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# Firm Entry and Exit and Aggregate Growth

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### **ABSTRACT**

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Applying the Foster, Haltiwanger, and Krizan (FHK) (2001) decomposition to plant-level manufacturing data from Chile and Korea, we find that the entry and exit of plants account for a larger fraction of aggregate productivity growth during periods of fast GDP growth. To analyze this relationship, we develop a model of firm entry and exit based on Hopenhayn (1992). 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 they do in the data from Chile and Korea.

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## 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 account for 25 percent of U.S. manufacturing productivity growth, while Brandt, Van Biesebroeck, and Zhang (2012), using the same methodology, find that entry and exit account for 72 percent of Chinese manufacturing productivity growth.<sup>1</sup> In this paper, we account for the stark differences in the U.S. and Chinese data by examining data from many countries to establish patterns about the contributions of entry and exit and the country's growth rate and by developing a model through which we can understand the forces driving those differences.

The first contribution of this paper is empirical. We apply the FHK decomposition to plant-level manufacturing data from Chile and South Korea. We find that plant entry and exit account for a larger fraction of aggregate manufacturing productivity growth during periods of fast growth in GDP per working-age person. We measure aggregate productivity as the weighted average productivity of plants, which is typically used with the FHK decomposition.<sup>2</sup> A meta-analysis of the productivity literature, spanning a number of countries and time periods, supports this empirical regularity. This empirical relationship is novel and suggests that plant entry and exit play an important role during periods of fast growth. Furthermore, in Chile and Korea, the changes in the contribution of entry and exit are accounted for by changes in the relative productivity of entering and exiting plants and not by their market shares.

Our second contribution is theoretical and quantitative. We develop a dynamic general equilibrium model with endogenous entry and exit that can quantitatively account for the patterns found in the data. Our model is simple enough that there are analytical expressions for the terms in the FHK decomposition. When we introduce reforms that reduce entry costs or barriers to technology adoption into a calibrated model, both the entry and exit terms in the FHK

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<sup>1</sup> To calculate that entry and exit account for 25 percent of U.S. manufacturing productivity growth, see Table 8.7 in FHK and find the average net entry share for the 1977–1982, 1982–1987, and 1987–1992 windows. To find the contribution of entry and exit in China, see Figure 7 in Brandt, Van Biesebroeck, and Zhang (2012) for the 1998–2007 window. Note that the contribution of entry and exit depends on the length of the window. In Section 2.2, we propose a methodology to adjust the window lengths to make these statistics comparable.

<sup>2</sup> This measure is not the Solow residual of an aggregate production function. We use the same measure of aggregate productivity in the empirical analysis and in the quantitative analysis.

decomposition become more important as GDP grows rapidly, just as they do in the data. Our simple model performs surprisingly well in quantitatively matching the data.<sup>3</sup>

Chile and Korea are good candidates for our empirical analysis because both countries have experienced periods of fast growth (defined as growth greater than 4 percent per year in GDP per working-age person) and slow growth (less than 4 percent per year).<sup>4,5</sup> 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 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.

Following FHK, we decompose the Chilean and Korean plant-level data into a net entry term and a continuing plant term. The net entry term is higher if entering plants or exiting plants have relatively large market shares, if entering plants are relatively productive, or if exiting plants are relatively unproductive, compared to the industry average. The continuing plant term consists of both within-plant productivity growth and the reallocation of market shares across continuing plants. During periods of slow growth, 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. Our findings are robust to using alternative decompositions.

We also investigate how the relative productivity of entering and exiting plants as well as their market shares evolved in Chile and Korea. We find that compared with periods of slow growth, periods of fast growth tend to have relatively productive entering plants. Furthermore, exiting plants tend to be relatively unproductive during periods of fast growth. We do not find consistent changes in the market shares of entering and exiting plants during fast and slow growth episodes. The relative productivities and market shares of entering and exiting plants are inputs into the FHK

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<sup>3</sup> Our model is of the entire economy, but because of data limitations, the productivity decompositions in both the existing literature and our work cover only manufacturing. To make comparisons between the model and the data, we assume that the contribution of net entry in non-manufacturing behaves identically to that in manufacturing.

<sup>4</sup> In contrast, for the time periods reported by FHK and Brandt, Van Biesebroeck, and Zhang (2012), the United States is always in slow growth and China is always in fast growth.

<sup>5</sup> If fast and slow growth are defined based on manufacturing productivity growth, our categorization of fast and slow growth periods remains unchanged. There is a high correlation between manufacturing productivity growth and GDP per working age person growth. For Chile and Korea, the correlation is 0.85.

contribution of net entry and help us understand the changes in the importance of entry and exit that we observe.

Studying periods of slow and fast growth in the same country allows us to avoid cross-country differences and to use data that are consistent through time, reducing measurement problems. Nonetheless, it is useful to get a broader understanding of the empirical relationship between growth and the role of net entry across countries. Our own analysis is limited by the availability of plant-level data, but the FHK decomposition is widely used in the literature. We survey papers that use the FHK decomposition. One challenge is that studies in the literature use sample windows of different duration. Because the FHK decompositions are sensitive to window length (longer windows are associated with higher contributions of entry and exit), the different durations make it difficult to compare the results of these studies. To ensure comparability, we develop a methodology to adjust the results from studies that use windows that are different from ours. We find that continuing plants 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 become increasingly important in accounting for manufacturing productivity growth. For example, China had a higher growth rate than Chile and Korea during the sample windows, and it also had a higher contribution of net entry in manufacturing.

Motivated by our empirical work, we build a simple model with three sources of aggregate 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 endogenously exit, inducing a selection effect in which inefficient firms exit.

The economy is subject to three types of 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 the 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 because of policies that restrict their adoption, they are not used.

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, which have grown at about 2 percent per year for several decades, despite persistent differences in income levels. Jones (1995) and Kehoe and Prescott (2002) provide in-depth discussions of these empirical regularities.

The simplicity of our model allows us to characterize analytically 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 affect the contribution of net entry to aggregate productivity growth. For example, if there is a decline in within-cohort heterogeneity (i.e., incoming firms have more similar efficiency draws), then the contribution of net entry increases. The reason is that reducing within-cohort differences in efficiency increases the importance of the efficiency differences across cohorts. We also show that the contribution of net entry increases with a parameter related to firm turnover. Furthermore, an increase in continuing firms' growth rate leads to a decline in the contribution of net entry. These forces are present in many growth models, and our model allows us to understand how they map into empirical decompositions.

We calibrate the model to the U.S. economy, in which entry and exit account for 25 percent of aggregate productivity growth. To study the kinds of reforms that could potentially account for the patterns we observe during periods of fast growth, we create three 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 we are studying. We increase one of the distortions in each economy so that the balanced growth path income level is 15 percent below that of the United States. On the balanced growth path, each of these distorted economies grows at 2 percent per year, and net entry accounts for 25 percent of aggregate productivity growth in the FHK decomposition.

We 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 net entry accounts for 60 percent of aggregate productivity growth. Even though net entry is relatively unimportant on the balanced growth path, the model matches the increasing

importance of net entry in the FHK decomposition during periods of fast GDP growth. As in the data, the reform features the entry of relatively efficient firms and the exit of relatively inefficient firms. When we decrease the barriers to technology adoption in the model, GDP growth and the importance of net entry to aggregate productivity growth along the transition are almost identical to those in the lower-entry-costs experiment.

While both reforms generate a positive correlation between GDP growth and the importance of net entry, the underlying mechanisms are very different. Lower entry costs increase the number of potential firms that draw efficiencies. The larger number of potential firms drives up the efficiency threshold for entry, thereby increasing aggregate productivity: More entry leads to higher productivity. This mechanism is in the spirit of Schumpeter (1947). Causation in the case of lower barriers to technology adoption runs in the opposite direction. When it is easier for firms to adopt higher efficiencies, the value of operating a firm increases, leading to more potential firms drawing efficiencies: Higher productivity leads to more entry.

The lower entry cost reform and the lower barriers to technology adoption reform generate similar outcomes, except in one dimension: The number of potential entrants is larger in the experiment with decreased entry costs. Both reforms increase the value of operating a firm, leading to more potential entrants. The lower entry cost also directly changes the cost of entry, creating an additional effect on the mass of potential entrants.

Not all the reforms we consider generate dynamics consistent with the data. When we lower the fixed continuation cost in the model, GDP growth increases, but aggregate productivity decreases. A lower fixed continuation cost allows less-productive firms to enter and remain in production, which results in decreasing aggregate productivity during periods of fast GDP growth. We do not observe this pattern in our empirical study.

Closest to our work is that of Garcia-Macia, Hsieh, and Klenow (2016), who derive a model-based decomposition to measure the fraction of growth in the economy due to incumbents and entrants. Their primary finding—that the bulk of growth in the U.S. economy is due to incumbents—is consistent with our own findings for slow-growing economies. In contrast to their work, ours uses the FHK decomposition. While it is not derived from a structural model, it is widely used in the literature, allowing us to use the findings from other papers to complement our study of Chile and Korea. In comparison with that of Garcia-Macia, Hsieh, and Klenow (2016),

the scope of our study is broader: In addition to the United States, we study many countries and trace out the importance of net entry in productivity growth in both fast- and slow-growing economies.

Our model is related to papers that attempt to understand how the FHK decomposition is related to structural models of firm entry and exit. We are the first to characterize analytically the FHK decomposition along the balanced growth path of a general equilibrium model, but other papers (Acemoglu et al. 2013; Arkolakis 2016; Lentz and Mortensen 2008) have used the FHK decomposition to compare calibrated models to data.

Our modeling approach is related to the endogenous growth literature in which productivities are drawn from a distribution that improves over time (see Alvarez, Buera, and Lucas 2013; Lucas and Moll 2014; Perla and Tonetti 2014; Buera and Oberfield 2016; Sampson 2016). Relative to these papers, ours takes a simplified approach in which the productivity distribution from which entrants draw improves at an exogenous rate, which is similar to Luttmer's (2007) approach. 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 (Eaton and Kortum 1999; Parente and Prescott 1999; Alvarez, Buera, and Lucas 2013).

Our empirical analysis is broadly related to the productivity decomposition literature (Baily, Hulten, and Campbell 1992; Griliches and Regev 1995; Olley and Pakes 1996; Petrin and Levinsohn 2012; Melitz and Polanec 2015), which develops methodologies for decomposing aggregate productivity. These decompositions are often used to study the effect of policy reform (Olley and Pakes 1996; Pavcnik 2002; Eslava et al. 2004; Bollard, Klenow, and Sharma 2013). Our work is the first to document the empirical relationship between the importance of plant entry and exit in the FHK decomposition and aggregate growth in GDP per working-age person. These empirical results suggest that the entry and exit of firms are important for fast economic growth. They also provide empirical facts that can be used to discipline models that study productivity growth in fast-growing countries.

Finally, our work is related to papers that use quantitative models to study the extent to which entry costs can account for cross-country income differences (Bergoeing, Loayza, and Piguillem 2010; Poschke 2010; Barseghyan and DiCecio 2011; Herrendorf and Teixeira 2011; D'Erasmus and Moscoso Boedo 2012; Moscoso Boedo and Mukoyama 2012; D'Erasmus, Moscoso Boedo, and



Senkal 2014; Bah and Fang 2016; 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 a related paper, Peng (2019) finds that Chinese structural reforms that promoted entry and exit of firms contributed to economic growth in China during 1998–2007.

In Section 2, we 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. 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 we find in Section 2. Section 8 concludes and provides directions for future research.

## **2. Productivity Decompositions**

In this section, we use the FHK productivity decomposition on Chilean and Korean manufacturing data to decompose changes in aggregate manufacturing productivity into the contribution from entering and exiting plants and the contribution from continuing plants. We find that the entry and exit of plants account for a larger share of aggregate manufacturing productivity growth during years of fast growth in GDP per working-age person than they do during periods of slow growth. We additionally investigate whether these results are driven by the productivity of entering and exiting plants or by changes in their market shares, which are inputs into the FHK net entry term.

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. Studies in the literature use window lengths of varying sizes, which pose a challenge because longer window lengths are associated with higher contributions of net entry. We develop a methodology using the calibrated model to adjust the varying window lengths used in the literature. We find 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 in the FHK decomposition.

We use manufacturing data because this information is more widely available than data for services. For example, we are not aware of any plant-level panel data on the Chilean or Korean service sectors. 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 experiencing fast growth if the growth rate of GDP per working-age person is 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 the GDP per working-age person growth rates and the FHK contribution of entry and exit as continuous (see Figure 3).

