternative model in which fixed costs are denominated in units of labor, which has the same property. We assume that the cost of entry, $\kappa = \kappa^T (1 + \tau^\kappa)$, is composed of two parts. The first, κ^T , is technological and is common across all countries. The second, $\tau^\kappa \geq 0$, is the result of policy. The fixed continuation cost is defined analogously as $f = f^T (1 + \tau^f)$.

The mass of potential entrants, μ_t , is determined by the free entry condition,

$$E_x[V_t(x)] = \kappa_t. \quad (16)$$

At time t , the mass of firms of age j in operation, η_{jt} , is

$$\eta_{jt} = \mu_{t+1-j} (1 - \delta)^{j-1} \left(1 - F_{t+1-j}(\hat{x}_{jt} / \tilde{g}_{jt}) \right), \quad (17)$$

where $\tilde{g}_{jt} = \prod_{s=1}^{j-1} g_{c,t-s+1}$ is a factor that converts the time- t efficiency of an operating firm to its initial efficiency, which is needed to index the efficiency distribution. The total mass of operating firms is

$$\eta_t = \sum_{i=1}^{\infty} \eta_{it}. \quad (18)$$

3.4. Equilibrium

The economy's initial conditions are the measures of firms operating in period zero for ages $j = 1, \dots, \infty$, given by $\{\mu_{t-j+1}, \hat{x}_{j0}, g_{c,t-j+1}\}_{j=1}^{\infty}$ and the households' bond holdings B_0 .

Definition: Given the initial conditions, an *equilibrium* is sequences of minimum efficiencies $\{\hat{x}_{jt}\}_{t=0}^{\infty}$ for $j = 1, \dots, \infty$, masses of potential entrants $\{\mu_t\}_{t=0}^{\infty}$, masses of operating firms $\{\eta_t\}_{t=0}^{\infty}$, firm allocations, $\{y_t(x), \ell_t(x)\}_{t=0}^{\infty}, x > 0$, prices $\{w_t, q_{t+1}\}_{t=0}^{\infty}$, aggregate dividends and output $\{D_t, Y_t\}_{t=0}^{\infty}$, and household consumption and bond holdings $\{C_t, B_{t+1}\}_{t=0}^{\infty}$, such that, for all $t \geq 0$:

1. Given $\{w_t, D_t, q_{t+1}\}_{t=0}^{\infty}$, the household chooses $\{C_t, B_{t+1}\}_{t=0}^{\infty}$ to solve (7).
2. Given $\{w_t\}_{t=0}^{\infty}$, the firm with efficiency $x > 0$ chooses $\{\ell_t(x)\}_{t=0}^{\infty}$ to solve (9).
3. The mass of potential entrants is characterized by the free entry condition in (16).
4. The mass of operating firms is characterized by (17) and (18).
5. The labor market clears,

$$1 = \sum_{j=1}^{\infty} \left[\mu_{t+j-1} (1 - \delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} \ell_t(x) dF_{t+j-1}(x / \tilde{g}_{jt}) \right]. \quad (19)$$

6. Entry-exit thresholds $\{\hat{x}_{jt}\}_{t=0}^{\infty}$ satisfy conditions (13) and (14) for all $j = 1, \dots, \infty$.
7. The bond market clears, $B_{t+1} = 0$.
8. The goods market clears,

$$C_t + \eta_t f_t + \mu_t \kappa_t = Y_t = \sum_{j=1}^{\infty} \left[\mu_{t+j-1} (1-\delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} x \ell_t(x)^\alpha dF_{t-j+1}(x / \tilde{g}_{jt}) \right]. \quad (20)$$

9. Aggregate dividends are the sum of firm dividends less entry costs,

$$D_t = \sum_{j=1}^{\infty} \left[\mu_{t+j-1} (1-\delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} d_t(x) dF_{t-j+1}(x / \tilde{g}_{jt}) \right] - \mu_t \kappa_t. \quad (21)$$

4. Balanced Growth Path

In this section, we define a balanced growth path for the model described in Section 3 and prove its existence. We also conduct comparative statics exercises to show how the output level on the balanced growth path depends on entry costs, fixed continuation costs, and barriers to technology adoption.

4.1. Definition and proof of existence

Definition: A *balanced growth path* is an equilibrium, for the appropriate initial conditions, such that the sequences of wages, output, consumption, dividends, and entry-exit thresholds grow at rate $g_e - 1$, and bond prices, measures of potential entrants, and measures of operating firms are constant. In the balanced growth path, for all $t \geq 0$ and $j \geq 1$,

$$\frac{w_{t+1}}{w_t} = \frac{Y_{t+1}}{Y_t} = \frac{C_{t+1}}{C_t} = \frac{D_{t+1}}{D_t} = \frac{\hat{x}_{j,t+1}}{\hat{x}_{jt}} = g_e, \quad (22)$$

and $q_{t+1} = \beta / g_e$, $\mu_t = \mu$, $\eta_t = \eta$.

Proposition 1. A *balanced growth path* exists.

Proof: On the balanced growth path, the profitability of a firm declines over time because of the continual entry of firms with higher efficiencies. Thus, once a firm becomes unprofitable, it exits, which implies that the cutoff efficiency is characterized by the static zero-profit condition, $d_t(\hat{x}_t) = 0$. Furthermore, firms of every age endogenously exit each period, so $\hat{x}_{jt}^1 = x_t$ for all $j \geq 1$. The mass of operating firms is

$$\eta(\kappa, f, \varphi) = \frac{\gamma(1-\alpha)-1}{\lambda(\kappa, f, \varphi) f^\gamma}, \quad (23)$$

where $\lambda(\kappa, f, \varphi) = g_e^t / Y_t(\kappa, f, \varphi)$, which is constant in the balanced growth path. Thus, the entry cost is a constant share of output per capita,

$$\lambda(\kappa, f, \varphi)\kappa = \frac{\kappa_t}{Y_t(\kappa, f, \varphi)}. \quad (24)$$

An analogous argument proves that the fixed continuation cost is also a constant share of output per capita. The mass of potential entrants is

$$\mu(\kappa, f, \varphi) = \frac{\xi}{\lambda(\kappa, f, \varphi)\kappa\gamma\omega}, \quad (25)$$

where ξ and ω are positive constants. The cutoff efficiency to operate is given by

$$\hat{\kappa}_t(\kappa, f, \varphi) = \frac{g_e^t}{\varphi} \left[\omega \frac{\mu(\kappa, f, \varphi)}{\eta(\kappa, f, \varphi)} \right]^{\frac{1}{\gamma}}, \quad (26)$$

which, because $\mu(\kappa, f, \varphi)$ and $\lambda(\kappa, f, \varphi)$ are constants, grows at rate $g_e - 1$.

Since the cutoffs grow at rate $g_e - 1$, the other aggregate variables related to income also grow at rate $g_e - 1$,

$$Y_t(\kappa, f, \varphi) = \left[\frac{\gamma(1-\alpha)}{\gamma(1-\alpha)-1} \eta(\kappa, f, \varphi) \right]^{1-\alpha} \hat{\kappa}_t(\kappa, f, \varphi), \quad (27)$$

$$w_t(\kappa, f, \varphi) = \alpha Y_t(\kappa, f, \varphi), \quad (28)$$

$$D_t(\kappa, f, \varphi) = \frac{\omega - \xi}{\gamma\omega} Y_t(\kappa, f, \varphi). \quad (29)$$

From the household's first order conditions, the bond price is given by $q_{t+1} = \beta / g_e$. Finally,

$$\lambda(\kappa, f, \varphi) = f^{\frac{\gamma(1-\alpha)-1}{\alpha\gamma}} \varphi^{\frac{1}{\alpha}} \kappa^{\frac{1}{\alpha\gamma}} \nu, \quad (30)$$

where ν is a positive constant. Appendix D contains further details. $\square$

How does the improving efficiency distribution of new firms generate growth? Each entering cohort of firms has a higher average efficiency than the previous cohort. These more-efficient firms increase the demand for labor, as seen in (10), increasing the wage and the

efficiency needed to operate. Thus, inefficient firms from previous generations are replaced by more efficient firms.

The balanced growth path has the interesting feature that, although there is efficiency growth among continuing firms, long-run output growth in the economy is solely determined by the improving efficiency of potential entrants, g_e . This is due to endogenous selection: Because inefficient firms exit, the remaining incumbents are more efficient than the previous cohort of incumbents by a factor of g_e . Furthermore, if two economies have the same g_e , they grow at the same rate, regardless of their entry costs, barriers to technology adoption, or fixed continuation costs. The cross-country differences in these parameters map into differences in the level of output on the balanced growth path.

4.2. Comparative Statics

We conduct comparative statics to understand the mechanisms through which lowering distortions raises output. Three points are worth mentioning. First, as seen in (27), income can rise because of an increase in the mass of operating firms or an increase in the efficiency cutoffs. Second, each policy change has both direct and indirect effects. The indirect effect is summarized by changes in $\lambda(\kappa, f, \varphi)$, which relates the size of fixed costs to output, as shown in (24). Finally, it is useful to know that ξ , ω , and ν are positive constants that do not depend on κ , φ , or f , whereas $\lambda(\kappa, f, \varphi)$ is increasing in each of its arguments.

We now show that each reform operates through different channels. We focus on the direct effect and thus hold $\lambda(\kappa, f, \varphi)$ fixed. First, consider an economy that decreases its entry cost, κ . Lower entry costs lead to an increase in the mass of potential entrants in (25), which increases the cutoff efficiency in (26). The increase in the cutoff efficiency results in an increase in output in (27). Second, when a country lowers the barriers to technology adoption, φ , there is an increase in the efficiency threshold in (26), which increases output. In contrast to the decline in entry costs, the mass of potential entrants remains unchanged. Rather, efficiency thresholds increase due to firms having access to a better efficiency distribution. Finally, consider a reduction in the fixed continuation cost, f . Equation (23) shows that this leads to an increase in the mass of operating firms. There are two resulting contradictory effects. On one hand, the

increase in the mass of operating firms lowers the efficiency cutoffs in (26) which lowers output in (27). On the other hand, the increase in the mass of operating firms also raises output in (27). We can show that the latter effect dominates. Thus, lowering fixed continuation costs raises output and, in contrast to reforms to entry costs and barriers to technology adoption, lowers efficiency cutoffs.

All of the reforms we discuss above have the same indirect effect through changes in $\lambda(\kappa, f, \varphi)$. A reduction in entry costs, barriers to technology adoption, or fixed continuation costs have the indirect effect of decreasing the fixed costs relative to output. This increases both the mass of operating firms in (23) and the mass of potential entrants in (25). The increase in the mass of operating firms results in an increase in output in (27). Note that these indirect effects have no impact on efficiency thresholds. To see how this is the case, substitute (23) and (25) into (26).