## 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

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

where  $s_{eit}$  is the share of plant  $e$ 's gross output in industry  $i$  and  $z_{et}$  is the plant's productivity.<sup>6</sup>

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

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

The industry-level change in productivity 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.<sup>7</sup>

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

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<sup>6</sup> The literature on productivity decompositions typically uses gross output weights when TFP is the measure of productivity. See page 318 of Foster, Haltiwanger, and Krizan (2001) for a discussion of this topic.

<sup>7</sup> We follow the literature on productivity decompositions and use a productivity index in logs. The difference in equation (2) can thus be interpreted as a percentage change. See page 318 of Foster, Haltiwanger, and Krizan (2001), which defines the productivity index. Also see equations (2)–(7) in Baily, Hulten, and Campbell (1992).

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

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 component, the entry term, positively contributes to aggregate productivity growth if entering plants' productivity levels are greater than the initial industry average. The second component, the exit term, positively contributes to aggregate productivity growth if the exiting plants' productivity levels are less than the initial industry average.

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

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

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 term, measures productivity growth that is accounted for by changes in the productivity of existing plants. The second term in (5), the reallocation term, measures productivity growth that is due to the reallocation of output shares among existing plants.<sup>8</sup>

## 2.2. The Role of Net Entry in Chile and Korea

We decompose aggregate manufacturing productivity using the FHK productivity decomposition 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. 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 fell 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 in the

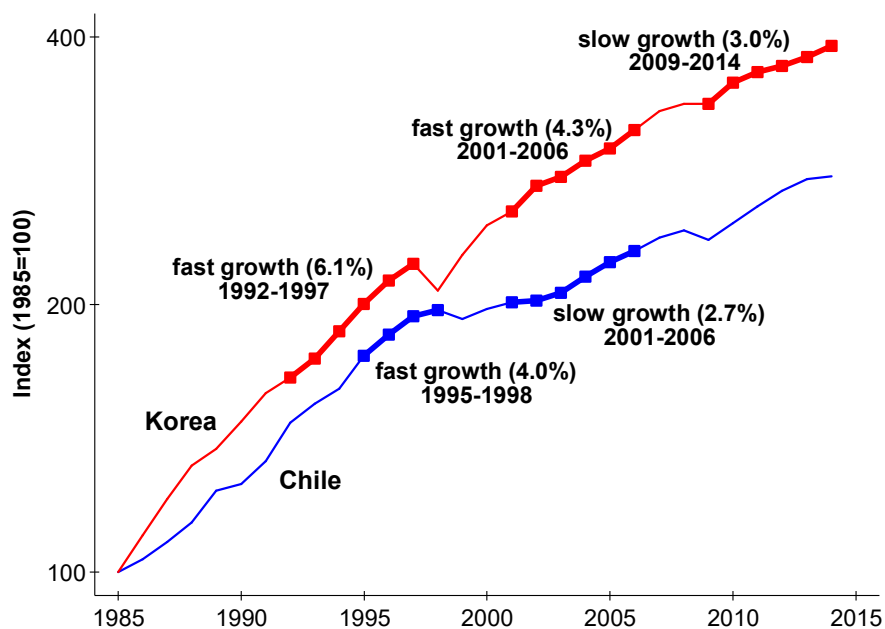
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<sup>8</sup> Note that the derivation uses the condition that  $\sum_{e \in C_{it}} s_{ei,t-1} + \sum_{e \in X_{it}} s_{ei,t-1} = \sum_{e \in C_{it}} s_{eit} + \sum_{e \in N_{it}} s_{eit} = 1$ .

FHK decomposition 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 data sets.

The Chilean data are drawn from the Instituto Nacional de Estadística (2014) *Encuesta Nacional Industrial Anual* data set provided by the Chilean statistical agency. The panel data set covers all manufacturing plants in Chile with more than 10 employees for the years 1995–2006. For Korea, we use the Statistics Korea (2020) Mining and Manufacturing Surveys data set provided by the Korean statistical agency. This panel data set covers all manufacturing plants in Korea with at least 5 workers in the 1992–1997 and 2001–2006 panels and at least 10 workers in the 2009–2014 panel. To make the analysis comparable across the two countries and windows, we drop observations with fewer than 10 employees when using the Korean data. The full details of the data preparation can be found in Appendix A.

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



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,  $\ell_{eit}$  is labor,  $m_{eit}$  is intermediate inputs, and  $\beta_j^i$  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 the four-digit International Standard Industrial Classification (ISIC) Revision 3. For the Korean data, depending upon the sample window, this is a Korean national system based on the four-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 output and 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.<sup>9</sup> For labor, we use man-years in the Chilean data and number of employees in the Korean data. Following FHK, the coefficients  $\beta_j^i$  are the industry-level factor cost shares, averaged over the beginning and end of each time window.

We use (1) to calculate the industry-level productivity,  $\log Z_{it}$ , for industry  $i$  in each year and use (4) and (5) to decompose these changes into net entry and continuing terms. 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 entry, exit, 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 cover the fast growth period are three years: The data begin in 1995, and the period of fast growth ends in 1998. Furthermore, in Section 2.5 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 the net entry term in productivity growth.

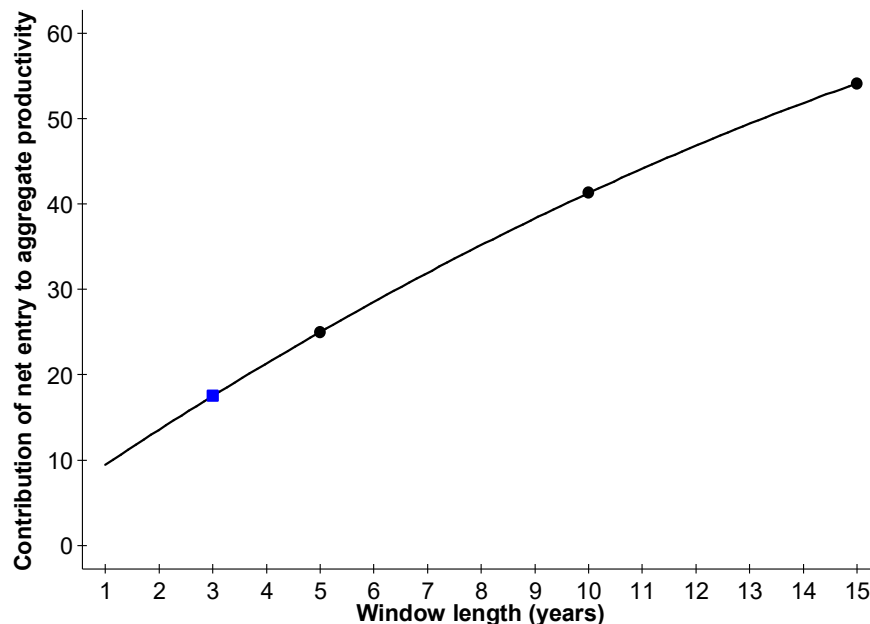
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<sup>9</sup> Note that we use industry-level deflators because we do not observe product-level prices for the products produced or for intermediate inputs used. This implies that our measure of productivity may confound other factors such as differences in markups across firms or distortions, as in Hsieh and Klenow (2009); this is a well-known limitation in this literature.

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 FHK 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.

For example, in Chile during the period 1995–1998, the contribution of net entry in the FHK decomposition to aggregate manufacturing productivity growth 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 5 years (25.0 percent) by the net entry contribution at 3 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.

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



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 in the FHK decomposition. From 1995 to 1998, Chilean manufacturing productivity experienced annual growth of 3.3 percent, compared with 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 with 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 with 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.

### 2.3. Entering and Exiting Cohorts: Relative Productivity and Market Shares

In this section, we decompose the FHK entering and exit terms to investigate whether the results from the previous section are driven by changes in the productivity of entering and exiting plants or in their market shares. First, we calculate a measure of the relative productivity of entering plants. For each industry, we find the difference between the weighted average productivity of entering plants and the industry-level productivity from the beginning of the window. We similarly calculate the difference between the weighted average productivity of exiting plants and the industry-level productivity at the beginning of the window. For the market shares, we use the market share of entering plants at the end of the window and that of exiting plants at the beginning

of the window. We then aggregate these measures using the industry-level weights described in Appendix C.1.

**Table 2: Relative productivity and market share of entering and exiting plants**

Period	Aggregate manufacturing productivity growth (percent)	Relative productivity of entrants (percent)	Market share of entrants	Relative productivity of exiters (percent)	Market share of exiters
Chile					
1995–1998*	17.6	28.1	0.24	–5.7	0.20
2001–2006	9.8	6.8	0.36	0.9	0.23
Korea					
1992–1997	19.3	15.0	0.38	–10.5	0.35
2001–2006	17.6	7.3	0.27	–18.9	0.24
2009–2014	7.7	–2.4	0.27	–10.5	0.24

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

Note: The measures of relative productivity compare the productivity of entrants and exiters to the industry-level productivity of the beginning of the window.

The results are reported in Table 2. We find that in both Chile and Korea, periods of fast growth are accompanied by increases in the relative productivity of entering plants. For example, during the 2001–2006 window in Korea, entering plants were 7.3 percent more productive than the average industry-level productivity at the beginning of the window. On the other hand, in the 2009–2014 window, entering plants were 2.4 percent less productive. We similarly find that periods of fast growth tend to be accompanied by the exit of relatively unproductive plants. This pattern is true for the case of Chile and is also true on average for Korea (comparing the slow growth window with the average of the two fast growth windows). In the case of Korea, for example, during the 2001–2006 window, exiting plants were 18.9 percent less productive than the average industry-level productivity at the beginning of the window, whereas in the 2009–2014 window, they were 10.5 percent less productive. Furthermore, we do not find a consistent pattern across Chile and Korea with respect to the market share of entering and exiting plants during periods of fast and



slow growth. In Appendix C.2, we find that the entry and exit rates of plants exhibit patterns similar to those of the market shares reported in Table 2.<sup>10</sup>

It is useful to notice that the columns in Table 2 are inputs into the calculation of the contribution of net entry. In particular, the net entry contribution can be calculated as the product of the relative productivity of entering plants and their market shares (in the case of the 2001–2006 window for Chile, this would be  $6.8 \times 0.36$ ) subtracted by the product of the relative productivity of exiting plants and their market shares ( $0.9 \times 0.23$ ), which is then divided by the aggregate manufacturing productivity growth (9.8). In the case of Chile, this calculation gives 23 percent, which is consistent with the results in Table 1. See Appendix C.1 for further details.

#### **2.4. Robustness Exercises and Additional Discussions**

In Appendix B, we conduct a series of robustness exercises. First, we consider alternative productivity decompositions as described in Griliches and Regev (1995) and Melitz and Polanec (2015) (see Appendix B.1). 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. In Appendix B.2, we also show that this result is robust to using the Wooldridge (2009) extension of the Levinsohn and Petrin (2003) methodology to estimate the production function. It is also robust to using value added as weights, as opposed to gross output weights (see Appendix B.3).

We also consider an additional robustness exercise, in which we use constant industry weights to assess whether our results are driven by the changing composition of industries rather than by within-industry dynamics (see Appendix B.3). Suppose, for example, that some industries have higher shares of productivity growth that are accounted for by entry and exit and that these shares are constant over time. If these industries have increasing shares of output during rapid growth periods, this could account for the empirical regularity we identify. The results of our robustness exercise show, however, that the empirical regularity remains after we use constant industry weights across windows.

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<sup>10</sup> In Appendix C, we report additional statistics for the windows we study, such as the entry and exit rate of plants, incumbent productivity growth, and the productivity of entrants and exiters relative to that of incumbents.

The analysis above considers only plants that have 10 or more employees. For this reason, we conduct robustness exercises to investigate whether this limitation affects our results (see Appendix B.4). First, we recompute the contribution of net entry for the windows 1992–1997 and 2001–2006 for Korea. For these time windows, the data include all plants with 5 or more employees. To ensure comparability with the 2009–2014 window for Korea and the two windows from Chile for which the data set covers only plants with 10 or more employees, we did not use plants with 5–9 employees in the baseline case. Second, we recompute the contribution of net entry for all windows, except that we use only data for plants with 15 or more employees. The baseline results do not change significantly with these different cutoffs.

We next investigate whether higher productivity growth is correlated with higher contributions of net entry at the industry level. In Appendix B.5, we estimate regressions in which the contribution of net entry is the dependent variable and industry productivity growth is the independent variable. We also include window and industry fixed effects in these regressions. In the case of Chile, the estimated coefficients are positive, although they are not statistically significant. In the case of Korea, the estimated coefficients are positive and statistically significant in some specifications. This evidence suggests that, especially in the case of Korea, changes in productivity growth rates within industry across time are associated with higher contributions of net entry. To give a sense of the magnitude for the case of Korea, an increase in industry-level productivity of 5 percentage points (annualized), equivalent to an increase of one standard deviation, is correlated with an increase of 25 percentage points in the contribution of net entry.

Finally, we discuss whether our results could be driven by structural transformation. For example, a rapidly expanding manufacturing sector during the periods of fast growth could lead to an increase in the entry of new plants. We find, however, that Chile and Korea do not have rapidly changing manufacturing sectors during the periods we study. For example, in the case of Chile, the average value added due to manufacturing is 19.9 percent during 1995–1998 and 17.8 percent during 2001–2006. In the case of Korea, the average value added accounted for by manufacturing is 27.3 percent during 1995–1998, 27.8 percent during 2001–2006, and 29.9 percent during 2009–2014. Moreover, of the five windows we study, the only significant change in manufacturing’s value added share occurs in the 2001–2006 window in Chile, during which the share declines from 20.7 percent to 14.0 percent. We do not believe, however, that the lower contribution of entry and

exit is due to the changes in sectoral composition. The reason is that the market share of entrants and exiters does not move systematically with productivity growth, as seen in Table 2.

## **2.5. The Role of Net Entry in the Cross Section**

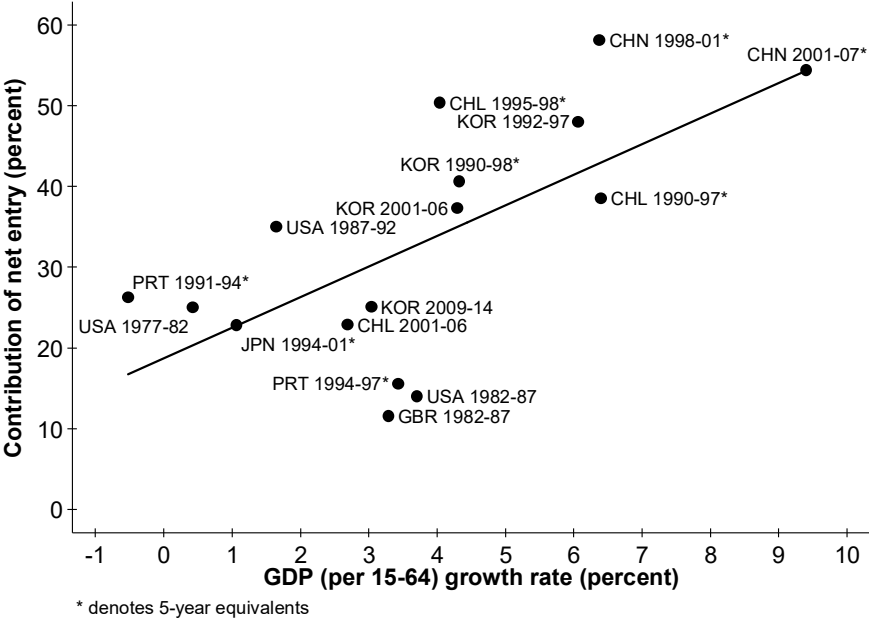
In Section 2.2, we studied the contribution of net entry in the FHK decomposition to aggregate manufacturing productivity growth in Chile and Korea, countries that experienced both fast growth in GDP per working-age person and a subsequent slowdown. This approach is ideal because we eliminate problems 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 we are able to consider. Fortunately, several researchers have used the same methodology 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 be growing relatively fast if the growth rate of GDP per working-age person is at least 4 percent per year. These studies are not focused on the questions 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 makes 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 in the FHK decomposition 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 of 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 of 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.

In Figure 3, we summarize our findings. On the vertical axis, we plot the contribution of net entry to aggregate manufacturing productivity growth in the FHK decomposition, and on the horizontal axis, we plot growth rate of GDP per working-age person. 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 those of 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 manufacturing productivity growth and net entry. This is not a surprise, since the correlation between growth rates of GDP per working-age person and aggregate manufacturing productivity is 0.73, and if we remove one outlier observation (Portugal 1991–1994), this correlation rises to 0.88.

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



**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
<b>Average</b>		<b>2.1</b>	<b>1.6</b>			<b>22</b>	
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
<b>Average</b>		<b>5.8</b>	<b>3.5</b>			<b>47</b>	

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, the gross output production function, gross output shares as weights, and 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. Openness was undoubtedly important in the growth experiences of Chile and Korea. In this paper, however, we focus on the simplest possible model so that we can understand how economic forces manifest in the FHK decomposition. Furthermore, when we look at the reforms implemented in Chile and Korea during the episodes we study, we do not find major trade reforms. In the conclusion, we discuss how our model can be extended to an open economy model.

Firms are heterogeneous in their marginal efficiencies and produce a single good in a perfectly competitive market at the same price. Time is discrete and there is no aggregate uncertainty. 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 the 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-plant 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.<sup>11</sup> One

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<sup>11</sup> Even though our model does not distinguish between establishments and firms, we conjecture that in a model in which incumbents can expand by creating new establishments, reforms would yield results that are qualitatively similar to those found in Section 7.3. For example, lower entry costs or barriers to technology adoption (for both new firms and existing firms creating new establishments) would encourage more draws of both types, leading to more entry of more-productive plants and exit of unproductive plants. Such a model would allow us to additionally analyze

concern may be whether the entry of plants is due to the entry of new firms or the creation of new plants by continuing firms. We find that in the case of the United States, the bulk of new plants are created by new firms: Statistics from the U.S. Census Longitudinal Business Database indicate that 76 percent of new plants are created by firms that are less than 4 years old (average 1980–2000).

### 3.1. Households

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

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

where  $\beta$  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,  $\kappa_t$ , 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  $\delta$ ) or may endogenously exit when the firm's value is negative.

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reforms that affect the creation of new firms (e.g., policies that support new entrepreneurs), as opposed to reforms that primarily affect the establishment of new plants by existing firms.

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

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

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 re-enter 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  $t+1$ .<sup>12</sup> 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  $\varepsilon$  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 on the balanced growth path.

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<sup>12</sup> In Online Appendix 4, we consider an alternative model in which continuing firms are subject to idiosyncratic efficiency growth shocks.



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 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  $\hat{x}_{1t} = \hat{x}_t$ , since firms enter only if the firm's value is positive. For all firms age  $j \geq 2$ ,  $\hat{x}_{jt}$  is characterized by

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

If there are firms in a cohort that choose to exit, then  $\hat{x}_{jt} = \hat{x}_t$ . 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,  $\hat{x}_{jt} = \hat{x}_{j-1,t-1} g_{ct}$ .

### 3.3. Entry

Upon paying the fixed entry cost,  $\kappa_t$ , 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  $\gamma$  governs the shape of the efficiency distribution. We assume that  $\gamma(1-\alpha) > 1$ , which is necessary for the distribution of profits to have a finite mean. In the spirit of Parente and Prescott (1994), the parameter  $\varphi$  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  $g_e^t / \varphi$ , so increasing the 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, Aghion, and Zilibotti (2003), who assume that fixed costs are proportional to the frontier technology. In Online Appendix 1, 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,  $\kappa^T$ , is technological and 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,  $\mu_t$ , 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,  $\eta_{jt}$ , 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 households' bond holdings  $B_0$  and the measures of firms operating in period zero for ages  $j = 1, \dots, \infty$ , given by  $\{\mu_{t-j+1}, \hat{x}_{j0}, g_{c,t-j+1}\}_{j=1}^{\infty}$ . We also need to define the distributions of efficiencies from which these existing firms were drawn. These distributions are analogous to those for firms born in period zero and later:

$$F_{1-j}(x) = 1 - \left( \frac{\varphi x}{g_e^{j-1}} \right)^{-\gamma}, \quad x \geq g_e^{j-1} / \varphi, \quad (19)$$

for  $j \geq 1$ .

**Definition:** Given the initial conditions, an *equilibrium* is sequences of minimum efficiencies  $\{\hat{x}_{jt}\}_{t=0}^{\infty}$  and firm allocations,  $\{y_t(x), \ell_t(x)\}_{t=0}^{\infty}$ ,  $x \geq g_e^{t-j+1} / \varphi$ , for  $j=1, \dots, \infty$ ; masses of potential entrants  $\{\mu_t\}_{t=0}^{\infty}$ ; masses of operating firms  $\{\eta_t\}_{t=0}^{\infty}$ ; 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  $x \geq g_e^{t-j+1} / \varphi$  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,

$$1 = \sum_{j=1}^{\infty} \left[ \mu_{t+j-1} (1-\delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} \ell_t(x) dF_{t+j-1}(x / \tilde{g}_{jt}) \right]; \quad (20)$$

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,

$$C_t + \eta_t f_t + \mu_t \kappa_t = Y_t = \sum_{j=1}^{\infty} \left[ \mu_{t+j-1} (1-\delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} x \ell_t(x)^\alpha dF_{t+j-1}(x / \tilde{g}_{jt}) \right]; \quad (21)$$

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

$$D_t = \sum_{j=1}^{\infty} \left[ \mu_{t+j-1} (1-\delta)^{j-1} \int_{\hat{x}_{jt}}^{\infty} d_t(x) dF_{t+j-1}(x / \tilde{g}_{jt}) \right] - \mu_t \kappa_t. \quad (22)$$

#### 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. On the balanced growth path, for all  $t \geq 0$  and  $j \geq 1$ ,

$$\frac{w_{t+1}}{w_t} = \frac{Y_{t+1}}{Y_t} = \frac{C_{t+1}}{C_t} = \frac{D_{t+1}}{D_t} = \frac{\hat{x}_{j,t+1}}{\hat{x}_{jt}} = g_e, \quad (23)$$

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  $\hat{x}_{jt} = \hat{x}_t$  for all  $j \geq 1$ . The mass of operating firms is

$$\eta(\kappa, f, \varphi) = \frac{\gamma(1-\alpha)-1}{\lambda(\kappa, f, \varphi) f \gamma}, \quad (24)$$

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

$$\lambda(\kappa, f, \varphi) \kappa = \frac{\kappa_t}{Y_t(\kappa, f, \varphi)}. \quad (25)$$

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

$$\mu(\kappa, f, \varphi) = \frac{\xi}{\lambda(\kappa, f, \varphi) \kappa \gamma \omega}, \quad (26)$$

where  $\xi$  and  $\omega$  are positive constants. The cutoff efficiency to operate is given by

$$\hat{x}_t(\kappa, f, \varphi) = \frac{g_e^t}{\varphi} \left[ \omega \frac{\mu(\kappa, f, \varphi)}{\eta(\kappa, f, \varphi)} \right]^{\frac{1}{\gamma}}, \quad (27)$$

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  $g_e - 1$ :

$$Y_t(\kappa, f, \varphi) = \left[ \frac{\gamma(1-\alpha)}{\gamma(1-\alpha)-1} \eta(\kappa, f, \varphi) \right]^{1-\alpha} \hat{x}_t(\kappa, f, \varphi), \quad (28)$$

$$w_t(\kappa, f, \varphi) = \alpha Y_t(\kappa, f, \varphi), \quad (29)$$

$$D_t(\kappa, f, \varphi) = \frac{\omega - \xi}{\gamma \omega} Y_t(\kappa, f, \varphi). \quad (30)$$

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

$$\lambda(\kappa, f, \varphi) = f^{\frac{\gamma(1-\alpha)-1}{\alpha\gamma}} \frac{1}{\varphi^\alpha} \kappa^{\alpha\gamma} \nu, \quad (31)$$

where  $\nu$  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 one. 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 determined solely 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 (28), 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 (25). Finally, it is useful to know that  $\xi$ ,  $\omega$ , and  $\nu$  are positive constants that do not depend on  $\kappa$ ,  $\varphi$ , 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,  $\kappa$ . Lower entry costs lead to an increase in the mass of potential entrants in (26), which increases the cutoff efficiency in (27). The increase in the cutoff efficiency results in an increase in output in (28). Second, when a country lowers the barriers to technology adoption,  $\varphi$ , there is an increase in the efficiency threshold in (27), which increases output. In contrast to the decline in entry costs, the mass of potential entrants remains unchanged. Rather, efficiency thresholds increase because firms have access to a better efficiency distribution. Finally, consider a reduction in the fixed continuation cost,  $f$ . Equation (24) shows that this leads to an increase in the mass of operating firms. There are two opposing effects. On the one hand, the increase in the mass of operating firms lowers the efficiency cutoffs in (27), which lowers output in (28). On the other hand, the increase in the mass of operating firms raises output in (28). 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 the efficiency cutoffs.