5. Measurement

We need to define the capital stock of firms in the model so that we can measure productivity in the model in the same way we measure it in the data. When a new firm is created, the firm invests $\kappa_t + f_t$ units of consumption to create $\kappa_t + f_t$ units of capital. We assume that, in each period, the capital stock depreciates by $f_t - (\kappa_{t+1} - \kappa_t)$ and, if the firm continues to operate, it invests f_{t+1} . This implies that the firm's capital stock in $t + 1$ is

$$k_{t+1} = \kappa_t + f_t - [f_t - (\kappa_{t+1} - \kappa_t)] + f_{t+1} = \kappa_{t+1} + f_{t+1}. \quad (31)$$

This formulation implies that all firms have the same capital stock, which keeps the model tractable. The complete details are available in Appendix E. In Appendix G, we also report the quantitative results from an alternative model in which labor is a composite of variable labor and variable capital. We find that the results are qualitatively similar but the contribution of entry and exit to aggregate productivity growth during periods of fast GDP growth is larger.

The productivity z of a firm with efficiency x is measured as

$$\log[z_t(x)] = \log[y_t(x)] - \alpha_{\ell t} \log[\ell_t(x)] - \alpha_{kt} \log(k_t), \quad (32)$$

where $\alpha_{\ell t} = w_t / Y_t$ is the labor share, $\alpha_{kt} = R_t K_t / Y_t$ is the capital share, $R_t = 1 / q_t - 1 + \delta_{kt}$ is the rental rate of capital, K_t is the aggregate capital stock, and δ_{kt} is the aggregate depreciation rate.

Note that P_t has been normalized to 1 in our model, which implies that $y_t(x) = P_t y_t(x)$. This is identical to the way productivities and factor shares are computed in Section 2, with the exception that we do not have intermediate goods in our model. In Appendix E, we provide the derivation of the aggregate depreciation rate, which is constant in the balanced growth path but not in the transition. Once we measure firm productivity, we calculate aggregate productivity and the FHK decompositions using the model-generated data as described in (4) and (5).

It is useful to discuss how measured productivity is related to efficiency in the model. We substitute the production function in (8) into (32) and use the fact that $\alpha_{tt} = \alpha$ to obtain

$$\log[z_t(x)] = \log x - \alpha_{kt} \log(\kappa_t + f_t). \quad (33)$$

Thus, measured productivity and efficiency are tightly linked, the only difference being the last term, which is common across all firms. It follows that, in the balanced growth path, the aggregate productivity growth rate is smaller than the GDP growth rate, g_e , due to the growth of capital. In particular, we have that

$$\Delta \log Z_{it} = (1 - \alpha_k) \log g_e. \quad (34)$$

6. Analytical Characterizations of the FHK Decomposition

A strength of our modeling approach is that we can recover analytic expressions for the FHK productivity decomposition on the balanced growth path. This allows us to understand how the parameters of our model are connected to the terms in the decomposition. In the balanced growth path, the decomposition is

$$\frac{\Delta \log Z^{Entry}}{\Delta \log Z} = 1 - (1 - \delta) \left(\frac{g_c}{g_e} \right)^\gamma, \quad (35)$$

$$-\frac{\Delta \log Z^{Exit}}{\Delta \log Z} = (1 - \delta) \left(\frac{g_c}{g_e} \right)^{\gamma \frac{1}{1-\alpha}} \frac{\log(g_e) - \log(g_c)}{(1 - \alpha_k) \log(g_e)}, \quad (36)$$

$$\frac{\Delta \log Z^C}{\Delta \log Z} = (1 - \delta) \left(\frac{g_c}{g_e} \right)^{\gamma \frac{1}{1-\alpha}} \left[\left(\frac{g_c}{g_e} \right)^{\frac{1}{1-\alpha}} - \frac{\log(g_e) - \log(g_c)}{(1 - \alpha_k) \log(g_e)} \right], \quad (37)$$

where $\Delta \log Z^{Entry}$ is the entering component in (4), $\Delta \log Z^{Exit}$ is the exiting component in (4), and $\Delta \log Z^C$ is defined in (5). The contribution of net entry to aggregate productivity growth is $(\Delta \log Z^{Entry} - \Delta \log Z^{Exit}) / \Delta \log Z$. To generate endogenous exit in the balanced growth path, we assume that $\bar{g} < g_e^{1-\varepsilon}$, which implies that $g_c < g_e$. Thus, the contribution of entry is bounded between δ and 1.

Before we discuss the relationship between model parameters and the importance of net entry, note that, in the balance growth path, the FHK decomposition of aggregate productivity growth, like the GDP growth rate, does not depend on the policy distortions ϕ , τ^κ , and τ^f . Any country on a balanced growth path, regardless of its levels of distortions, has the same FHK decomposition.

The analytic decompositions in (35)–(37) highlight the three fundamental forces that drive aggregate productivity growth in the model: firm turnover, related to δ ; firm heterogeneity and selection, governed by γ ; and productivity growth in incumbent firms relative to entrants, determined by g_e and g_c . We turn to comparative statics to demonstrate these relationships.

To understand the ways that firm turnover shape the decompositions, first consider the case in which δ , the exogenous death probability, is one: All firms die at the end of each period. In this case, all aggregate productivity growth is attributed to entering firms. The contribution of the exiting term is zero because it depends on the difference between the productivity of exiting firms and the overall productivity in the prior period when these firms were active, which, in this case, is zero since the two sets of firms are identical.

As δ falls, more firms remain in operation from one period to the next and the fraction of productivity growth that is attributed to continuing firms increases. The contribution of firm exit also increases. The larger mass of incumbent firms implies a larger mass of firms that endogenously exit. Finally, since a smaller δ implies less exit and thus less entry, the contribution from entry to aggregate productivity growth falls.

Firm heterogeneity in the balanced growth path is a function of the heterogeneity in the underlying distribution of entrant productivity, which is governed by γ . To see how firm heterogeneity affects the FHK productivity decomposition, consider the limiting case in which γ approaches infinity. Since $g_c < g_e$, the entry term accounts for all of aggregate productivity

growth. When γ approaches infinity, there is no heterogeneity within each cohort. The lack of heterogeneity in each cohort, along with the fact that entrants have higher productivities, implies that entrants will displace all of the continuing firms. In this case, even though the incumbent firms exit endogenously, they do not contribute to aggregate productivity growth because their productivity is the same as the average productivity in the previous period. If there is no selection, exit does not contribute to aggregate productivity growth.

As γ decreases, heterogeneity within each cohort increases. As a result, the entry term becomes less important. Greater heterogeneity implies that there are high-productivity incumbent firms that do not exit. This also implies that the continuing component becomes more important, as more firms from previous cohorts remain. The importance of the exiting component also increases, as the larger mass of continuing firms induces selection, forcing out firms that are relatively inefficient compared to continuing firms.

How does the difference in entrant and incumbent efficiency growth rates shape the productivity decomposition? Suppose $g_c = g_e$. This implies that the efficiency distributions of entering and continuing firms are the same. To see why, consider a cohort of firms that enters in period t . In period $t+1$, the efficiency distribution of the cohort has increased by a factor of g_c . Since $g_c = g_e$, the distribution of efficiencies of the cohort of entering firms is the same as the cohort that entered the previous period. In this case once a firm enters, it will only exit through exogenous death. The reason is that the firm cutoffs grow at g_e , which is the same growth factor as the efficiencies of continuing firms. Since the efficiency distributions are identical, the contribution of entering firms is equal to their market share, which is given by the exogenous death probability of existing firms, δ , and the contribution of continuing firms is characterized by their market share, $1-\delta$. Exiting firms do not contribute to productivity growth since their productivity is the same as the average productivity in the previous period.

In the general case in which $g_c < g_e$, the entering term always decreases with g_c . We can similarly show that the exiting term is decreasing in g_c whenever

$$\log\left(\frac{g_e}{g_c}\right)g_e < \frac{1-\alpha}{\gamma(1-\alpha)-1}. \quad (38)$$

In Section 7, we find that this condition is satisfied with the calibrated parameters. Thus, in the range of parameters we consider, the importance of entry and exit declines with g_c .

The balanced growth path analytics make it easy to see how firm turnover, selection, and the entrant productivity advantage shape the contribution of net entry to aggregate productivity growth. We cannot analytically characterize the decompositions off of the balanced growth path, but the intuition we have developed here will carry over.

7. Quantitative Exercises

We now take our model to the data. We begin by calibrating the model so that it replicates key features of the entire U.S. economy. We think of the U.S. economy as being distortion-free, $\tau^f = \tau^k = 0$ and $\varphi = 1$, so the calibration identifies the model's technological parameters. A period in the model is five years, the same length as the time window for the productivity decompositions.

After calibrating the model, we create three separate distorted economies that have income levels that are 15 percent below that of the United States. The first distorted economy is the same as the United States except that entry costs are higher. Similarly, the second and third distorted economies are the same as the United States except for higher barriers to technology adoption and higher fixed continuation costs respectively. We then introduce a reform into each of these distorted economies to determine whether the reforms can quantitatively match the relationships that we observe in the data regarding GDP growth and the importance of entry and exit.

We find that the reforms to entry costs and barriers to technology adoption result in growth in GDP and aggregate productivity. Furthermore, we find that both of these reforms induce similar transition dynamics, including the importance of entry and exit in productivity growth, during the reform. One important difference between the two reforms is that the mass of potential entrants increases more in the reform to entry costs. Even though the efficiency distribution of the potential entrants remains the same when entry costs are lowered, the increase in the mass of potential entrants increases the efficiency threshold. Thus, we find that lowering entry costs is almost equivalent to improving the efficiency distribution of potential entrants through the lowering of barriers to technology adoption. Finally, we find that the reform to the fixed continuation cost causes an increase in GDP but results in a decline in aggregate

productivity, which is not consistent with the data on Chile and Korea nor the evidence of other episodes from the literature.

It is worth noting that Y_t in the model is real GDP. Equation (20) shows that Y_t is the sum of all consumption and investment in the economy. Furthermore, because the labor endowment is constant in the model, growth in Y_t is the same as growth in real GDP per working age person.

7.1. Calibration

A summary of the calibrated parameters is given in Table 4. We set the fixed continuation cost, f^T , so that the model generates an average establishment size of 14.0 employees, which is the mean during the period of 1976 to 2000 as found in U.S. Census Bureau (2011). We set κ^T so that the ratio of the entry cost to the annual fixed continuation cost, $\kappa^T / (f^T / 5)$, is 0.82, which is consistent with the findings of Barseghyan and DiCecio (2011) who survey the empirical literature on entry and continuation costs. We calibrate the tail parameter, γ , to match the standard deviation of establishment employment, which has an average value of 89.0 between 1976 and 2000 according to U.S. Census Bureau (2011). The exogenous death rate, δ , is set so that exiting plants destroy 19.3 percent of employment every five years, which is the average between 1976 and 2000 according to U.S. Census Bureau (2011).