All 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 has the indirect effect of decreasing the fixed costs relative to output. This increases both the mass of operating firms in (24) and the mass of potential entrants in (26). The increase in the mass of operating firms results in an increase in output in (28). Note that these indirect effects have no impact on the efficiency thresholds. To see this, substitute (24) and (26) into (27).

## 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

$$k_{t+1} = \kappa_t + f_t - [f_t - (\kappa_{t+1} - \kappa_t)] + f_{t+1} = \kappa_{t+1} + f_{t+1}. \quad (32)$$

This formulation implies that all firms have the same capital stock, thereby keeping the productivity analysis tractable. The complete details are available in Appendix E. In Online Appendix 2, 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

$$\log[z_t(x)] = \log[y_t(x)] - \alpha_{\ell_t} \log[\ell_t(x)] - \alpha_{k_t} \log(k_t), \quad (33)$$

where  $\alpha_{\ell_t} = w_t / Y_t$  is the labor share,  $\alpha_{k_t} = R_t K_t / Y_t$  is the capital share,  $R_t = 1/q_t - 1 + \delta_{k_t}$  is the rental rate of capital,  $K_t$  is the aggregate capital stock, and  $\delta_{k_t}$  is the aggregate depreciation rate. Note that  $P_t$  has been normalized to 1 in our model, implying 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 on 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 (33) and use the fact that  $\alpha_{\ell_t} = \alpha$  to obtain

$$\log[z_t(x)] = \log x - \alpha_{k_t} \log(\kappa_t + f_t). \quad (34)$$

Thus, measured productivity and efficiency are tightly linked, the only difference being the last term, which is common across all firms. To be consistent with the measure of aggregate productivity in the empirical analysis, we define aggregate productivity as the weighted average of firm productivities,

$$\log(Z_t) = \sum_{j=1}^{\infty} \left\{ \mu_{t+j-1} (1-\delta)^{j-1} \int_{\tilde{x}_j}^{\infty} s_t(x) \log[z_t(x)] dF_{t+j-1}(x / \tilde{g}_{jt}) \right\}, \quad (35)$$

where  $s_t(x)$  is the market share of a firm with efficiency  $x$ . It follows that on the balanced growth path, the aggregate productivity growth rate is smaller than the GDP growth rate,  $g_e$ , because of the growth of capital. In particular, we have that

$$\Delta \log Z_t = (1 - \alpha_k) \log g_e. \quad (36)$$

## 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. On the balanced growth path, the decomposition is

$$\frac{\Delta \log Z^{Entry}}{\Delta \log Z} = 1 - (1 - \delta) \left( \frac{g_c}{g_e} \right)^\gamma, \quad (37)$$

$$-\frac{\Delta \log Z^{Exit}}{\Delta \log Z} = (1 - \delta) \left( \frac{g_c}{g_e} \right)^{\gamma - \frac{1}{1 - \alpha}} \frac{\log(g_e) - \log(g_c)}{(1 - \alpha_k) \log(g_e)}, \quad (38)$$

$$\frac{\Delta \log Z^C}{\Delta \log Z} = (1 - \delta) \left( \frac{g_c}{g_e} \right)^{\gamma - \frac{1}{1 - \alpha}} \left[ \left( \frac{g_c}{g_e} \right)^{\frac{1}{1 - \alpha}} - \frac{\log(g_e) - \log(g_c)}{(1 - \alpha_k) \log(g_e)} \right], \quad (39)$$

where  $\Delta \log Z^{Entry}$  is the entry term in (4),  $\Delta \log Z^{Exit}$  is the exit term in (4), and  $\Delta \log Z^C$  is defined in (5). The contribution of net entry to aggregate productivity growth in the FHK decomposition is  $(\Delta \log Z^{Entry} - \Delta \log Z^{Exit}) / \Delta \log Z$ . To generate endogenous exit on the balanced



growth path, we have assumed that  $\bar{g} < g_e^{1-\varepsilon}$ , which implies that  $g_c < g_e$ . Thus, the contribution of entry is bounded between  $\delta$  and 1.

Notice that the contribution of entry to aggregate productivity growth in (37) is homogenous of degree 0 in  $g_e$  and  $g_c$ : If both  $g_e$  and  $g_c$  increase by the same factor, the proportional contribution of entry to aggregate productivity growth stays constant. The contribution of exit to growth in (38), however, decreases if both  $g_e$  and  $g_c$  increase by the same factor. The entry and exit terms are asymmetric in our analytic expressions (37) and (38) because the corresponding terms in (4) in the FHK decomposition are asymmetric: The entry term compares productivity of firms across time periods (productivity of entrants at the end of the window with average productivity of firms at the beginning of the window), and the exit term compares productivity of firms in the same time period (productivity of exiting firms at the beginning of the window with the average productivity of all firms at the beginning of the window).

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

The analytic decompositions in (37)–(39) highlight the three fundamental forces that drive aggregate productivity growth in the model: firm turnover, related to  $\delta$ ; firm heterogeneity and selection, governed by  $\gamma$ ; and productivity growth in incumbent firms relative to that in entrants, determined by  $g_e$  and  $g_c$ . We turn to comparative statics to demonstrate these relationships.

To understand how firm turnover shapes the decompositions, first consider the case in which  $\delta$ , the exogenous death probability, is one: All firms die at the end of each period. In this case, all aggregate productivity growth in the FHK decomposition is attributed to entrants. The contribution of the exit 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  $\delta$  falls, more firms remain in operation from one period to the next, and the fraction of productivity growth attributed to continuing firms in the FHK decomposition 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  $\delta$  implies less exit and thus less entry, the contribution from entry to aggregate productivity growth falls.

Firm heterogeneity on the balanced growth path is a function of the heterogeneity in the underlying distribution of entrant productivity, which is governed by  $\gamma$ . To see how firm heterogeneity affects the FHK productivity decomposition, consider the limiting case in which  $\gamma$  approaches infinity. Since  $g_c < g_e$ , the entry term accounts for all the aggregate productivity growth in the FHK decomposition. When  $\gamma$  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 the continuing firms. In this case, even though the incumbent firms exit endogenously, they do not contribute to aggregate productivity growth, since 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 in the FHK decomposition.

As  $\gamma$  decreases, heterogeneity within each cohort increases. As a result, the entry term becomes less important in the FHK decomposition. Greater heterogeneity implies that there are high-productivity incumbent firms that do not exit. This also implies that the continuing term becomes more important, as more firms from previous cohorts remain. The importance of the exit term also increases, as the larger mass of continuing firms induces selection, forcing out firms that are inefficient compared with 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 that of the cohort that entered in the previous period. In this case, once a firm enters, it will exit only 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 in the FHK decomposition is equal to their market share, which is given by the exogenous death probability of existing firms,  $\delta$ , 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 entry term in the FHK decomposition always decreases with  $g_c$ . We can similarly show that the exit term is decreasing in  $g_c$  whenever

$$\log\left(\frac{g_e}{g_c}\right)g_e < \frac{1 - \alpha}{\gamma(1 - \alpha) - 1}. \quad (40)$$

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 net entry's contribution to aggregate productivity growth. We cannot analytically characterize the decompositions off 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 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 5 years, the same length as the time window for the productivity decompositions.

After calibrating the model, we create three separate distorted economies with 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 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 in the FHK decomposition, 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 or with the evidence of other episodes from the literature. Furthermore, reforms that lead to a uniform increase in efficiency for all firms or reforms that benefit incumbents more than entrants are similarly not consistent with the growth episodes we study.

It is worth noting that  $Y_t$  in the model is real GDP. Equation (21) 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

We report the calibrated parameters in Table 4. A model period is five years. We set the fixed continuation cost,  $f^T$ , so that the model generates an average plant size of 14.0 employees, which is the mean during the period 1976 to 2000, as found in U.S. Census Bureau (2011). We set  $\kappa^T$  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,  $\gamma$ , to match the standard deviation of plant employment, which between 1976 and 2000 has an average value of 89.0, according to U.S. Census Bureau (2011). We set  $g_e$  to be 1.02 so that on the balanced growth path, the model matches the long-term average growth rate of the U.S. economy, as discussed by Kehoe and Prescott (2002). The parameter  $\alpha$  is chosen so that the labor share on the balanced growth path is 0.67. The discount factor,  $\beta$ , is set so that the model matches a real interest rate of 4 percent, which is consistent with McGrattan and Prescott (2005). The exogenous death rate,  $\delta$ , 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).

Our empirical work studied the manufacturing sector, but our model is of the entire economy. To make the two comparable, we assume that net entry is as important for productivity growth in nonmanufacturing as it is in manufacturing. We are not aware of any work that calculates the FHK productivity decomposition for the entire U.S. economy. The paper by Garcia-Macia, Hsieh, and Klenow (2016), however, is one of the few papers that use data for the entire U.S. economy to study the relative importance of incumbents and entrants in accounting for productivity growth. They find that incumbents account for the bulk of productivity growth in the economy. Although their results are consistent with those of FHK for the manufacturing sector, we should be cautious in comparing the two results, since Garcia-Macia, Hsieh, and Klenow (2016) do not use the FHK decomposition but rather use a decomposition derived from their model. We set  $\bar{g}$ , which determines the efficiency growth rate of continuing firms  $g_c$ , 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 $\times$ 5	Average U.S. plant size: 14.0
Entry cost (technological)	$\kappa^T$	0.38	Entry cost/continuation cost: 0.82
Tail parameter	$\gamma$	6.10	S.D. of U.S. plant size: 89.0
Entrant efficiency growth	$g_e$	1.02 <sup>5</sup>	BGP growth rate of U.S.: 2 percent
Returns to scale	$\alpha$	0.67	BGP labor share of U.S.: 0.67
Death rate	$\delta$	1 – 0.96 <sup>5</sup>	Exiting plant employment share of U.S.: 19.3 percent
Discount factor	$\beta$	0.98 <sup>5</sup>	Real interest rate of U.S.: 4 percent
Firm growth	$g_c$	1.019 <sup>5</sup>	FHK contribution of entry and exit to U.S. manufacturing productivity growth: 25 percent
Spillover term	$\varepsilon$	0.64	Authors' estimate

We next pin down  $\varepsilon$ , 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 these data, we use data

for Chilean and Korean manufacturing plants. To quantify this relationship, we take the logarithm of (12),

$$\log g_{ct} = \log \bar{g} + \varepsilon \log g_t, \quad (41)$$

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

$$\log g_{ct,i} = \beta_0 + \varepsilon \log g_{it} + \nu_{it}, \quad (42)$$

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  $\nu_{it}$  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  $\varepsilon$  governs the growth rate of continuing-firm efficiency, we use productivity data to estimate (42). The estimated  $\varepsilon$  is nonetheless consistent with the model, 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 reports the results of the regression across the five windows we study. We find that the regression coefficient ranges from 0.38 to 0.70 for Korea and from 0.72 to 0.83 for Chile. We use the average over the five estimates to find that  $\varepsilon = 0.64$ .

**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. <i>R</i> -squared	0.69	0.73	0.26	0.69	0.30

Notes: Estimates of (42) using plant-level data from Chile and Korea. Standard errors are reported in parentheses. \*\*\* Denotes  $p < 0.01$ .

One concern in this estimation is that we are not measuring spillovers but rather an unrelated factor that affects the correlation between plant productivity growth and industry productivity growth (for example, Manski, 1993). A second concern is that although we are calibrating the

model to an economy that is on the balanced growth path, we estimate  $\varepsilon$  using plant-level data for countries that are not on a balanced growth path. The second concern, however, is mitigated by the lack of a systematic relationship between the regression coefficient and whether the economy is in a period of fast growth.

We study the robustness of our results by redoing the quantitative exercise when  $\varepsilon = 0.38$  and  $\varepsilon = 0.83$ , which are the range of estimates for  $\varepsilon$  in Table 5. These results are reported in Appendix G. For both cases, the model matches the positive correlation between fast growth and the contribution of net entry. If it is the case that our estimate of  $\varepsilon$  is biased upward (for example, there is an unobserved factor that positively affects both the productivity growth of continuing plants and the entire industry during periods of fast growth), then it is useful to focus on the robustness exercise that uses lower values of  $\varepsilon$ . The results show that lower values of  $\varepsilon$  result in a greater contribution of net entry because of the diminished spillovers to continuing firms.