We assume that the FHK decomposition for aggregate manufacturing productivity growth assigns the same proportions to entry and exit as would a productivity decomposition for the entire economy. We set $\bar{g}$, which determines the efficiency growth rate of continuing firms, to match the contribution of entry and exit to U.S. aggregate manufacturing productivity growth, which FHK find to be 25 percent.

Table 4: Calibrated parameters.

Parameter		Value	Target
Operating cost (technological)	f^T	0.46×5	Average U.S. establishment size: 14.0
Entry cost (technological)	κ^T	0.38	Entry cost / continuation cost: 0.82
Tail parameter	γ	6.10	S.D. of U.S. establishment size: 89.0
Entrant efficiency growth	g_e	1.02 ⁵	BGP growth rate of U.S.: 2 percent
Returns to scale	α	0.67	BGP labor share of U.S.: 0.67

Death rate	δ	$1 - 0.96^5$	Exiting plant employment share of U.S.: 19.3 percent
Discount factor	β	0.98^5	Real interest rate of U.S.: 4 percent
Firm growth	$\bar{g}$	1.006^5	Effect of entry and exit on U.S. manufacturing productivity growth: 25 percent

We next pin down ε , which characterizes the relationship between continuing-plant and aggregate efficiency growth. In the data, we observe an increase in the productivity growth of continuing plants when there is an increase in industry-level productivity growth. Ideally, for this exercise we would like to use data for all U.S. plants, but without access to this data, we use data for Chilean and Korean manufacturing plants. To quantify this relationship, we take the logarithm of (12)

$$\log g_{ct} = \log \bar{g} + \varepsilon \log g_t, \quad (39)$$

to arrive at an equation that we can estimate using plant-level data. Using ordinary least squares, we estimate

$$\log g_{ct,i} = \beta_0 + \varepsilon \log g_{it} + \nu_{it}. \quad (40)$$

where $g_{ct,i}$ is the productivity growth of continuing plants of industry i (weighted by the gross output of plants), g_{it} is the aggregate productivity growth in industry i , and ν_{it} is an error term. In the data, a continuing plant is one that is present at both the beginning and the end of the sample window. Although ε governs the growth rate of continuing-firm efficiency, we use productivity data to estimate (40). The estimated ε is correct, however, since log productivity is a linear transformation of log efficiency. The constant term in the regression is not an estimate of $\bar{g}$.

Table 5: Productivity spillover estimates.

	Chile		Korea		
	1995–1998	2001–2006	1992–1997	2002–2007	2009–2014
Industry productivity growth	0.720*** (0.051)	0.834*** (0.054)	0.551*** (0.079)	0.700*** (0.036)	0.378*** (0.043)
Observations	92	89	138	170	179
Adj. R-squared	0.69	0.73	0.26	0.69	0.30

Notes: Estimates of (40) using plant-level data from Chile and Korea. Standard errors are reported in parentheses.
 *** Denotes $p < 0.01$.

Table 5 reports the results of the regression across the five windows that we study. We find that the regression coefficient ranges from 0.38 to 0.70 for Korea and 0.72 to 0.83 for Chile. We use the average over the five estimates to find that $\varepsilon = 0.64$. One concern is that, whereas we are calibrating the model to an economy that is on the balanced growth path, we estimate ε using plant-level data for countries that are not on a balanced growth path. However, we do not see any systematic relationship between the regression coefficient and whether the economy is in a period of fast growth. Nonetheless, in Appendix H, we also explore the robustness of our quantitative results to changing ε . The quantitative results show that the model matches the positive correlation between fast growth and the contribution of net entry for ε ranging from 0.38 to 0.83.

We now compare the efficiency growth rates of continuing and entering firms in the calibrated economy. As mentioned before, the efficiency distribution of entering plants has a growth factor of $g_e = 1.02^5$. We use (12) to compute the efficiency growth factor of continuing firms and arrive at $g_c = 1.019^5$, using the fact that average efficiency grows by g_e in the balanced growth path. Note that condition (38), which is the condition under which increases in g_c lead to a decline in the importance of entry and exit, is satisfied under the calibrated parameters.

7.2. Policy Reforms in Chile and Korea

We summarize the key reforms conducted in Chile and Korea during the periods of fast growth in Appendix I. For Chile, we consider reforms in the 1993–1997 period, affecting the 1995–1998 window. For Korea, we consider reforms in the 1990–1995 period and the 1998–2004 period, affecting the 1992–1997 window and the 2002–2007 window, respectively.

We attempt to map these reforms to changes in the policy variables in our model, which are entry and fixed continuation costs and barriers to technology adoption. We find that the types of reforms that Chile and Korea undertook are mostly consistent with the lowering of entry costs and barriers to technology adoption. For example, we find that both Chile and Korea relaxed FDI restrictions, which reduces the barriers to technology adoption as it improves access to foreign

technologies. Similarly, both of these countries made reforms to the financial system, making it easier for firms to finance large up-front costs and, in that sense, lower barriers to technology adoption and entry costs. It is worth noting that Midrigan and Xu (2014) use a model of establishment dynamics with financial frictions calibrated to Korean manufacturing plants and find that financial frictions primarily distort entry and technology adoption decisions. Finally, the Korean government instituted pro-competitive reforms to allow for greater competition, which lowers entry costs.

We do not find that either Chile or Korea implemented major trade reforms during the periods of fast growth. It is worth noting, however, that the literature on trade and productivity emphasizes improvements in the efficiency distribution of firms resulting from a trade reform. In that sense, reforms to barriers to technology adoption in the model has features that resemble the efficiency gains emphasized by this literature. For instance, Sampson (2016) builds a model in which potential entrants draw efficiencies from a distribution that is related to the efficiency of incumbent firms. In this model, trade reforms lead to the exit of unproductive firms, which results in the improvement of the efficiency distribution that entrants draw from. Perla et al. (2015) and Buera and Oberfield (2016) also build models in which trade reforms lead to an improvement in the efficiency distribution that firms draw from.

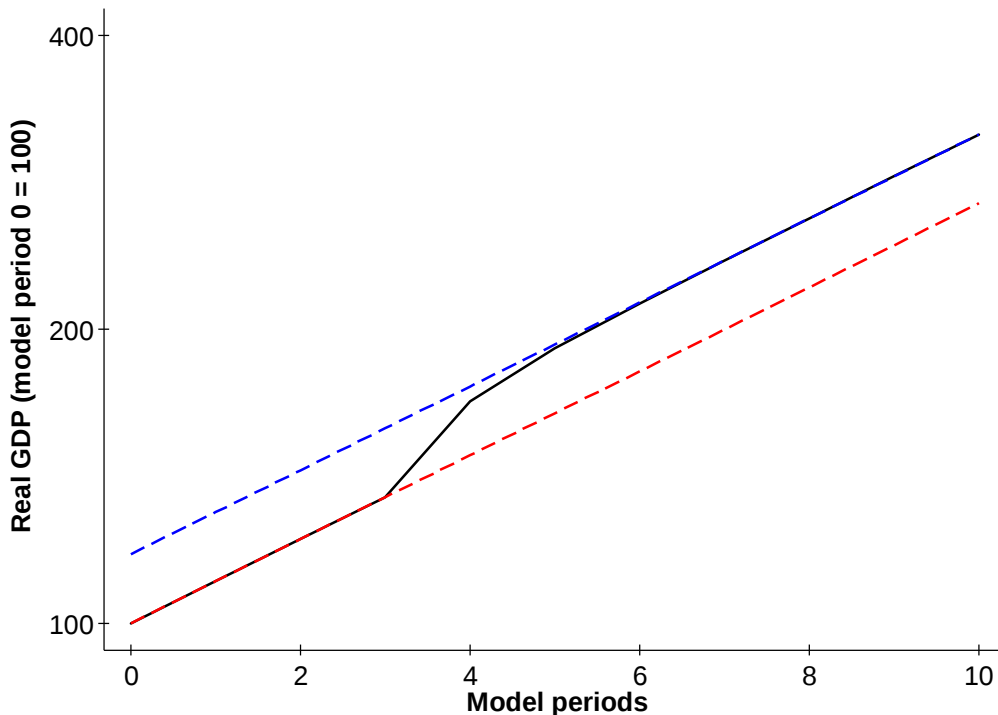
7.3. Policy Reforms in the Model

In this section, we consider policy reforms that move the economy to a higher balanced growth path by lowering either entry costs, barriers to technology adoption, or the fixed continuation costs. The goal of these experiments is to determine whether these types of reforms can quantitatively account for the contribution of entry and exit to productivity growth during periods of fast GDP growth. Although the reforms that Chile and Korea conducted over this period are most similar to reducing entry costs and barriers to technology adoption, we also examine the quantitative results of reductions in the fixed continuation costs.

We first create three separate distorted economies. Each economy is parameterized as the U.S. economy, with one exception. In the first distorted economy, we increase the policy-related portion of the entry costs, τ^k , so that GDP on the balanced growth path is 15 percent lower than in the nondistorted economy. In the second and third distorted economies, we raise the barriers to technology adoption, φ , and the policy-related portion of the fixed continuation cost, τ^f , so

that GDP on the balanced growth path also declines 15 percent respectively in each of these economies. This requires setting $\kappa = 0.74$ and $\varphi = 1.12$ and $f = 4.48$.

Figure 4: Real GDP (entry cost reform).



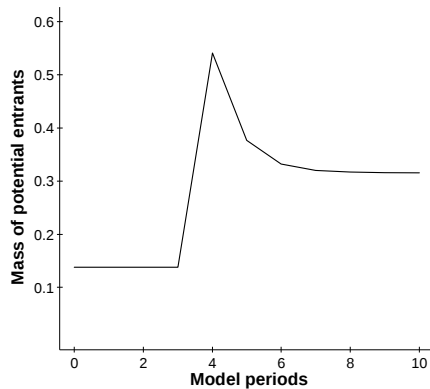
We institute a reform by eliminating the distortion in each economy and then studying the transition to the new balanced growth path. We begin by reporting the results of the reform that reduces entry costs. In Figure 4, we plot the GDP of the economy. The transition of the economy is quick and within two model periods the economy is very close to converging to the new balanced growth path. GDP grows 4.6 percent annually in the initial 5-year period after the reform and quickly declines to 2 percent.

To understand the mechanisms at work in the model, we plot key economic variables during the transition. The smaller entry costs leads to a permanent increase in the mass of potential entrants, as seen in Figure 5(a). The increase in the mass of potential entrants leads to an increase in the efficiency threshold needed for an entrant to successfully operate. There is also an increase in the mass of failed entrants. In Figure 5(b), we plot the efficiency threshold, normalizing the first period value to 100. The series has been detrended by dividing the threshold by g_e^t so that the detrended efficiency threshold is constant when the economy is on the balanced growth path.