We now compare the efficiency growth rates of continuing and entering firms in the calibrated economy. As mentioned before, the efficiency distribution of entrants 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  $g_e$  on the balanced growth path. Note that condition (40), which is the condition under which increases in  $g_c$  lead to a decline in the importance of entry and exit in the FHK decomposition, is satisfied under the calibrated parameters.

## 7.2. Policy Reforms in Chile and Korea

In Appendix H, we summarize the key reforms conducted in Chile and Korea during the periods of fast growth. 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

restrictions on foreign direct investment (FDI), which reduces the barriers to technology adoption, since it improves access to foreign technologies. Similarly, both of these countries made reforms to their financial systems, making it easier for firms to finance large up-front costs and, in that sense, lower barriers to technology adoption and entry costs. Midrigan and Xu (2014) use a model of plant 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 have 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 improves the efficiency distribution from which entrants draw. Perla, Tonetti, and Waugh (2015) and Buera and Oberfield (2016) also build models in which trade reforms lead to an improvement in the efficiency distribution from which firms draw.

### **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 in the FHK decomposition during periods of fast GDP growth. Although the reforms that Chile and Korea implemented over this period are most similar to reducing entry costs and barriers to technology adoption, we examine the quantitative results of reductions in the fixed continuation costs. We also simulate a uniform efficiency increase for both entrants and incumbents to study whether this type of reform can account for the patterns we document.



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,  $\tau^\kappa$ , 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,  $\varphi$ , and the policy-related portion of the fixed continuation cost,  $\tau^f$ , so that GDP on the balanced growth path also declines 15 percent in each of these economies. This requires setting  $\kappa = 0.74$  and  $\varphi = 1.12$  and  $f = 4.48$ .

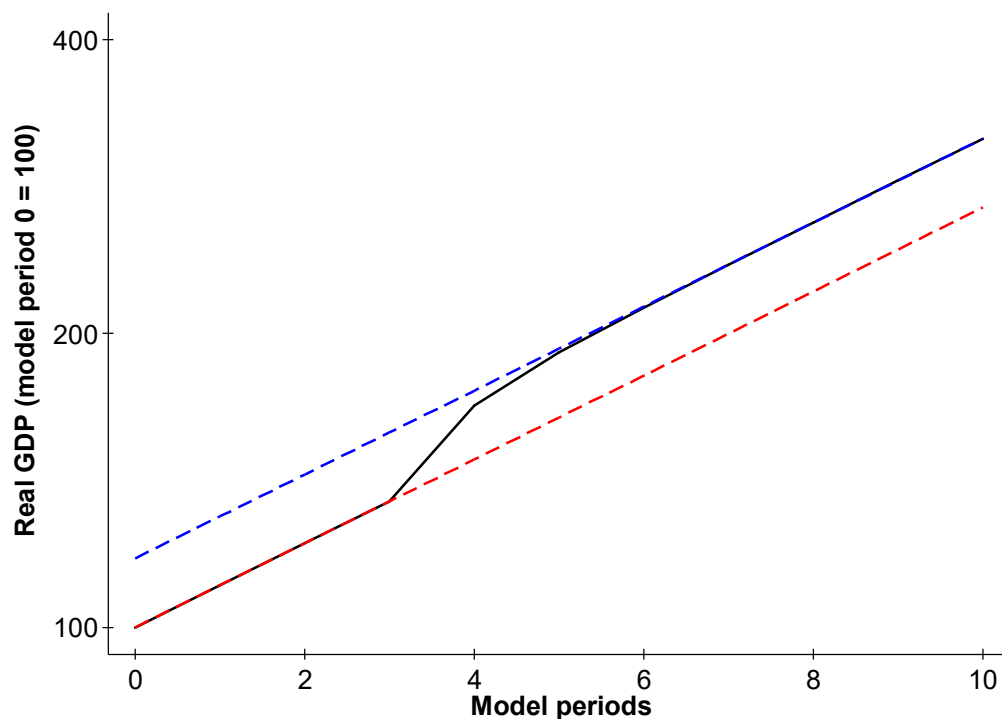
Note that we choose the income levels of the distorted economies to be 15 percent lower than in the calibrated model so that after a reform the distorted economies will have similar growth rates as in the periods of fast growth in the data. Furthermore, the quantitative results reported below are driven by the size of the reform rather than the initial level of the economy. Thus, we would find the same results if we simulated an economy that began with a much lower income and conducted a reform of the same size (i.e., a reform that results in a 15 percent increase in the balanced growth path income level).

### 7.3.1 Reform: Entry Costs

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 GDP. 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 falls to 2 percent.

To understand the mechanisms at work in the model, we plot key economic variables during the transition. The smaller entry costs lead 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

**Figure 4: Real GDP (entry cost reform)**

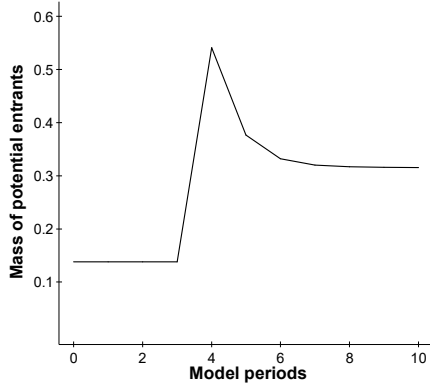


value to 100. The series has been detrended by dividing the threshold by  $g_e^t$  so that the detrended efficiency threshold is constant when the economy is on the balanced growth path. Note that we have exit in each cohort, so the threshold efficiency level is the same for all incumbents and successful entrants.

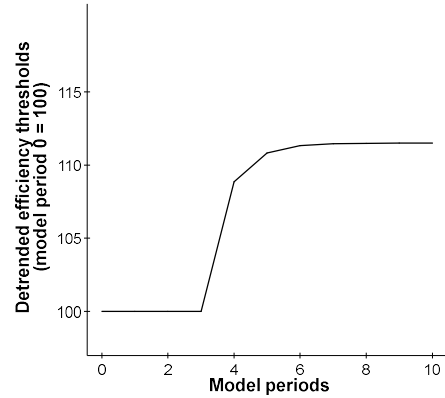
In Figure 6, we plot firm entry and exit. The reform leads to a spike in firm turnover during the transition, and firm turnover is permanently higher on the new balanced growth path. We also see that during the transition, relatively inefficient firms exit and relatively efficient firms enter, which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

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

**(a) Mass of potential entrants**

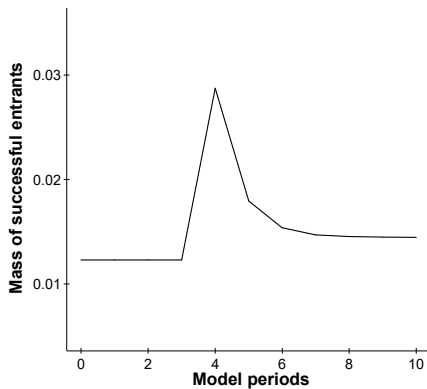


**(b) Detrended efficiency thresholds**

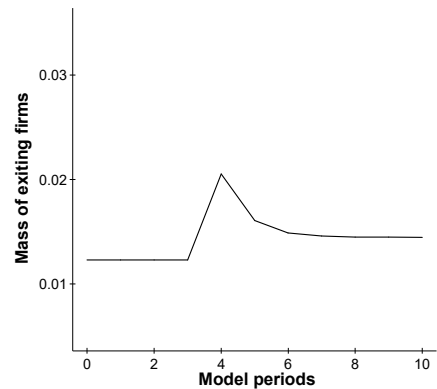


**Figure 6: Firm entry and exit (entry cost reform)**

**(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 forgoes consumption to create long-lived firms that increase 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)**

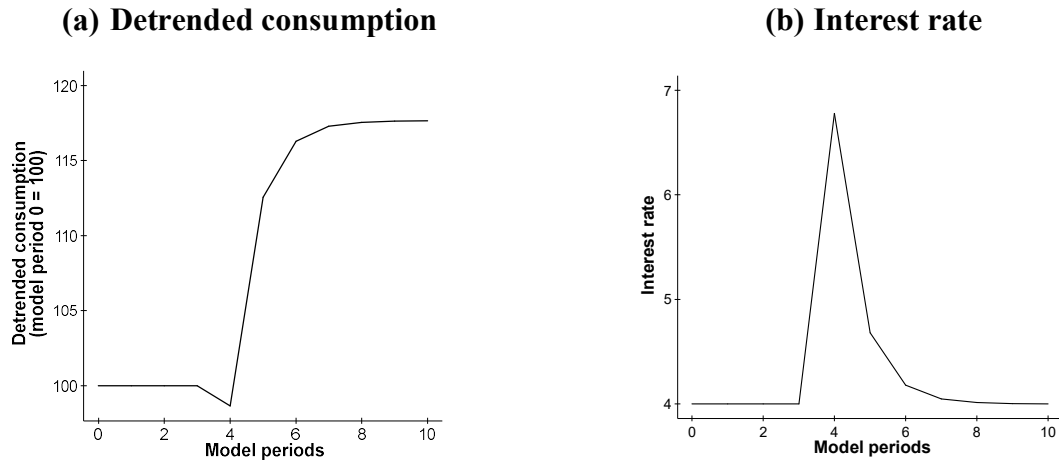


Table 6 reports the GDP and productivity growth rates and the contribution of net entry to productivity growth in the FHK decomposition when we decrease entry costs in the model. Before the reform, the calibrated economy is on a balanced growth path in which GDP grows at 2 percent per year and net entry 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 capital stock imply that productivity growth is smaller than 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

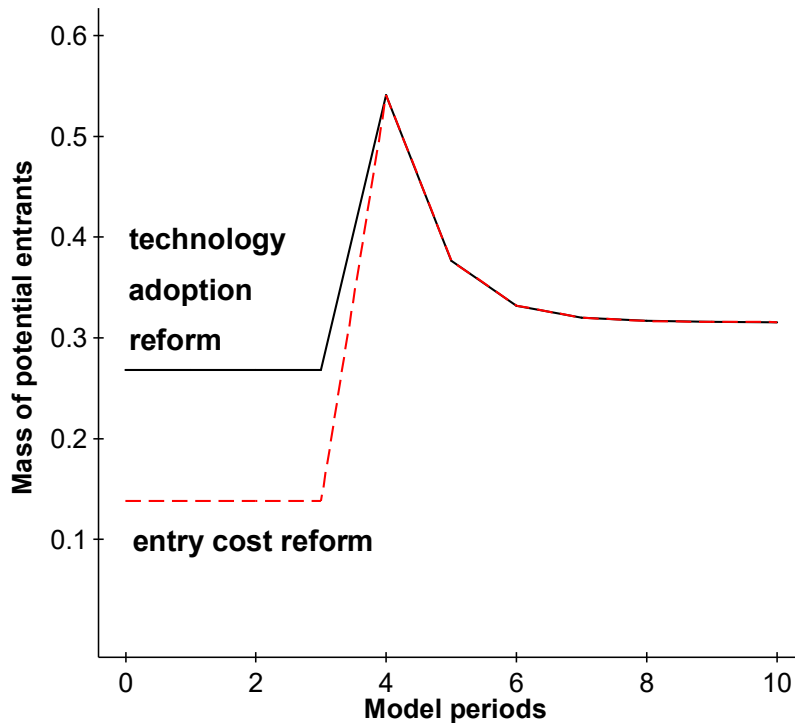
### 7.3.2 Reform: Barriers to Technology Adoption

Our second reform, lowering the barriers to technology adoption ( $\varphi$ ), generates outcomes similar to those from lowering entry costs. For example, when a reform to  $\varphi$  takes place (period 4), GDP

growth and the FHK contribution of 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 between the two reforms is that the mass of potential entrants increases less after the reform to  $\varphi$ . In Figure 8, we plot the mass of potential entrants under both reforms. Note that after the reform, both economies converge to the same nondistorted economy, so the reform to entry costs generates a larger increase in potential entrants. The change in entry costs generates more potential entry, because as seen in (26), lowering  $\kappa$  directly affects the mass of potential entrants. This is in addition to the indirect effects that operate through  $\lambda$ . Lowering  $\varphi$ , however, does not have a direct effect on the mass of potential entrants, only an indirect one.

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



### 7.3.3 Reform: Fixed Continuation Cost

We now evaluate the effect of reforms to the fixed continuation cost. Equation (27), which characterizes the efficiency thresholds in the balanced growth path, highlights two opposing forces that influence how the reform will affect the efficiency of the firms in the economy. On the one hand, lower continuation costs make it more attractive to operate a firm, leading to an increase in the mass of potential entrants. An increase in the mass of potential entrants,  $\mu$ , leads to an increase in the efficiency threshold. On the other hand, lower continuation costs allow for less efficient firms to operate, increasing the mass of firms,  $\eta$ , resulting in a lower efficiency threshold.

We report the results of this reform in Table 7. A surge in GDP growth occurs immediately after the reform. This reform leads to a decline in aggregate productivity, indicating that the second effect mentioned above dominates.<sup>13</sup> Note the contrast between lowering entry costs and lowering fixed continuation costs. In equilibrium, 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.

**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

<sup>13</sup> The measure of aggregate productivity used in the model is defined as the weighted average productivity of firms, as shown in equation (35). This measure is consistent with the measure of aggregate productivity used in Section 2.

### **7.3.4 Uniform Efficiency Shock**

In Appendix F, we simulate a uniform increase in efficiency for both incumbents and entrants. We find that this uniform increase in efficiency does not lead to an increase in the contribution of entry and exit. In fact, the importance of entry and exit falls during the transition. The reason is that while the continuing and entry terms in the FHK decomposition proportionally increase by the same amount, the exit term does not change. The exit term remains unchanged because neither the market share of exiters nor their relative productivities change. As a result, the share of productivity growth accounted for by entry and exit declines.

Based on this finding, we can also rule out other reforms that improve the efficiency of incumbents relative to that of entrants. The reason is that it would lead to an even larger decrease in the contribution of entry and exit.

### **7.4. Robustness to Alternative Modeling Choices**

Our findings are robust to alternative modeling choices. In Online Appendices 1–4, we present alternative models. For each model, we characterize the balanced growth path, recalibrate the model, and perform the same quantitative experiments as before. We find that the transition dynamics are similar to those of the baseline case, in that the contribution of net entry increases immediately after the reform. We conclude that our results are robust to different modeling choices.

In Online Appendix 1, we consider a model in which the fixed costs are denominated in labor rather than the consumption good; this is another common approach in the literature. In Online Appendix 2, we recalibrate the model in Online Appendix 1; in the recalibrated model, labor is interpreted as being a composite input of labor and capital. This formulation allows for firms to have different levels of variable capital. Online Appendix 3 presents a model with monopolistically competitive firms that produce differentiated products. In Online Appendix 4, we allow for continuing firms to be subject to idiosyncratic efficiency growth shocks. The model with idiosyncratic growth shocks and the baseline model yield similar results when the average growth rate of continuing firms is calibrated to match the same contribution of entry and exit.

## 7.5. 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 in the FHK decomposition 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 growth per working-age person and net entry’s contribution to productivity growth over all the fast- and 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.

**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 ( $\kappa$ )	4.6	60
Model reform ( $\varphi$ )	4.6	60
Data slow growth	2.1	22
Model BGP	2.0	25

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 FHK contribution of net entry 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 with 5.8 percent in the data. The contribution of net entry during this period is 60 percent in the model, compared with 47 percent in the data.

We further analyze the model’s outcomes by studying the relative productivity of entrants or exiters and their gross output shares. In Table 9, we report the results from our model as well as a summary of the data found in Table 2. Overall, the model matches these nontargeted moments



well. During periods of fast growth, entrants in the model are 14 percent more productive than the average firm in the previous period, compared with 17 percent in the data. During periods of slower GDP growth, the relative productivity of entrants falls to 6 percent in the model, compared with 2 percent in the data. Similarly, during periods of fast growth, exiters are 10 percent less productive than the average firm in the model, compared with 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 with 5 percent in the data.

**Table 9: Relative productivity and market share of entrants and exiters: Model and data**

Period	Aggregate productivity growth (percent)	Relative productivity of entrants (percent)	Entrant market share	Relative productivity of exiters (percent)	Exiter market share
Fast growth					
Data	18.3	16.8	0.30	-11.7	0.26
Model reform ( $\kappa$ )	14.1	14.1	0.42	-9.5	0.27
Model reform ( $\varphi$ )	14.0	14.0	0.42	-9.5	0.27
Slow growth					
Data	8.8	2.2	0.32	-4.8	0.24
Model BGP	6.4	6.4	0.20	-1.6	0.19

Notes: The relative productivity term is the average entrant (or exiter) firm productivity at  $t$  (or  $t-1$ ) relative to the average productivity of all firms in  $t-1$ .

Table 9 also indicates that the model does not completely match all features of the data. 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, whereas 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 in the FHK decomposition are driven mainly by changes in the relative productivity of entrants and exiters. 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.

## **8. Conclusion and Direction for Future Research**

Our work suggests three areas for future research. First, this paper, as well as most of the literature that studies aggregate productivity growth, has focused on the manufacturing sector. Because of this limitation, we have assumed that the fraction of productivity growth accounted for by entry and exit in the FHK decomposition is the same in manufacturing as it is in the entire economy. Decomposing productivity for an entire economy, especially one 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. In a model with international trade, a trade reform generates incentives to attempt entry and will affect the importance of entry and exit in the FHK decomposition. If the economy is open to international capital flows, then it would not see an increase in the interest rate after a reform. In our economy, the rising interest rate slows down the transition. 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 (Reynolds and Curtin, 2011). After 72 months, 30 percent of businesses 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, Haltiwanger, and Scarpetta (2013), who, in their calibration, interpret failed entrants as businesses that do not survive the first five years.

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## Appendix A: Data Appendix

### A.1. Data Description for Chilean Manufacturing Productivity Decompositions

We use the ENIA (*Encuesta Nacional Industrial Anual*) data set provided by the Chilean statistical institute INE (*Instituto Nacional de Estadística*) in September 2014. Similar data are now publicly available through the INE website. The data set covers 1995–2006 and is a panel of all manufacturing plants in Chile with more than 10 employees. The data use the four-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:

$$\log y_{eit} = \log z_{eit} + \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit}, \quad (1)$$

where  $z_{eit}$  is the plant's productivity,  $y_{eit}$  is gross output,  $k_{eit}$  is capital,  $\ell_{eit}$  is total labor measured in man-years,  $m_{eit}$  is intermediate inputs, and  $\beta_j^i$  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 plants; 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 four-digit level (ISIC Rev. 3) to convert these variables into 1995 pesos. These deflators were created by the INE to be used with the ENIA plant-level data. For the labor input, we use man-years, adjusted for labor quality (between blue-collar and white-collar workers) using relative wages.

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  $\beta_k^i$ ,  $\beta_\ell^i$ , and  $\beta_m^i$  of the production function, we use nominal industry cost shares for each input. The cost shares we calculate are at the four-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 no-arbitrage relationship to find the user cost of capital,  $j$ ,

$$R_{jt} = \max \left\{ 1 + r_t - (1 - \delta_j) \frac{P_t}{P_{t+1}} \frac{P_{t+1,j}^K}{P_{tj}^K}, \delta_j \right\}, \quad (2)$$

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 from World Bank (2017), for  $P_{t+1} / P_t$  we use the GDP deflator from World Bank (2017), and for  $P_{t+1,j}^K / P_{tj}^K$  we use the aggregate investment deflator from Banco Central de Chile (2015).

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

$$\log z_{eit} = \log y_{eit} - \left( \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit} \right). \quad (3)$$

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 it accounts for, averaged over beginning and end. We follow the exact same process to compute the aggregate contribution of continuing firms and net entry.

## A.2. Data Description for Korean Manufacturing Productivity Decompositions

We use the Mining and Manufacturing Survey from the Korean National Statistical Office. The Microdata Service Division of Statistics Korea provides microdata through the Microdata Integrated Service (MDIS) system (<https://mdis.kostat.go.kr/index.do>) for a fee to approved users. This data set is a panel that covers all manufacturing plants 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 five-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).<sup>14</sup> As in the Chilean data, we use four-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:

$$\log y_{eit} = \log z_{eit} + \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit}, \quad (4)$$

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

For gross output, we use the production value reported in Korean won. We use producer price indices (obtained from the Bank of Korea, henceforth BOK), broken down at the four-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 Baily, Hulten, and Campbell (1992), the adjustment is made using the relative earnings of nonproduction workers, calculated separately for each plant.<sup>15</sup> 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,

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<sup>14</sup> 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.

<sup>15</sup> For the 2009–2014 window, in which employees are reported as full-time and temporary workers, the analogous adjustment is made for temporary workers.

$$k_{et} = \sum_j k_{eij}. \quad (5)$$

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

$$\underline{D}_{\text{industry codes} \times \text{years}} = \exp \left[ \underline{I}_{\text{industry codes} \times \text{product codes}} \cdot \log \left( \underline{P}_{\text{product codes} \times \text{years}} \right) \right], \quad (6)$$

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

The factor elasticities  $\beta_k$ ,  $\beta_\ell$ , and  $\beta_m$  of the production function are obtained using the four-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

$$R_{jt} = \max \left\{ 1 + r_t - (1 - \delta_j) \frac{P_t}{P_{t+1}} \frac{P_{t+1,j}^K}{P_{tj}^K}, \delta_j \right\}, \quad (7)$$

where  $r_t$  is the real interest rate,  $\delta_j$  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 from World Bank (2017), for  $P_{t+1} / P_t$  we use the GDP deflator from World Bank (2017), and for  $P_{t+1,j}^K / P_{tj}^K$  we use the aggregate investment deflator from Statistics Korea (2020). 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

$$\log z_{eit} = \log y_{eit} - \left( \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit} \right). \quad (8)$$

## Appendix B: Sensitivity of Empirical Results

### B.1. 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. In particular, using the GR and MP decompositions, we decompose aggregate manufacturing productivity growth over the same windows to 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 on 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

$$\log Z_{it} = s_{it}^N \log Z_{it}^N + s_{it}^C \log Z_{it}^C, \quad (9)$$

where  $s_{it}^N$  is the share of gross output accounted for by entering plants in industry  $i$  at time  $t$ , and  $\log Z_{it}^N$  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

$$\log Z_{i,t-1} = s_{i,t-1}^C \log Z_{i,t-1}^C + s_{i,t-1}^X \log Z_{i,t-1}^X, \quad (10)$$

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

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

$$\Delta \log Z_{it}^{NE} = \underbrace{s_{it}^N (\log Z_{it}^N - \log Z_{i,t-1}^C)}_{\text{entry term}} - \underbrace{s_{i,t-1}^X (\log Z_{i,t-1}^X - \log Z_{i,t-1}^C)}_{\text{exit term}} \quad (11)$$

and

$$\Delta \log Z_{it}^C = \underbrace{s_{i,t-1}^C (\log Z_{it}^C - \log Z_{i,t-1}^C)}_{\text{within term}} + \underbrace{(s_{it}^C - s_{i,t-1}^C) (\log Z_{it}^C - \log Z_{i,t-1}^C)}_{\text{reallocation term}}. \quad (12)$$

Note that the entry, exit, within, and reallocation terms in (11) and (12) are the same as those in (4) and (5). Thus, the only statistics needed to calculate the FHK decompositions are the weighted productivity of continuing, entering, and exiting plants and their share of output.

The MP decomposition rewrites the continuing and net entry terms as

$$\begin{aligned} \Delta \log Z_{it}^C &= \log Z_{it}^C - \log Z_{i,t-1}^C \\ \Delta \log Z_{it}^{NE} &= s_{it}^N (\log Z_{it}^N - \log Z_{it}^C) - s_{i,t-1}^X (\log Z_{i,t-1}^X - \log Z_{i,t-1}^C). \end{aligned} \quad (13)$$

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

$$\begin{aligned} \Delta \log Z_{it}^C &= s_{it}^C (\log Z_{it}^C - \log \bar{Z}_{it}) - s_{i,t-1}^C (\log Z_{i,t-1}^C - \log \bar{Z}_{it}) \\ \Delta \log Z_{it}^{NE} &= s_{it}^N (\log Z_{it}^N - \log \bar{Z}_{it}) - s_{i,t-1}^X (\log Z_{i,t-1}^X - \log \bar{Z}_{it}), \end{aligned} \quad (14)$$

where

$$\log \bar{Z}_{it} = \frac{\log Z_{it} + \log Z_{i,t-1}}{2}. \quad (15)$$

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. 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 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: Contributions of net entry**

Periods	Country	FHK	GR	MP
1995–1998*	Chile	50.4	23.5	22.4
2001–2006	Chile	22.8	10.8	$-50.9$
1992–1997	Korea	48.0	43.1	3.9
2001–2006	Korea	37.3	31.5	$-2.7$
2009–2014	Korea	25.1	25.6	$-16.5$

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

We calculate these decompositions using output from the model. The results can be found in Table A2. 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 Foster, Haltiwanger, and Krizan (2001), who find 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 contribution after the reforms.