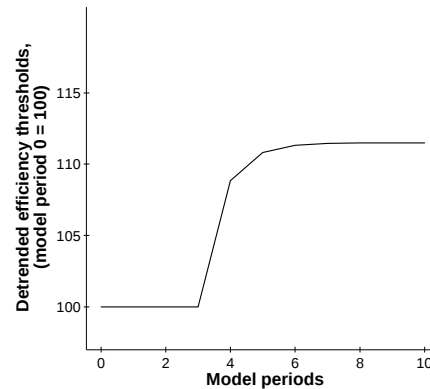
Note that we have exit in each cohort, so the threshold efficiency level is the same for all incumbents and successful entrants.

Figure 5: Potential entrants and efficiency thresholds (entry cost reform).

(a) Mass of potential entrants



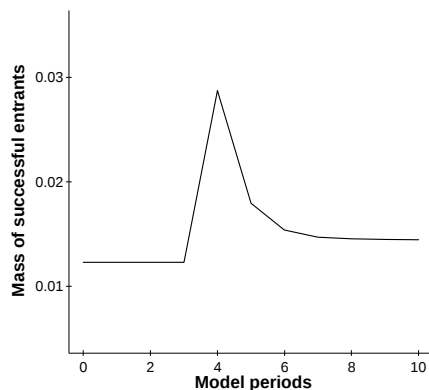
(b) Detrended efficiency thresholds



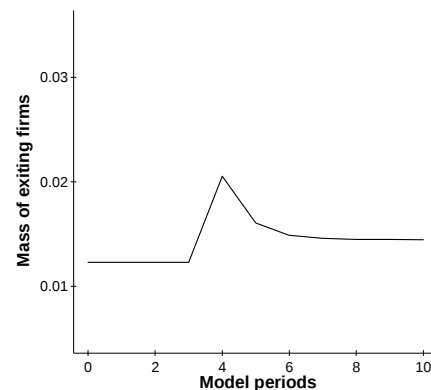
In Figure 6, we plot firm entry and exit. The reform leads to a spike in firm turnover during the transition, and firm turnover is permanently higher on the new balanced growth path. We also see that during the transition, relatively inefficient firms exit and relatively efficient firms enter, which drives the increased importance of entry and exit for productivity growth during periods of fast growth in GDP.

Figure 6: Firm entry and exit (entry cost reform).

(a) Mass of successful entrants



(b) Mass of exiting firms



Other model variables exhibit patterns similar to the neoclassical growth model. We plot consumption and interest rates in Figure 7. To understand their behavior, recall that creating new

firms is investment: The household foregoes consumption to create long-lived firms that generate increases in future income. Decreasing entry costs leads to an increase in the demand for potential entrants. As a result, there is an increase in the interest rate during the reform and a decline in consumption growth. As the investment boom subsides, consumption rises to its new balanced growth path value.

Figure 7: Consumption and interest rates (entry cost reform).

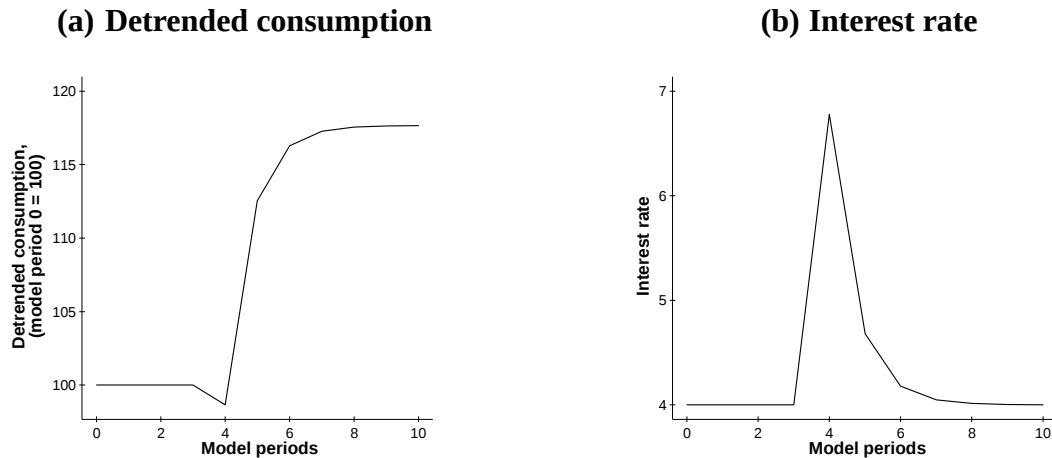


Table 6 reports the GDP and productivity growth rates and the contribution of net entry to productivity growth when we decrease entry costs in the model. Before the reform, the calibrated economy is on a balanced growth path in which GDP grows at 2 percent per year and net entry contributes 25 percent of aggregate productivity growth. During the reform period, GDP grows at an annualized rate of 4.6 percent and there is a surge in the contribution of net entry to 59.6 percent. Note that increases in the aggregate capital stock imply that productivity growth is smaller than in GDP growth.

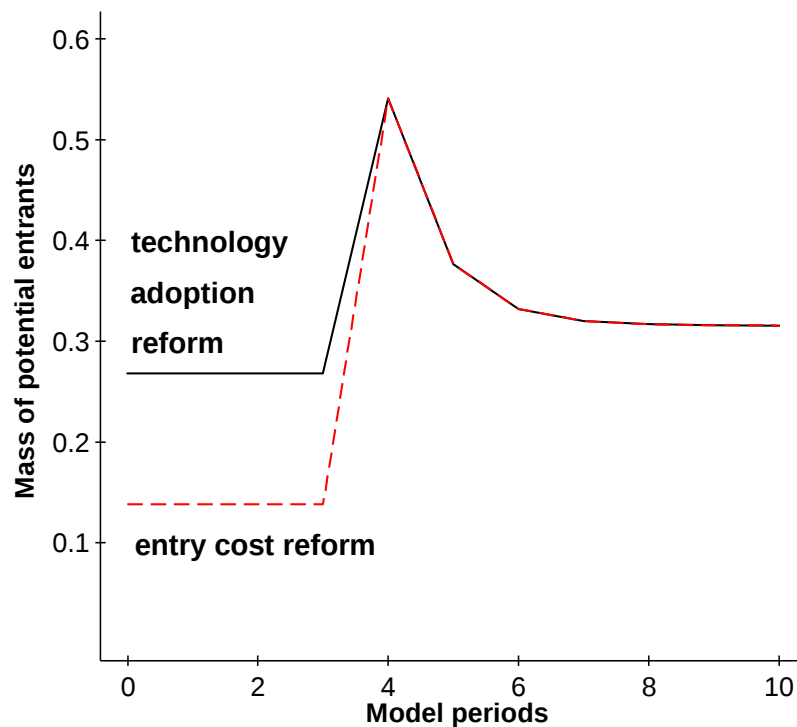
Table 6: Productivity decompositions (entry cost reform).

Model periods (five years)	Entry cost	Real GDP growth (percent, annualized)	Aggregate productivity growth (percent, annualized)	Contribution of net entry to aggregate productivity (percent)
0–3	0.74	2.0	1.3	25.0
4 (reform)	0.38	4.6	2.9	59.6
5	0.38	2.5	1.5	36.5
6	0.38	2.1	1.3	28.1
7+	0.38	2.0	1.3	25.0

Our second reform, lowering the barriers to technology adoption (φ), generates similar outcomes as lowering entry costs. For example, when a reform to φ takes place (period 4), GDP growth and net entry are the same up to the first decimal place as those reported in Table 6, while aggregate productivity growth is a little lower (2.7 percent). The figures that characterize the key economic variables for the reform to barriers to technology adoption are similar to those in Figures 4–7. The only substantial difference is that the mass of potential entrants in Figure 5(a) increases less after the reform to φ . In Figure 8 we show the mass of potential entrants under both reforms. Note that after the reform, both economies converge to the same nondistorted economy. As seen in (25), lowering κ directly affects the mass of potential entrants. This is in addition to the indirect effects that operate through λ . Lowering φ , however, does not have a direct effect on the mass of potential entrants.

The increased competition after entry costs are lowered generates a better efficiency distribution of successful entrants through the increase in the mass of potential entrants. Furthermore, this reform has a very similar effect as does the reform to lowering barriers to technology adoption which directly improves the efficiency distribution from which potential entrants draw.

Figure 8: Mass of potential entrants (entry cost vs. barriers to technology adoption reform).



We now quantitatively evaluate the effect of reforms to the fixed continuation cost. We report the results of this reform in Table 7. There is a surge in GDP growth immediately after the reform. However, this reform leads to a decline in aggregate productivity. Note the contrast between lowering entry costs and lowering fixed continuation costs. The former generates more potential entrants, thereby raising the efficiency threshold needed to operate. The latter discourages unproductive firms from exiting once they are operating. In the data, we observe that periods of higher GDP growth are associated with higher productivity growth, which is not consistent with reforms to the fixed continuation cost in the model. Given this counterfactual implication, we do not further study reforms to the fixed continuation cost. It is also worth noting that reforms to the continuation cost result in capital deepening in the model: GDP rises, the total labor input of the economy is fixed, aggregate productivity falls, and the capital stock of the economy increases. This increase in capital is due to the increasing number of firms.

Table 7: Productivity decompositions (fixed continuation cost reform).

Model periods (five years)	Operation cost	Real GDP growth (percent, annualized)	Aggregate productivity growth (percent, annualized)	Contribution of net entry (percent)
0–3	4.48	2.0	1.3	25.0
4 (reform)	2.32	4.1	–1.1	88.8
5	2.32	2.8	1.1	36.9
6	2.32	2.2	1.2	28.5
7+	2.32	2.0	1.3	25.1

In Appendix F, we consider an alternative model in which the fixed costs are denominated in labor. We calibrate this model and redo the quantitative exercise. We find similar quantitative results as in the baseline case. In Appendix G, we use the same model as in Appendix F but reinterpret labor to be a composite input of labor and capital. We calibrate and redo the quantitative exercise under this alternative interpretation. We find that the new quantitative results yield a similar pattern but have a larger increase in the contribution of entry and exit relative to the baseline.

7.4. Net Entry in the Model and the Data

In this section, we examine the extent to which reforms to entry costs and barriers to technology adoption quantitatively match the contribution of net entry to aggregate productivity growth that we observe in the data during periods of fast growth. In Table 8, we report growth in GDP per working-age person and the contribution of net entry to aggregate manufacturing productivity growth in the data. Since Table 3 has multiple observations for countries that are experiencing fast and slow growth, we report the average GDP per working-age person growth and contribution of net entry to productivity growth over all the fast-growing economies and all the slow-growing economies. We also report the equivalent statistics from the model. Recall that the labor endowment is fixed in the model which implies that growth in GDP is equivalent to growth in GDP per working-age person.