**Table A2: Model output contributions of net entry**

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

## **B.2. Alternative Method to Determine Production Function: Wooldridge-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 A3. We find a pattern similar to the one before, in which the contribution of net entry is higher during periods of fast growth.

**Table A3: Net entry in manufacturing productivity decompositions (WLP)**

Period	Country	Annual growth rate (percent)		Contribution of net entry (percent)
		Real GDP per working-age person	Aggregate productivity	
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.

### B.3. 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 A4, show that the pattern still holds: The contribution of net entry is higher during periods of fast growth.

**Table A4: Net entry in manufacturing productivity decompositions (VA weights)**

Period	Country	Annual growth rate (percent)		Contribution of net entry (percent)
		Real GDP per working-age person	Aggregate productivity	
1995–1998	Chile	4.0	4.2	59.1*
2001–2006	Chile	2.7	1.7	–9.4
1992–1997	Korea	6.1	4.3	46.3
2001–2006	Korea	4.3	4.2	38.6
2009–2014	Korea	3.0	1.7	28.2



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

Another concern is that the results may be driven by the changing composition of industries across time. Industries that consistently have a higher fraction of productivity growth accounted for by entry and exit in the FHK decomposition could also be the ones that increase their output share during periods of rapid growth. For this reason, we redo the decomposition, using the same output shares across windows. Specifically, we use the average weight across windows for each industry. The results are reported in Table A5. Using these alternative weights, we find that entry and exit still account for a larger fraction of aggregate productivity growth during periods of rapid GDP growth.

**Table A5: Net entry in manufacturing productivity decompositions (output shares averaged across windows)**

Period	Country	Annual growth rate (percent)		Contribution of net entry (percent)
		Real GDP per working-age person	Aggregate productivity	
1995–1998	Chile	4.0	6.0	87.4*
2001–2006	Chile	2.7	1.5	33.4
1992–1997	Korea	6.1	5.1	47.2
2001–2006	Korea	4.3	4.0	36.8
2009–2014	Korea	3.0	1.2	17.4

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

#### **B.4. Analysis Considers Plants with at Least 10 Employees**

The Chilean data set contains information about plants with 10 or more employees. The Korean data set covers plants with 5 or more employees for the windows 1992–1997 and 2001–2006; the data set covers plants with 10 or more employees for the window 2009–2014. In order to make the analysis comparable across the two countries and windows, we use observations with 10 or more employees when using the Korean data.

To address the concerns that may arise from this 10-employee cutoff, we recompute the contribution of net entry using different employee cutoffs. The results of these exercises are reported in Table A6. In the first exercise, we redo the productivity decompositions, using a 5-

employee cutoff for the 1992–1997 and 2001–2006 windows for the case of Korea. This analysis is useful because it expands the coverage of plants and thus mitigates the concerns raised by the 10-employee cutoff. We find that the results are very similar to the baseline results, which are also shown in Table A6. Because the market share of these plants tends to be very low, we suspect that including plants with 1–4 employees would not significantly change the analysis. For example, manufacturing plants with 1–4 employees account for approximately 1 percent of total U.S. manufacturing employment based on calculations from the U.S. Census Longitudinal Business Database (average 1980–2000). In the second exercise, we use a cutoff of 15 employees for Chile and Korea to recompute the productivity decompositions. This exercise is useful to check whether the results are sensitive to using higher cutoffs. As before, we do not find significant changes in the contribution of net entry using this higher cutoff.

**Table A6: FHK NE contribution**

Period	Country	Cutoff of 10 employees (baseline)	Cutoff of 5 employees	Cutoff of 15 employees
1995–1998	Chile	50.4*		52.9*
2001–2006	Chile	22.8		15.5
1992–1997	Korea	48.0	46.0	47.9
2001–2006	Korea	37.3	37.4	37.6
2009–2014	Korea	25.1		23.2

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

### B.5. Productivity Growth and the Contribution of Net Entry across Industries

We want to study whether industries that have high productivity growth also have a higher fraction of productivity growth that is accounted for by entry and exit. To do so, we estimate the following industry-level regression for both Chile and Korea:

$$\frac{\Delta \log Z_{it}^{NE}}{\Delta \log Z_{it}} = \alpha_0 + \alpha_1 \Delta \log Z_{it} + I_t^{NE} + I_i^{NE} + v_{it}^{NE}, \quad (16)$$

where  $\Delta \log Z_{it}^{NE}$  and  $\Delta \log Z_{it}$  are defined in equations (2)–(4),  $I_t^{NE}$  is a window fixed effect,  $I_i^{NE}$  is an industry fixed effect, and  $v_{it}^{NE}$  is an error term. Note that the dependent variable is the

fraction of productivity growth that is attributed to net entry. For each country, we combine the industry-level information for all windows. We exclude observations with annualized growth rates of  $-0.2$  to  $0.2$  percent. Owing to the small denominator, these observations, which represent 3 percent of the total observations for Chile and 6 percent for Korea, tend to have extremely large values for the dependent variable in equation (16).

Table A7 presents the results of the estimation. Columns 1–4 report the results for Chile and columns 5–8 report the results for Korea. Columns 3 and 7 show the results for the specification with window and industry fixed effects for Chile and Korea, respectively. Both coefficients are positive, although not statistically significant. Columns 4 and 8 show the results for the same specification, except that we use the industry-level weights used to aggregate across industries as described in Section 2.2. This result is useful because it places greater importance on industries that are weighted more heavily in the FHK decomposition. For both Chile and Korea, the coefficient is positive, and in the case of Korea, it is also statistically significant at the 5 percent level. These results suggest that changes in the productivity growth rates within industry across time are associated with higher contributions of net entry.

**Table A7: Net entry and industry-level productivity growth**

	$\Delta \log Z_{it}^{NE} / \Delta \log Z_{it}$							
	Chile				Korea			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta \log Z_{it}$	0.138 (0.113)	0.226 (0.283)	0.430 (0.327)	0.554 (0.459)	0.131 (0.087)	0.379*** (0.122)	0.337 (0.307)	0.819** (0.318)
Observations	175	175	175	175	474	474	474	474
R-squared	0.008	0.006	0.702	0.832	0.010	0.020	0.387	0.499
Weighted	No	Yes	No	Yes	No	Yes	No	Yes
Window FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	No	No	Yes	Yes

Notes: Estimates of (16) using plant-level data from Chile and Korea. Standard errors are reported in parentheses. \*\*\* denotes  $p < 0.01$  and \*\* denotes  $p < 0.05$ . Errors are clustered at the industry level.

To better understand the economic significance of the results in Table A7, consider a one standard deviation increase in industry-level productivity,  $\Delta \log Z_{it}$ , of 0.3 in the case of Korea.

Column 8 indicates this change is correlated with an increase of 25 percentage points in the contribution of net entry.

## Appendix C: Additional Statistics

### C.1. Entering and Exiting Cohorts: Relative Productivity and Market Shares

In Section 2.2, we showed that there was an increase in the contribution of net entry during periods of fast growth in Chile and Korea. We now develop a methodology to further investigate whether these results are driven by changes in the productivity of entering and exiting plants or in their market shares. In particular, we show that the FHK entry and exit terms can be decomposed into components that correspond to changes in the productivity and markets shares of entering and exiting plants.

To calculate the aggregate net entry term, we first calculate the industry-level net entry term,  $\Delta \log Z_{it}^{NE}$ , and then aggregate it using industry-level weights,  $w_{it}$ . These weights are the fraction of nominal gross output accounted for by that industry, averaged over the beginning and end of each time window. These steps are described in Section 2.2. We use the characterization of the industry-level net entry term described in (11) and aggregate it using the industry-level weights to find the following expression:

$$\underbrace{\sum_{i=1}^I [w_{it} \Delta \log Z_{it}^{NE}]}_{\text{aggregate net entry term}} = \underbrace{\sum_{i=1}^I [w_{it} s_{it}^N (\log Z_{it}^N - \log Z_{i,t-1})]}_{\text{aggregate entry term}} - \underbrace{\sum_{i=1}^I [w_{it} s_{i,t-1}^X (\log Z_{i,t-1}^X - \log Z_{i,t-1})]}_{\text{aggregate exit term}}, \quad (17)$$

where  $I$  is the number of industries;  $s_{it}^N$  and  $\log Z_{it}^N$  are the gross output share and weighted average productivity, respectively, of entering plants at the end of the window; and  $s_{i,t-1}^X$  and  $\log Z_{i,t-1}^X$  are the gross output share and the weighted average productivity, respectively, of exiting plants at the beginning of the window. We rearrange (17) to find the following expression:

$$\underbrace{\sum_{i=1}^I [w_{it} \Delta \log Z_{it}^{NE}]}_{\text{aggregate net entry term}} = \underbrace{\sum_{i=1}^I [w_{it}^N (\log Z_{it}^N - \log Z_{i,t-1})]}_{\text{average relative productivity of entrants}} \underbrace{\sum_{j=1}^I w_{jt} s_{jt}^N}_{\text{average entrant market share}} - \underbrace{\sum_{i=1}^I [w_{it}^X (\log Z_{i,t-1}^X - \log Z_{i,t-1})]}_{\text{average relative productivity of exiters}} \underbrace{\sum_{j=1}^I w_{jt} s_{j,t-1}^X}_{\text{average exiter market share}}, \quad (18)$$

where  $w_{it}^N = w_{it}s_{it}^N / \sum_{j=1}^I w_{jt}s_{jt}^N$  and  $w_{it}^X = w_{it}s_{i,t-1}^X / \sum_{j=1}^I w_{jt}s_{j,t-1}^X$ . This expression allows us to determine whether changes in the entry and exit terms are driven by changes in the shares or the relative productivities. For example, in the first term we decompose the aggregate entry term into two components. First,  $\log Z_{it}^N - \log Z_{i,t-1}$  is the relative productivity of entering plants in industry  $i$  compared with that industry's productivity in the previous period. This measure is then aggregated using the industry-level weight,  $w_{it}^N$ , which is related to the gross output share of entering plants in industry  $i$  relative to that of entering plants across all industries. Second, the market share of entering plants in industry  $i$ ,  $s_{it}^N$ , is aggregated using the industry's weight,  $w_{it}$ . We similarly decompose the aggregate exit term.

The results of this decomposition can be found in Table 2. These results, which are discussed in Section 2.2, show that the most consistent driver of the changes in the entry and exit terms across Chile and Korea is the relative productivity of entering and exiting plants.

It is also useful to follow a similar exercise with the net entry term of the MP decomposition, which is described in equation (13) of Appendix B.1. The results in Table A1 show that the net entry term of the MP decomposition also increases during periods of fast growth. We now lay out a similar strategy to study whether these changes in net entry of the MP decomposition arise from changes in productivity of entering and exiting plants or their market shares.

First, it is important to point out the differences of the net entry term in the FHK and MP decompositions. The FHK decomposition of the net entry term in (18) compares the productivity of entering and exiting plants to the industry-level productivity at the beginning of the window. The MP decomposition, on the other hand, uses the productivity of continuing plants as a benchmark for comparison. In particular, the productivity of entrants is compared with the productivity of continuing plants at the end of the window, and the productivity of exiting plants is compared with the productivity of continuing plants at the beginning of the window.