During periods of slow growth in GDP, which correspond to the balanced growth path in our model, the model is calibrated to generate the GDP growth rate and the net entry contribution that we observe in the U.S. data. We have not used any of the model’s transition path behavior in the calibration, so the net entry contribution following reform is informative about the model’s

performance. The model successfully matches the patterns we find in the data. GDP in the model grows at 4.6 percent during the reform, compared to 5.8 percent in the data. The contribution of net entry during this period is 60 percent in the model, compared to 47 percent in the data.

Table 8: Contribution of net entry, model and data.

	Real GDP per working-age person growth (percent, annualized)	Contribution of net entry to productivity growth (percent)
Data fast growth	5.8	47
Model reform (κ)	4.6	60
Model reform (φ)	4.6	60
Data slow growth	2.1	22
Model BGP	2.0	25

We further analyze the model's outcomes by decomposing the entering and exiting terms in (4) into components that correspond to the relative productivity of entrants or exiters and their gross output shares. In Table 9, we report the decomposition from our model as well as a summary of the data found in Table 2. Overall, the model matches these non-targeted moments well. In the data, changes in the entering and exiting terms were driven mainly by changes in the relative productivities of entrants and exiters. During periods of fast growth, entrants in the model are 14 percent more productive than the average firm in the previous period, compared to 17 percent in the data. During periods of slower GDP growth, the relative productivity of entrants falls to 6 percent in the model, compared to 2 percent in the data. Similarly, during periods of fast growth, exiting firms are 10 percent less productive than the average firm in the model, compared to 12 percent less productive in the data. During periods of slow growth, the model also generates exiters that are 2 percent less productive than the average firm, compared to 5 percent in the data.

There are two caveats to the results in Table 9. First, in the two data rows, we report results from Chilean and Korean manufacturing data whereas the model results apply to the entire economy. Second, notice that the decomposition of the entering term in the data does not completely match that in the model. In particular, changes in shares play an important role in the model but not in the data. In the model, the entrants' market share increases from 20 percent in periods of slow growth to 42 percent in periods of fast growth, while there is no such

corresponding increase in the data. Similarly, the exiter market share in the model increases from 19 percent in periods of slow growth to 27 percent in periods of fast growth, qualitatively matching the increase in exiter market share in the data. Our simple model of firm dynamics captures the relative productivity of entering and exiting firms reasonably well. This is important because Table 2 indicates that changes in the contribution of entry and exit is mainly driven by changes in the relative productivity of entering and exiting plants. A more nuanced model of firm growth may be able to better capture the behavior of market shares, but our model performs well along many dimensions and is simple enough to retain analytic tractability.

Table 9: FHK entering and exiting terms decomposed, model and data.

	Entering term			Exiting term		
	Entering term	Relative productivity entrants	Entrant market share	Exiting term	Relative productivity exiters	Exiter market share
Fast growth						
Data	4.7	16.8	0.30	-3.1	-11.7	0.26
Model reform (κ)	5.9	14.1	0.42	-2.5	-9.5	0.27
Model reform (φ)	5.9	14.0	0.42	-2.5	-9.5	0.27
Slow growth						
Data	1.0	2.2	0.32	-1.2	-4.8	0.24
Model BGP	1.3	6.4	0.20	-0.3	-1.6	0.19

Notes: The entering and exiting terms are the components of the net entry term in (4). The relative productivity term is the average entering (or exiting) firm productivity at t (or $t-1$) relative to the average productivity of all firms in $t-1$. Since each component is averaged over several observations, the multiplicative decomposition may not hold in the data exactly.

8. Conclusion and Direction for Future Research

Our work shows three areas for potential future research. First, this paper, as well as most of the literature that studies aggregate productivity growth, has focused on the manufacturing sector. Due to this limitation, we have assumed that the fraction of productivity growth accounted for by entry and exit is the same in manufacturing as in the entire economy. Thus, conducting the FHK decompositions for an entire economy, especially an economy that has experienced both fast and slow growth, would be useful to better understand the importance of entry and exit during periods of fast and slow growth. We are not aware of any study that has calculated the FHK

decomposition for the entire economy using firm or plant-level TFP as the measure of productivity.

A second area of future research is to extend our model to an open economy setting, which would allow us to study the importance of entry and exit after a reform under this alternative setting. As mentioned before, we abstract from international trade and capital flows in order to build a simple model that allows us to understand the economics of the FHK decomposition. In a model with international trade, a trade reform can give firms more incentive to attempt entry and will affect the importance of entry and exit. Furthermore, if the economy is open to international capital flows, then it would not see an increase in the interest after a reform. In our economy, the rising interest rate slows down the transition. Thus, an economy that is open to capital flows will see a faster transition.

A final area of research is to understand how being a potential entrant (an entrepreneur who has taken an efficiency draw), a failed entrant (a potential entrant who does not have an efficiency high enough to operate), and a successful entrant (a potential entrant who has an efficiency high enough to operate) maps to the data. For example, a longitudinal study of business creation, the Panel Study of Entrepreneurial Dynamics, documents the different stages of creating a new business. (See Reynolds and Curtin, 2011.) After 72 months, 30 percent have begun production, 48 percent have quit, and 22 percent are still in the start-up process. Do we consider a potential entrant to be a start-up, a failed entrant to be a start-up that quit, and a successful entrant to be a start-up that began production? An alternative interpretation is given by Bartelsman et al. (2013) who in their calibration interpret failed entrants as businesses that do not survive the first five years. Future research should investigate how the phases of starting a new business map to the process of firm creation in our model, which is the same manner as Hopenhayn (1992).

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Appendix A: Data Appendix

Data Description for Chilean Manufacturing Productivity Decompositions

We use the ENIA (*Encuesta Nacional Industrial Anual*) dataset provided by the Chilean statistical institute INE (*Instituto Nacional de Estadística*). The dataset is a panel of all manufacturing establishments in Chile with more than 10 employees covering 1995–2006. The data use 4-digit ISIC Rev. 3 industry classification system. To give a sense of the level of disaggregation, we note that ISIC Rev. 3 has 127 industries.

The first step is to compute plant-level productivity. We assume that plant e in industry t operates the following production function:

$$\log y_{eit} = \log z_{eit} + \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit} \quad (A1)$$

where z_{eit} is the plant's productivity, y_{eit} is gross output, k_{eit} is capital, ℓ_{eit} is total labor measured in man-years, m_{eit} is intermediate inputs, and β_j^i is the coefficient of input j in industry i .

We construct gross output and factor inputs in the same manner as Liu and Tybout (1996) and Tybout (1996). Gross output is the sum of total income (sales of goods produced; goods shipped to other establishments; resales of products; and work, repairs and installations for third parties), electricity sold, buildings produced for own use, machinery produced for own use, vehicles produced for own use, goods produced that go to inventory (final inventory of goods in process plus final inventory of goods produced minus initial inventory of goods in process minus initial inventory of goods produced). For intermediate inputs, we include the purchases of intermediates (materials, fuels, goods purchased for resale, cost of work done by third parties, water, greases, and oil), electricity, and the materials used from inventories (initial inventories minus final inventories). We use gross output and intermediate input deflators at the 4-digit level (ISIC Rev. 3) to convert these variables into 1995 pesos. These deflators were created by INE to be used with the ENIA plant-level data.² For the labor input, we use man-years, adjusted for labor quality (between blue-collar and white-collar workers) using relative wages.

² For more details, see

http://www.ine.cl/canales/chile_estadistico/estadisticas_economicas/industria/series_estadisticas/series_estadisticas_enia.php.

In constructing the real capital stock, we consider three types of capital: buildings, machinery, and vehicles. We use the book value of capital reported by firms and use an investment deflator to arrive at the real stock of capital in 1995 pesos.

To find the parameters β_k^i , β_ℓ^i , and β_m^i of the production function, we use nominal industry cost shares for each input. The cost shares that we calculate are at the 4-digit industry level for each input, averaged over the beginning and end of the period. For cost of labor, we use total employee remuneration. For intermediate input usage, we use the nominal value constructed to create the real intermediate input usage.

We do not have a direct measure of the user cost of capital to use in computing the cost share of capital. We use the following no-arbitrage relationship to find the user cost of capital, j

$$R_{jt} = \max \left\{ 1 + r_t - (1 - \delta_j) \frac{P_t}{P_{t+1}} \frac{P_{t+1,j}^K}{P_{tj}^K}, \delta_j \right\}, \quad (\text{A2})$$

where R_{jt} is the user cost of capital, P_t is the price level of the aggregate economy, P_{tj}^K is the price of a unit of capital type j in period t , and r_t is the real interest rate. For r_t we use the economy-wide real interest rate, for P_{t+1} / P_t we use the GDP deflator, and for $P_{t+1,j}^K / P_{tj}^K$ we use the aggregate investment deflator.

Given real input factors and cost shares, we determine the productivity of plant e in industry i as

$$\log z_{eit} = \log y_{eit} - \left(\beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit} \right). \quad (\text{A3})$$

We can thus calculate the industry-level productivity Z_{it} for industry i for all years using (1). Furthermore, we decompose these changes in industry-level productivity using (2), (3), (4), and (5). To compute the changes in aggregate productivity, we weight the productivity growth of each industry by the fraction of nominal gross output accounted for by that industry, averaged over beginning and end. We follow the exact same process to compute the aggregate contribution of continuing firms and net entry.

Data Description for Korean Manufacturing Productivity Decompositions

We use the Mining and Manufacturing Survey purchased from the Korean National Statistical Office. This dataset is a panel that covers all manufacturing establishments in Korea with at least 10 workers. We have three panels: 1992–1997, 2001–2006, and 2009–2014. Each plant's industry is given at the 5-digit level using the Korean Standard Industrial Classification (KSIC Rev. 6 for 1992–1997, Rev. 8 for 2001–2006, and Rev. 9 for 2009–2014).³ As in the Chilean data, we use 4-digit KSIC industries as the main unit of industry analysis.

The first step is to compute plant-level productivity. We assume that plant e in industry i operates the following production function:

$$\log y_{eit} = \log z_{eit} + \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit}, \quad (\text{A4})$$

where y_{eit} is gross output, z_{eit} is total factor productivity, k_{eit} is capital, ℓ_{eit} is labor, m_{eit} is intermediate inputs, and β_j^i is the coefficient of input j in industry i .

For gross output, we use production value reported in Korean won. We use producer price indices (obtained from the Bank of Korea, henceforth BOK), broken down at the 4-digit level, to put this series into real 2010 Korean won. For labor, we use the number of production workers plus a quality-adjusted estimate of nonproduction workers. As in Bailey et al. (1992), the adjustment is made using the relative earnings of nonproduction workers, calculated separately for each plant.⁴ For the capital stock, we consider three types of capital: buildings and structures, machinery and equipment, and vehicles and ships. We use the average reported book value of each type of capital at the beginning and end of each year, deflated by the GDP deflator for gross fixed capital formation (BOK). Once we have computed the real capital stock series, we sum the value of buildings and structures, machinery and equipment, and vehicles and ships to obtain the total capital stock of the plant,

$$k_{et} = \sum_j k_{eitj}. \quad (\text{A5})$$

For intermediate inputs, we use the total value of materials, electricity, fuel, and water usage, and outsourced processing costs reported by the plant in Korean won. We use intermediate input

³ KSIC Revs. 6 and 8 are comparable to the International Standard Industrial Classification (ISIC Rev. 3), and KSIC Rev. 9 is comparable to ISIC Rev. 4.

⁴ For the 2009–2014 window, in which employees are reported as full-time and temporary workers, the analogous adjustment is made for temporary workers.

deflators constructed using the input-output matrix (BOK) to convert this series into real 2010 Korean won. We build three sets of deflators: one based on KSIC Rev. 6 using the input-output matrix for 1995, one based on KSIC Rev. 8 using the input-output matrix for 2003, and one based on KSIC Rev. 9 using the input-output matrix for 2011. We obtain the matrix of intermediate deflators, $\underline{D}$, by

$$\underline{D}_{\text{industry codes} \times \text{years}} = \exp \left[\underline{I}_{\text{industry codes} \times \text{product codes}} \cdot \log \left(\underline{P}_{\text{product codes} \times \text{years}} \right) \right], \quad (\text{A6})$$

where $\underline{I}$ is the input-output matrix and $\underline{P}$ is the matrix of the producer price indices by year.

The factor elasticities β_k , β_ℓ , and β_m of the production function are obtained using the 4-digit industry average nominal cost shares, averaged over the beginning and ending year of the sample period. For the labor input, we use the total annual salary reported by the plant in Korean won. For capital, we impute the user cost of capital j , R_{jt} as

$$R_{jt} = \max \left\{ 1 + r_t - (1 - \delta_j) \frac{P_t}{P_{t+1}} \frac{P_{t+1,j}^K}{P_{tj}^K}, \delta_j \right\}, \quad (\text{A7})$$

where r_t is the real interest rate, δ_j is the depreciation rate for capital of type j , P_t is the price level of the aggregate economy, and P_{tj}^K is the price of a unit of capital type j in period t . For r_t we use the economy-wide real interest rate, for P_{t+1}/P_t we use the GDP deflator, and for $P_{t+1,j}^K/P_{tj}^K$ we use the aggregate investment deflator. Following Levinsohn and Petrin (2003), we use depreciation rates of 5 percent for buildings and structures, 10 percent for machinery and equipment, and 20 percent for vehicles and ships.

Given these estimates, the productivity of plant e in industry i at time t is

$$\log z_{eit} = \log y_{eit} - \left(\beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit} \right). \quad (\text{A8})$$

Appendix B: Sensitivity of Empirical Results

Alternative Decompositions for Chile and Korea

To check the robustness of our findings for Chile and Korea, we consider alternative decompositions proposed by Griliches and Regev (1995) and Melitz and Polanec (2015), henceforth GR and MP, respectively. In particular, we decompose aggregate manufacturing productivity growth over the same windows using the GR and MP decompositions and see if the contribution of net entry is higher during the period of fast growth. Furthermore, we decompose productivity growth using model output to examine the contribution of net entry in the balanced growth path and during the transition.

It is informative to see that the net entry term, $\Delta \log Z_{it}^{NE}$, and the continuing term, $\Delta \log Z_{it}^C$, can be rewritten using aggregate statistics of entering, exiting, and continuing plants as described by Melitz and Polanec (2015). To do so, we first rewrite the end-of-window productivity of industry i at time t as

$$\log Z_{it} = s_{it}^N \log Z_{it}^N + s_{it}^C \log Z_{it}^C, \quad (A9)$$

where s_{it}^N is the share of gross output accounted for by entering plants in industry i at time t , and Z_{it}^N is the aggregate productivity of entering plants at time t , and likewise for continuing plants (C). In the same manner, we rewrite the beginning-of-window industry productivity at time $t-1$ as

$$\log Z_{i,t-1} = s_{i,t-1}^C \log Z_{i,t-1}^C + s_{i,t-1}^X \log Z_{i,t-1}^X, \quad (A10)$$

where $s_{i,t-1}^X$ is the share of gross output accounted for by exiting plants at time $t-1$. Notice that an entrant is only active at time t , and an exiting plant is only active at time $t-1$.

Second, we rewrite (4) and (5) of the FHK decomposition as

$$\Delta \log Z_{it}^{NE} = \underbrace{s_{it}^N (\log Z_{it}^N - \log Z_{i,t-1})}_{\text{entering}} - \underbrace{s_{i,t-1}^X (\log Z_{i,t-1}^X - \log Z_{i,t-1})}_{\text{exiting}} \quad (A11)$$

and

$$\Delta \log Z_{it}^C = s_{it}^C (\log Z_{it}^C - \log Z_{i,t-1}) - s_{i,t-1}^C (\log Z_{i,t-1}^C - \log Z_{i,t-1}). \quad (A12)$$

Equations (A11) and (A12) show that the only statistics needed to calculate the net entry and continuing plant components of the FHK decompositions are the share of output and the weighted productivity of continuing, entering, and exiting plants.

The MP decomposition rewrites the continuing and net entry terms as

$$\begin{aligned}\Delta \log Z_{it}^C &= \log Z_{it}^C - \log Z_{i,t-1}^C \\ \Delta \log Z_{it}^{NE} &= s_{it}^N (\log Z_{it}^N - \log Z_{it}^C) - s_{i,t-1}^X (\log Z_{i,t-1}^X - \log Z_{i,t-1}^C).\end{aligned}\tag{A13}$$

Notice that the reference group for new plants is the productivity of continuing plants at time t , and the reference group for exiting plants is the productivity of continuing plants at time $t-1$. The change in reference group would affect the net entry term.

Lastly, we can write the GR decomposition as

$$\begin{aligned}\Delta \log Z_{it}^C &= s_{it}^C (\log Z_{it}^C - \log \bar{Z}_{it}) - s_{i,t-1}^C (\log Z_{i,t-1}^C - \log \bar{Z}_{it}) \\ \Delta \log Z_{it}^{NE} &= s_{it}^N (\log Z_{it}^N - \log \bar{Z}_{it}) - s_{i,t-1}^X (\log Z_{i,t-1}^X - \log \bar{Z}_{it})\end{aligned}\tag{A14}$$

where

$$\log \bar{Z}_{it} = \frac{\log Z_{it} + \log Z_{i,t-1}}{2}.\tag{A15}$$

In the GR decomposition, the reference group for all plants is the industry-level productivity, averaged over the beginning and end of the window. GR decomposition may be less prone to measurement error in output and inputs because of the averaging over time.

The results from the three decompositions can be found in Table A1 and Table A2. We see that the pattern of high contributions of net entry during the fast growth years, followed by lower contributions of net entry, still holds under all of the decompositions. For Chile, the contribution of net entry goes from 23.8 percent to 10.8 percent using GR and 22.4 percent to -50.9 percent using MP. The GR net entry contribution has been adjusted using the model so that the 1995–1998 window is comparable to other 5-year windows. The MP net entry contribution does not depend on the window length used. In the case of Korea, the contribution of net entry goes from 43.1 percent to 31.5 percent and then to 25.6 percent using GR. The contribution of net entry goes from 3.9 percent to -2.7 percent and then to -16.5 percent using MP.

Table A1: Chilean contribution of net entry.

Periods	FHK	GR	MP
1995–1998*	50.4	23.5	22.4
2001–2006	22.8	10.8	–50.9

*Measurements adjusted to be comparable with the results from the 5-year windows.

Table A2: Korean contribution of net entry.

Periods	FHK	GR	MP
1992–1997	48.0	43.1	3.9
2001–2006	37.3	31.5	–2.7
2009–2014	25.1	25.6	–16.5

We calculate these decompositions using output from the model. The results can be found in Table A3. The decompositions for the “reform” use model output from the 5-year window immediately after the reform. We find that the results for GR are very similar to those of FHK. This finding is consistent with FHK, which finds that the contribution of net entry to productivity growth is similar under both FHK and GR in U.S. manufacturing data. We find that both the MP and GR decompositions show an increase in the net entry component after the reforms.

Table A3: Model output contribution of net entry.

Periods	FHK	GR	MP
Reform (lower entry costs)	59.6	42.8	24.4
Reform (lower φ)	59.6	42.9	24.4
BGP	25.0	15.3	5.9

Alternative Method to Determine Production Function: Woolridge-Levinsohn-Petrin

In our baseline specification, we use industry-level cost shares to remain consistent with FHK. As a robustness check, we use the Wooldridge (2009) extension of the Levinsohn and Petrin (2003) method (WLP) for estimation of the production function. With the new elasticities of the production function, we find the plant-level productivities and compute the FHK productivity

decompositions. The contribution of net entry and aggregate manufacturing productivity growth is reported in Table A4. As before, we find a similar pattern in which the contribution of net entry is higher during periods of fast growth.

Table A4: Net entry in manufacturing productivity decompositions (WLP).

Period	Country	Real GDP per working-age person annual growth (percent)	Aggregate productivity annual growth (percent)	Contribution of net entry (percent)
1995–1998	Chile	4.0	4.4	73.6*
2001–2006	Chile	2.7	3.4	45.4
1992–1997	Korea	6.1	4.3	39.1
2001–2006	Korea	4.3	3.5	39.2
2009–2014	Korea	3.0	1.4	23.4

*Results have been adjusted to be comparable with the results from the 5-year windows using the calibrated model.

Alternative Weighting across Plants

In our baseline specification, we use gross output as weights to calculate industry productivity and then to aggregate changes in industry productivity. This methodology is consistent with that of FHK. As a robustness check, we redo the exercise using value added as weights. The results, reported in Table A5, show that the pattern still holds: the contribution of net entry is higher during periods of fast growth.

Table A5: Net entry in manufacturing productivity decompositions (VA weights).

Period	Country	Real GDP per working-age person annual growth (percent)	Aggregate productivity annual growth (percent)	Contribution of net entry (percent)
1995–1998	Chile	4.0	4.2	59.1*
2001–2006	Chile	2.7	1.7	–9.4
1992–1997	Korea	6.1	3.9	45.9
2001–2006	Korea	4.3	4.0	35.8
2009–2014	Korea	3.0	1.9	20.7

*Results have been adjusted to be comparable with the results from the 5-year windows using the calibrated model.

Appendix C: Net Entry Term Further Decomposed

We now describe the decomposition of the entering and exiting terms. To do so, we aggregate the net entry term in (A11) in the following manner:

$$\begin{aligned} \sum_{i=1}^I \left[w_{it} \Delta \log Z_{it}^{NE} \right] &= \sum_{i=1}^I \left[w_{it} s_{it}^N \left(\log Z_{it}^N - \log Z_{i,t-1} \right) \right] \\ &\quad - \sum_{i=1}^I \left[w_{it} s_{i,t-1}^X \left(\log Z_{i,t-1}^X - \log Z_{i,t-1} \right) \right], \end{aligned} \quad (\text{A16})$$

where I is the number of industries and w_{it} is the weight given to industry i when aggregating.