To calculate the aggregate MP net entry term, we first calculate the industry-level net entry term and then aggregate using the industry-level weights. We use the characterization of the industry-level net entry term described in (13) and aggregate it using the industry-level weights to find the following expression:

$$\begin{aligned}
\underbrace{\sum_{i=1}^I [w_{it} \Delta \log Z_{it}^{NE}]}_{\text{aggregate MP net entry term}} &= \underbrace{\sum_{i=1}^I [w_{it} s_{it}^N (\log Z_{it}^N - \log Z_{it}^C)]}_{\text{aggregate MP entry term}} \\
&\quad - \underbrace{\sum_{i=1}^I [w_{it} s_{i,t-1}^X (\log Z_{i,t-1}^X - \log Z_{i,t-1}^C)]}_{\text{aggregate MP exit term}},
\end{aligned} \tag{19}$$

where  $\log Z_{it}^C$  and  $\log Z_{i,t-1}^C$  are the weighted average productivity of continuing plants at the end and beginning of the window, respectively. We rearrange (19) to find the following expression:

$$\begin{aligned}
\underbrace{\sum_{i=1}^I [w_{it} \Delta \log Z_{it}^{NE}]}_{\text{aggregate MP net entry term}} &= \underbrace{\sum_{i=1}^I [w_{it}^N (\log Z_{it}^N - \log Z_{it}^C)]}_{\text{average relative productivity of entrants}} \underbrace{\sum_{j=1}^I w_{jt} s_{jt}^N}_{\text{average entrant market share}} \\
&\quad - \underbrace{\sum_{i=1}^I [w_{it}^X (\log Z_{i,t-1}^X - \log Z_{i,t-1}^C)]}_{\text{average relative productivity of exiters}} \underbrace{\sum_{j=1}^I w_{jt} s_{j,t-1}^X}_{\text{average exiter market share}}.
\end{aligned} \tag{20}$$

Similarly, we can also aggregate the MP continuing term in equation (13), using the same weights, to obtain

$$\sum_{i=1}^I [w_{it} \Delta \log Z_{it}^C] = \sum_{i=1}^I [w_{it} (\log Z_{it}^C - \log Z_{i,t-1}^C)]. \tag{21}$$

This expression is the productivity growth of continuing plants at the industry-level, which is then aggregated using the industry-level weights.

The results are reported in Table A8. We do not see a consistent pattern in the changes of the relative productivity of entering plants for Chile and Korea. Chile saw a decline in the relative productivity of entering plants during the slow-growth window. In contrast, there was an increase in the relative productivity of entering plants in Korea when comparing the slow-growth window with the average of the two fast-growth windows.

On the other hand, in both Chile and Korea the relative productivity of exiters increased during the window of slow growth. For example, during the 1995–1998 window in Chile, the relative productivity of exiters was –2.8 percent. This number increased to 1.9 percent during the 2001–2006 window. In Korea, the relative productivity of exiters was on average –18.9 percent during the fast-growth windows. During the slow-growth window, the relative productivity of exiters was only –6.8. The relative productivity of exiters term increasing (or becoming less negative) suggests

that the selection effect weakened as growth slowed. Note that the market share of entering and exiting plants is the same as in Table 2.

It is useful to notice that columns 4–7 in Table A8 are inputs into the calculation of the contribution of net entry in the MP decomposition. In particular, the net entry contribution can be calculated as the product of the relative productivity of entering plants and their market shares (in the case of the 2001–2006 window for Chile, this would be  $-12.8 \times 0.36$ ) subtracted by the product of the relative productivity of exiting plants and their market shares ( $1.9 \times 0.23$ ), which is then divided by the aggregate productivity growth (9.8). In the case of Chile, this calculation gives  $-51$  percent, which is consistent with the results in Table A1. Similarly, the contribution of continuing plants in the MP decomposition can be calculated using the information in this table. In this case, it would be the productivity growth of continuing plants divided by the aggregate productivity growth ( $14.8 \div 9.8$ ), or 151 percent.

**Table A8: Relative productivity and market share of entering and exiting plants**

Period	Aggregate manufacturing productivity growth (percent)	Productivity growth of continuing plants (percent)	Relative productivity of entrants (percent)	Market share of entrants	Relative productivity of exiters (percent)	Market share of exiters
Chile						
1995–1998*	17.6	13.6	14.0	0.24	–2.8	0.20
2001–2006	9.8	14.8	–12.8	0.36	1.9	0.23
Korea						
1992–1997	19.5	18.7	–11.8	0.38	–14.8	0.35
2001–2006	17.7	18.2	–22.3	0.27	–23.0	0.24
2009–2014	7.7	8.9	–10.9	0.27	–6.8	0.24

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

Notes: The productivity growth of continuing plants reports equation (21). The relative productivity of entrants compares the productivity of entering plants with that of continuing plants at the end of the window. The relative productivity of exiters compares the productivity of exiting plants with that of continuing plants at the beginning of the window. The entrant and exiter market shares are computed as in equation (20).

## C.2. Entry and Exit Rates

Table 2 in Section 2.3 shows the market share of entering and exiting plants during the windows we study (Table A8 in Appendix C.1 also contains this information). Additionally, it is useful to



examine other statistics, such as the entry and exit rate of plants, to see if they changed in a manner similar to that of market shares during periods of fast and slow growth. Column 2 of Table A9 shows the entry rate of plants for all the windows in Chile and Korea, and column 3 shows the exit rate. The changes in the entry and exit rates in both countries are qualitatively similar to the changes in the market share of entrants and exiters, respectively. As an additional check, we report the annual entry and exit rates averaged over the entire window in columns 4 and 5, respectively. The changes in the annual rates are also similar to those of the entire window, with the main difference being that the annual rates are smaller.

**Table A9: Entry and exit rates**

Period	Entry rate (entire window)	Exit rate (entire window)	Annual entry rate (averaged over window)	Annual exit rate (averaged over window)
Chile				
1995–1998	0.371*	0.400*	0.097	0.103
2001–2006	0.415	0.415	0.132	0.131
Korea				
1992–1997	0.702	0.703	0.351	0.353
2001–2006	0.625	0.584	0.283	0.267
2009–2014	0.584	0.511	0.244	0.224

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

Notes: The entry rate is calculated as the number of entering plants divided by the number of plants at the end of the window. The exit rate is calculated as the number of exiting plants divided by the number of plants at the beginning of the window. We follow a similar process to calculate the annual entry and exit rate.

## 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

$$w_t = \alpha \left( \frac{1-\alpha}{\lambda f} \right)^{1-\alpha} \hat{x}_t, \quad (22)$$

where

$$\lambda = g_e^t / Y_t, \quad (23)$$

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

$$1 = \left( \frac{w_t}{\alpha} \right)^{\frac{1}{\alpha-1}} \frac{\gamma(1-\alpha)}{\gamma(1-\alpha)-1} \hat{x}_t^{\frac{1}{1-\alpha}} \eta_t. \quad (24)$$

Substituting (22) into (24), we obtain the expression for the mass of operating firms:

$$\eta = \frac{\gamma(1-\alpha)-1}{\gamma\lambda f}. \quad (25)$$

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

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

where

$$\omega = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left( \frac{g_e}{g_c} \right)^{\gamma(1-i)}. \quad (27)$$

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

$$\kappa_t = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left( \prod_{s=1}^{i-1} q_{t+s} \right) \int_{\hat{x}_{t+i-1} \prod_{s=1}^{i-1} g_{c,t+s}}^{\infty} d_{t+i-1} \left( \prod_{s=1}^{i-1} g_{c,t+s} x \right) dF_t(x). \quad (28)$$

Evaluating the integral in (28) and substituting (24), we obtain

$$\kappa_t = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left( \prod_{s=1}^{i-1} q_{t+s} \right) \varphi^{-\gamma} g_e^{\gamma t} \hat{x}_{t+i-1}^{-\gamma} \prod_{s=1}^{i-1} g_{c,t+s}^{\gamma} \left\{ \frac{w_{t+i-1}}{\alpha} \frac{1-\alpha}{\eta} - f_t \right\}. \quad (29)$$

Substituting  $Y_{t+i-1} = w_{t+i-1} / \alpha$  and (25) into (29), we obtain

$$w_t \lambda \kappa = \frac{g_e^{\gamma t}}{\gamma \eta} \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left( \prod_{s=1}^{i-1} q_{t+s} g_{c,t+s}^{\gamma} \right) w_{t+i-1} \hat{x}_{t+i-1}^{-\gamma}. \quad (30)$$

Substituting (26) into (30) and applying the balanced growth path conditions ( $w_{t+1} / w_t = g_e$ ,  $q_{t+1} = \beta / g_e$ ,  $g_{cl} = g_c$ ), we obtain

$$\mu = \frac{\xi}{\gamma \lambda \kappa \omega}, \quad (31)$$

where

$$\xi = \sum_{i=1}^{\infty} \beta^{i-1} (1-\delta)^{i-1} \left( \frac{g_e}{g_c} \right)^{\gamma(1-i)}. \quad (32)$$

Finally, substituting  $Y_t = w_t / \alpha$  into (23) and applying the balanced growth path conditions, we obtain

$$\lambda = \left( \frac{f}{1-\alpha} \right)^{\frac{\gamma(1-\alpha)-1}{\alpha\gamma}} \varphi^{\frac{1}{\alpha}} \left[ \frac{\kappa \gamma (1-\alpha) - 1}{\xi (1-\alpha)} \right]^{\frac{1}{\alpha\gamma}}, \quad (33)$$

which is increasing in  $\kappa$ ,  $\varphi$ , 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 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:

$$k_{t+1} = (1 - \tilde{\delta}_{kt})k_t + I_t, \quad (34)$$

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

$$\tilde{\delta}_{kt} = \frac{f_t - (\kappa_{t+1} - \kappa_t)}{\kappa_t + f_t}, \quad (35)$$

then the subsequent capital stock is

$$k_t = k_t + f_t, \quad (36)$$

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

$$\tilde{\delta}_{kt}(\kappa_t + f_t) = f_t - (\kappa_{t+1} - \kappa_t). \quad (37)$$

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

$$\delta_{kt} = 1 - \frac{\eta_{t+1}(\kappa_{t+1} + f_{t+1}) + (\mu_{t+1} - \eta_{t+1})\kappa_{t+1}}{\eta_t(\kappa_t + f_t) + (\mu_t - \eta_t)\kappa_t} + \frac{\mu_t \kappa_t + \eta_t f_t}{\eta_t(\kappa_t + f_t) + (\mu_t - \eta_t)\kappa_t}. \quad (38)$$

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

## Appendix F: Uniform Productivity Increase

In this section, we investigate the effects of a uniform productivity increase for potential entrants and incumbents.<sup>16</sup> In this case, the annualized efficiency growth rate of potential entrants rises from 2.0 to 5.4 percent and that of incumbents rises from 1.9 to 5.3 percent during the reform period.

We report the results of this exercise in Table A10. We find that as before, GDP and productivity growth rates increase immediately after the reform. During the reform period, the economy immediately jumps to the higher balanced growth path. Both entrants and incumbents experience efficiency growth rates that are 3.4 percentage points (annualized) higher than those during the balanced growth paths. As a result, there are no changes in entry or exit rates. In terms of the FHK decomposition, both the FHK entry and continuing terms increase by the same magnitude. The FHK exit term, on the other hand, remains the same because neither the market share of exiters nor their relative productivities change. As a result, the contribution of entry and exit slightly decreases during the uniform productivity increase.

**Table A10: Productivity decompositions (uniform productivity increase)**

Model periods (five years)	Incumbent efficiency growth (percent, annualized)	Entrant efficiency growth (percent, annualized)	Real GDP growth (percent, annualized)	Aggregate productivity growth (percent, annualized)	Contribution of net entry to aggregate productivity (percent)
0–3	1.9	2.0	2.0	1.3	25.0
4 (shock)	5.3	5.4	5.4	4.6	21.6
5	1.9	2.0	2.0	1.3	25.0
6	1.9	2.0	2.0	1.3	25.0
7+	1.9	2.0	2.0	1.3	25.0

<sup>16</sup> A uniform productivity increase for potential entrants and incumbents can be achieved by setting  $\varepsilon = 1$  and recalibrating  $\bar{g}$  to maintain the same contribution of entry and exit as in the baseline and by reducing the barriers to technological adoption  $\varphi$ . In addition, to focus on the direct effects of the uniform productivity increase, we eliminate the indirect effect of  $\lambda(\kappa, f, \varphi)$  described in Section 4.2 by adjusting  $\kappa$  and  $f$  to keep the fixed costs as a percent of output per capita constant.

## Appendix G: Sensitivity Analysis of Spillover Parameter, $\varepsilon$

In this section, we report the sensitivity analysis when we use alternative values of the spillover parameter,  $\varepsilon$ . We redo the quantitative exercise using  $\varepsilon$  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  $\varepsilon$ , we recalibrate all the parameters using the same targets as in Table 4. In both cases, all 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. As can be seen in Table A11, 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  $\varepsilon$ .

**Table A11: Contribution of net entry with entry cost reform (percent)**

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

## Appendix H: Reforms in Chile and Korea

Table A12 describes the reforms conducted in Chile (enacted 1993–1997) and Korea (enacted 1990–1995 and 1998–2004).

**Table A12: 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