Thus, we have the following decomposition:

$$\begin{aligned} \sum_{i=1}^I \left[w_{it} \Delta \log Z_{it}^{NE} \right] &= \underbrace{\sum_{i=1}^I \left[\frac{w_{it} s_{it}^N}{\sum_{j=1}^I w_{jt} s_{jt}^N} \left(\log Z_{it}^N - \log Z_{i,t-1} \right) \right]}_{\text{average relative productivity of entrants}} \underbrace{\sum_{j=1}^I w_{jt} s_{jt}^N}_{\text{average entrant market share}} \\ &\quad - \underbrace{\sum_{i=1}^I \left[\frac{w_{it} s_{i,t-1}^X}{\sum_{j=1}^I w_{jt} s_{j,t-1}^X} \left(\log Z_{i,t-1}^X - \log Z_{i,t-1} \right) \right]}_{\text{average relative productivity of exiters}} \underbrace{\sum_{j=1}^I w_{jt} s_{j,t-1}^X}_{\text{average exiter market share}}, \end{aligned} \quad (\text{A17})$$

which allows us to determine whether changes in the entering and exiting term are driven by changes in the shares or the relative productivities.

Appendix D: Proof of Proposition 1

The proof of Proposition 1 involves guessing and verifying the existence of an equilibrium with a balanced growth path.

From the first order condition of the consumer and applying the balanced growth path conditions ($C_{t+1}/C_t = g_e$), we obtain $q_{t+1} = \beta/g_e$. Next, using the zero profit condition, we can derive

$$w_t = \alpha \left(\frac{1-\alpha}{\lambda f} \right)^{1-\alpha} \hat{x}_t, \quad (\text{A18})$$

where

$$\lambda = g_e^t / Y_t, \quad (\text{A19})$$

which is constant in the balanced growth path. The labor market clearing condition gives

$$1 = \left(\frac{w_t}{\alpha} \right)^{\frac{1}{\alpha-1}} \frac{\gamma(1-\alpha)}{\gamma(1-\alpha)-1} \hat{x}_t^{\frac{1}{1-\alpha}} \eta_t. \quad (\text{A20})$$

Substituting (A18) into (A20) we obtain the expression for the mass of operating firms

$$\eta = \frac{\gamma(1-\alpha)-1}{\gamma\lambda f}. \quad (\text{A21})$$

Using equation (18) and applying the balanced growth path conditions ($\mu_t = \mu, Y_{t+1}/Y_t = g_e, g_{ct} = \bar{g}g_e^\varepsilon$), we obtain the expression for the entry-exit threshold,

$$\hat{x}_t = \frac{g_e^t}{\varphi} \left(\frac{\omega\mu}{\eta} \right)^{\frac{1}{\gamma}}, \quad (\text{A22})$$

where

$$\omega = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\frac{g_e}{g_c} \right)^{\gamma(1-i)}. \quad (\text{A23})$$

The free entry condition in (16) can be rewritten as

$$\kappa_t = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\prod_{s=1}^{i-1} q_{t+s} \right) \int_{\hat{x}_{t+i-1}}^{\infty} \prod_{s=1}^{i-1} g_{c,t+s}^{-1} d_{t+i-1} \left(\prod_{s=1}^{i-1} g_{c,t+s} x \right) dF_t(x). \quad (\text{A24})$$

Evaluating the integral in (A24) and substituting (A20), we obtain

$$\kappa_t = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\prod_{s=1}^{i-1} q_{t+s} \right) \varphi^{-\gamma} g_e^{\gamma t} \hat{x}_{t+i-1}^{-\gamma} \prod_{s=1}^{i-1} g_{c,t+s}^{\gamma} \left\{ \frac{w_{t+i-1}}{\alpha} \frac{1-\alpha}{\eta} - f_t \right\}. \quad (\text{A25})$$

Substituting $Y_{t+i-1} = w_{t+i-1} / \alpha$ and (A21) into (A25), we obtain

$$w_t \lambda \kappa = \frac{g_e^{\gamma t}}{\gamma \eta} \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\prod_{s=1}^{i-1} q_{t+s} g_{c,t+s}^{\gamma} \right) w_{t+i-1} \hat{x}_{t+i-1}^{-\gamma}. \quad (\text{A26})$$

Substituting (A22) into (A26) and applying the balanced growth path conditions ($w_{t+1} / w_t = g_e$, $q_{t+1} = \beta / g_e$, $g_{ct} = g_c$), we obtain

$$\mu = \frac{\xi}{\gamma \lambda \kappa \omega}, \quad (\text{A27})$$

where

$$\xi = \sum_{i=1}^{\infty} \beta^{i-1} (1-\delta)^{i-1} \left(\frac{g_e}{g_c} \right)^{\gamma(1-i)}. \quad (\text{A28})$$

Finally, substituting $Y_t = w_t / \alpha$ into (A19) and applying the balanced growth path conditions, we obtain

$$\lambda = \left(\frac{f}{1-\alpha} \right)^{\frac{\gamma(1-\alpha)-1}{\alpha\gamma}} \varphi^{\frac{1}{\alpha}} \left[\frac{\kappa}{\xi} \frac{\gamma(1-\alpha)-1}{1-\alpha} \right]^{\frac{1}{\alpha\gamma}}, \quad (\text{A29})$$

which is increasing in κ , φ , and f .

Thus, our guess has been verified and all optimality conditions are satisfied. $\square$

Appendix E: Measuring Capital in the Model

We construct a measure of capital at the firm level in order to estimate productivity using the model output in the same manner as we did with the data, which is described in Section 2.2.

When a firm enters at time t , its investment is $f_t + \kappa_t$. Subsequently, its investment each period is the fixed continuation cost. Capital, k_t , evolves as follows:

$$k_{t+1} = (1 - \tilde{\delta}_{kt})k_t + I_t, \quad (\text{A30})$$

where $\tilde{\delta}_{kt}$ is the depreciation rate and I_t is investment at time t . When a firm enters at time t , its capital stock is $k_t = \kappa_t + f_t$. If the depreciation rate is

$$\tilde{\delta}_{kt} = \frac{f_t - (\kappa_{t+1} - \kappa_t)}{\kappa_t + f_t}, \quad (\text{A31})$$

then the subsequent capital stock is

$$k_t = k_t + f_t, \quad (\text{A32})$$

for all t after entry. Note that the total depreciation in a given period is

$$\tilde{\delta}_{kt}(\kappa_t + f_t) = f_t - (\kappa_{t+1} - \kappa_t). \quad (\text{A33})$$

This expression implies that the total depreciation of capital at the firm level is the fixed continuation cost minus any increase in the fixed capital stock. The fact that all firms have the same capital stock is counterfactual but allows us to keep the model analytically tractable.

We now define the aggregate depreciation rate and the aggregate capital stock. Aggregate investment is $\mu_t \kappa_t + \eta_t f_t$, and the aggregate capital stock is $\eta_t(\kappa_t + f_t) + (\mu_t - \eta_t)\kappa_t$. The depreciation of capital is the sum of the capital of firms that die, entry costs of failed entrants, and $f_t - (\kappa_{t+1} - \kappa_t)$ for continuing firms as discussed above. We find that the aggregate depreciation rate is

$$\delta_{kt} = 1 - \frac{\eta_{t+1}(\kappa_{t+1} + f_{t+1}) + (\mu_{t+1} - \eta_{t+1})\kappa_{t+1}}{\eta_t(\kappa_t + f_t) + (\mu_t - \eta_t)\kappa_t} + \frac{\mu_t \kappa_t + \eta_t f_t}{\eta_t(\kappa_t + f_t) + (\mu_t - \eta_t)\kappa_t}. \quad (\text{A34})$$

Notice that this depreciation rate is constant on the balanced growth path but not in the transition.

Appendix F: Fixed costs denominated in terms of labor

In this section, we change our baseline model so that the fixed costs are denominated in terms of labor. We then calibrate the new model and redo the quantitative exercise in Section 7.

All of the equations that characterize the model in Section 3 remain the same except for the equations that we now characterize. Potential entrants pay an entry cost, κ , which is denominated in units of labor to draw a marginal efficiency, x . The condition in (9) becomes

$$d_t(x) = \max_{\ell_t} x \ell_t(x)^\alpha - w_t \ell_t(x) - w_t f, \quad (\text{A35})$$

where f is the fixed continuation cost paid in units of labor. The mass of potential entrants, μ_t , characterized by (16) becomes

$$E_x[V_t(x)] = w_t \kappa. \quad (\text{A36})$$

The labor market condition, characterized by (19), becomes

$$1 = \sum_{j=1}^{\infty} \left[\mu_{t+j-1} (1-\delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} \ell_t(x) dF_{t+j-1}(x / \tilde{g}_{jt}) \right] + \eta_t f + \mu_t \kappa. \quad (\text{A37})$$

The goods market clearing condition, characterized by (20), becomes

$$C_t = Y_t = \sum_{j=1}^{\infty} \left[\mu_{t+j-1} (1-\delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} x \ell_t(x)^\alpha dF_{t+j-1}(x / \tilde{g}_{jt}) \right]. \quad (\text{A38})$$

Aggregate dividends, characterized by (21), become

$$D_t = \sum_{j=1}^{\infty} \left[\mu_{t+j-1} (1-\delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} d_t(x) dF_{t+j-1}(x / \tilde{g}_{jt}) \right] - \mu_t w_t \kappa. \quad (\text{A39})$$

Under the new formulation, we can show a proposition similar to Proposition 1 in which (22) is satisfied along with $q_{t+1} = \beta / g_e$, $\mu_t = \mu$, $\eta_t = \eta$. The equations that characterize the balanced growth path become

$$\hat{x}_t = \frac{g_e^t}{\varphi} \left(\frac{\omega \mu}{\eta} \right)^{\frac{1}{\gamma}}, \quad (\text{A40})$$

$$w_t = \alpha \left(\frac{1-\alpha}{\alpha f} \right)^{1-\alpha} \hat{x}_t, \quad (\text{A41})$$

$$Y_t = \psi \alpha \left(\frac{1-\alpha}{\alpha f} \right)^{1-\alpha} \hat{x}_t, \quad (\text{A42})$$

$$\mu = \frac{\xi}{\gamma \kappa \omega} \psi, \quad (\text{A43})$$

$$\eta = \frac{\gamma(1-\alpha)-1}{\gamma f} \psi, \quad (\text{A44})$$

$$\psi = \frac{\gamma \omega}{(\gamma-1)\omega + \xi}. \quad (\text{A45})$$

As before, the efficiency cutoffs, real wages, and output grow at rate $g_e - 1$. The mass of potential entrants, μ , and the mass of operating firms, η , are also constant on the balanced growth path.

As in our baseline, we treat fixed costs as investment. When a firm enters at time t , its nominal investment is $w_t(f + \kappa)$. The firm's real investment is $I_t = w_0 g_e^t (f + \kappa)$, where w_0 is the base year wages, and g_e^t reflects improvements in the quality of capital. After a firm enters, nominal investment each period is the fixed continuation cost $w_t f$ and its real investment is $I_t = w_0 g_e^t f$. Real capital, k_t , evolves as follows:

$$k_{t+1} = (1 - \tilde{\delta}_{kt}) k_t + I_{t+1}, \quad (\text{A46})$$

where $\tilde{\delta}_{kt}$ is the depreciation rate and I_{t+1} is real investment at time $t+1$. When a firm enters at time t , its real capital stock is $k_t = w_0 g_e^t (f + \kappa)$. If the depreciation rate is

$$\tilde{\delta}_{kt} = 1 - \frac{g_e \kappa}{f + \kappa}, \quad (\text{A47})$$

then the subsequent capital stock is

$$k_t = w_0 g_e^t (f + \kappa), \quad (\text{A48})$$

for all t after entry. As in the baseline model, the fact that all firms have the same fixed capital stock generates a clean relationship between efficiency and productivity.

To calibrate the model, we follow a similar strategy as before. The calibrated parameters are reported in Table A6. One thing to note is that firm size is measured in units of variable labor, as in the baseline calibration.

Table A6: Calibrated parameters.

Parameter		Value	Target
Operating cost (technological)	f^T	0.69×5	Average U.S. establishment size: 14.0
Entry cost (technological)	κ^T	0.57	Entry cost / continuation cost: 0.82
Tail parameter	γ	6.10	S.D. of U.S. establishment size: 89.0
Entrant efficiency growth	g_e	1.02^5	BGP growth rate of U.S.: 2 percent
Returns to scale	α	0.67	BGP labor share of U.S.: 0.67
Death rate	δ	$1 - 0.960^5$	Exiting plant employment share of U.S.: 19.3 percent
Discount factor	β	0.98^5	Real interest rate of U.S.: 4 percent
Firm growth	$\bar{g}$	1.006^5	Effect of entry and exit on U.S. manufacturing productivity growth: 25 percent

As before, we create distorted economies in order to study the transition dynamics when we remove distortions. We only report the results for the quantitative exercise that involve lowering entry costs since reducing barriers to technology adoption yields similar results. In the distorted economy, we raise the entry cost to 1.53 so that income is 15 percent lower on the balanced growth path. We report the results of the reforms to entry costs in Table A7. We find that, as before, there is an increase in GDP and productivity growth rates immediately after the reform. We also see an increase in the contribution of net entry. The results are quantitatively similar to our baseline.

Table A7: Productivity decompositions (entry cost reform).

Model periods (five years)	Entry cost	Real GDP growth (percent, annualized)	Aggregate productivity growth (percent, annualized)	Contribution of net entry to aggregate productivity (percent)
0–3	1.53	2.0	1.3	25.0
4 (reform)	0.57	4.7	4.3	56.5
5	0.57	2.4	1.3	34.0
6	0.57	2.2	1.3	28.0
7+	0.57	2.0	1.3	24.9

Appendix G: Model with a Composite of Variable Labor and Capital

In this section, we recalibrate the model that was presented in Appendix F in which fixed costs are denominated in terms of labor. We reinterpret labor in the model to be equipped labor. Equipped labor is created by a bundler that uses a Cobb-Douglas technology to combine variable labor and variable capital, both of which are owned by the household. The bundler operates under perfect competition.

The new interpretation of α is the span-of-control parameter in Lucas's (1978) model. We use a value of $\alpha = 0.85$, which is consistent with Gomes and Kuehn (2014) and Atkeson and Kehoe (2005). Given the new value of α , we recalibrate all other parameters as described in Table A8. Most targets are similar to the baseline calibration. One point to make is that after normalizing the labor and capital endowments, we can calculate the targets that use employment statistics in the model, such as the average establishment size. We also set the coefficient of variable labor in the bundler's Cobb-Douglas technology so that the model matches a labor share of 0.67.

Table A8: Calibration of model with a composite of variable labor and capital.

Parameter		Value	Target
Operating cost (technological)	f^T	0.25×5	Average U.S. establishment size: 14.0
Entry cost (technological)	κ^T	0.20	Entry cost / continuation cost: 0.82
Tail parameter	γ	13.42	S.D. of U.S. establishment size: 89.0
Entrant efficiency growth	g_e	1.02^5	BGP growth rate of U.S.: 2 percent
Span-of-control	α	0.85	Atkeson and Kehoe (2005)
Death rate	δ	$1 - 0.963^5$	Exiting plant employment share of U.S.: 19.3 percent
Discount factor	β	0.98^5	Real interest rate of U.S.: 4 percent
Firm growth	$\bar{g}$	1.006^5	Effect of entry and exit on U.S. manufacturing productivity growth: 25 percent

We create a distorted economy by raising the entry cost so that income on the balanced growth path is 15 percent lower. We then conduct a reform by reducing entry costs and study the subsequent transition to the new balanced growth path. Table A9 summarizes the new results. We find that the results are qualitatively the same as before. The main difference is that the

contribution of net entry in the period of reform is higher than in the baseline case (74.0 vs. 59.6). Notice, however, that the model can still account for the positive correlation between GDP growth and the contribution of net entry.

Table A9: Productivity decompositions (entry cost reform).

Model periods (five years)	Entry cost	Real GDP growth (percent, annualized)	Aggregate productivity growth (percent, annualized)	Contribution of net entry to aggregate productivity (percent)
0–3	1.80	2.0	1.7	25.0
4 (reform)	0.20	5.0	4.8	74.0
5	0.20	2.3	1.6	33.5
6	0.20	2.1	1.7	26.6
7+	0.20	2.0	1.7	25.0

Appendix H: Sensitivity Analysis of Spillover Parameter, ε

In this section, we report the sensitivity analysis when we use alternative values of the spillover parameter, ε . We redo the quantitative exercise using ε values of 0.38 and 0.83, which are the minimum and maximum values that we found in the Chilean and Korean data as reported in Table 5. For each ε , we recalibrate all of the parameters using the same targets as in Table 4. In both cases, all of the parameters remain the same as in the baseline calibration except for $\bar{g}$. We then use each calibrated economy to create a distorted economy that has higher entry costs. Income is 15 percent lower on the balanced growth path in these distorted economies. When we conduct a reform, we find that there is an immediate increase in the net entry term, which ranges from 46.9 to 73.9 percent (vs. 59.6 percent in the baseline case). We conclude that the model can quantitatively account for the positive correlation between output growth and the contribution of net entry for a wide range of empirically relevant values of ε .

Table A10: Contribution of net entry with entry cost reform (percent).

Robustness	Parameter (baseline value)	BGP	Reform
Low spillovers	$\varepsilon = 0.38$ (0.64)	25.0	73.9
High spillovers	$\varepsilon = 0.83$ (0.64)	25.0	46.9
Baseline		25.0	59.6

Appendix I: Reforms in Chile and Korea

Table A11 describes the reforms conducted in Chile (enacted 1993–1997) and Korea (enacted 1990–1995 and 1998–2004).

Table A11: Summary of reforms in Chile and Korea.

Country (Year)	Reform	Details	Source
Chile (1993)	FDI reforms	“The last revision of that rule [minimum permanence requirement for the equity portion of the investment] was made in 1993, when the limit was reduced from three years to one year.”	OECD (2003), p. 77
Chile (1993)	Financial reforms	“This law [banking regulatory reform in 1986] ... was complemented by a securities law in 1993 that increased transparency in the capital markets and regulated conflicts of interest.”	Perry and Leipziger (1999), p. 113
Chile (1993)	Deregulation and privatization of services	“The law [1982 regulatory law of Chilean telecoms sector] was amended ... in 1993 to allow for competition in long-distance telephone services.”	Perry and Leipziger (1999), p. 358
Chile (1997)	Financial reforms	“At the end of 1997 a new law widened banks' activities and set rules for the internationalization of the banking system.”	Perry and Leipziger (1999), p. 113
Chile (1997)	Deregulation and privatization of services	“Legislation was passed in 1997 to allow private involvement in the water and sewage sector and private management of the state-owned ports.”	Perry and Leipziger (1999), p. 287
Korea (1990)	Monopoly Regulation and Fair Trade Act	“the government strengthened the institutional basis to regulate unfair and anticompetitive trade practices”	Suh (2007), p. 23
Korea (1991)	FDI reforms	“allowed foreign investment in manufacturing with a foreign-investment ratio not exceeding 50 percent.”	Chung (2007), pp. 278-279
Korea (1992)	Subsidy for high-tech firms	“The government specified 58 areas for which tax exemption [for foreign-invested firms] would apply. Among these were high-tech manufacturers”	Chung (2007), p. 279
Korea (1993)	Entry and financial reforms	“a combination of deregulation of corporate entry and of the financial system”	Haggard and Mo (2000)
Korea (1994)	Entry reforms	“relax entry and investment restrictions in steel and semiconductor industries.”	Haggard and Mo (2000)
Korea (1994)	Financial reforms	“the authorities lifted ceilings on short-term foreign currency borrowing by commercial banks”	Eichengreen et al. (2015), p.166

Korea (1995)	FDI reforms	“raise the ceiling on foreign equity ownership of listed corporations”	Chung (2007), p. 280
Korea (1998)	FDI reforms	“Ceilings on foreign investment in equities, with the exception of investment in public corporations, were then lifted”	Eichengreen et al. (2015), p.100
Korea (1998)	Financial reforms	“Firms were permitted to borrow abroad on long as well as short terms, and other foreign exchange transactions were relaxed.”	Eichengreen et al. (2015), p.169
Korea (1998)	Financial reforms	“removed most of the restrictions on foreign exchange transactions and domestic transactions in foreign currencies”	Chung (2007), p. 281
Korea (1998)	FDI reforms	“Abolished ceiling on equity investment by foreigners”	Lee et al. (2007), p. 60
Korea (1998)	Labor Standards Act	“labor market reforms focused on labor market flexibility”	Lee et al. (2007), p. 75
Korea (1998–2001)	Corporate governance	“Adopted international accounting and auditing standards”	Lee et al. (2007), p. 60
Korea (1999)	Monopoly Regulation and Fair Trade Act	“merger-specific efficiencies now had to clearly outweigh the harmful effects of reduced competition.”	Eichengreen et al. (2015), p.169
Korea (1999)	Omnibus Cartel Repeal Act	“removed legal exemptions for 20 cartels and 18 statutes.”	Eichengreen et al. (2015)
Korea (2004)	Financial reforms	“waves of financial liberalization set off in 1993, 1998, and 2004”	Eichengreen et al. (2015)
Korea (2004)	Second Cartel Reformation Act	“legislated to abolish anticompetitive laws and systems.”	Lee et al. (2007), p. 61
