Research Division
FEDERAL RESERVE BANK of MINNEAPOLIS

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https://www.minneapolisfed.org/research/

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ABSTRACT

Using data from Chile and Korea, we find that a larger fraction of aggregate productivity growth is due to firm entry and exit during fast-growth episodes compared to slow-growth episodes. Studies of other countries confirm this empirical relationship. We develop a model of endogenous firm entry and exit based on Hopenhayn (1992). Firms enter with efficiencies drawn from a distribution whose mean grows over time. After entering, a firm's efficiency grows with age. In the calibrated model, reducing entry costs or barriers to technology adoption generates the pattern we document in the data. Firm turnover is crucial for rapid productivity growth.

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

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*This paper has benefited from helpful discussions at numerous conference and seminar presentations. We especially thank Pete Klenow for his insights and suggestions. We also thank James Tybout, the Instituto Nacional de Estadística of Chile, and the Korean National Statistical Office for their assistance in acquiring data. All of the publicly available data used in this paper can be found at http://users.econ.umn.edu/~tkehoe/. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

1. Introduction

Underlying aggregate productivity growth — a fundamental determinant of aggregate output growth — are the fortunes of the firms that produce in the economy.[1] These firms are created, they produce, and, eventually, they exit. Dubbed *creative destruction* by Schumpeter (1942), firm entry and exit is generally regarded as necessary for economic growth.

Our empirical understanding of the relationship between firm outcomes and aggregate productivity comes largely from the decomposition of aggregate productivity growth into a contribution from incumbent firms and a contribution from firm entry and exit. In these studies, the role of entry and exit in accounting for aggregate productivity growth, also referred to as the *net entry* component, varies considerably. Take, for example, two widely cited empirical studies: Foster, Haltiwanger, and Krizan (2001) find that plant entry and exit accounts for 25 percent of U.S. productivity growth, while Brandt, Van Biesebroeck, and Zhang (2012) find that firm entry and exit accounts for 72 percent of Chinese productivity growth. Why is firm turnover important for productivity growth in some countries and times and not in others?

This wide range of findings presents a difficulty for researchers developing models in which firm entry and exit is explicitly modeled. Should firm entry and exit play an important role in models? Models of firm entry and exit are often used to study the impact of economic reform on aggregate outcomes. An important mechanism in these models is the exit of inefficient firms and the entry of efficient firms in response to reform. How can researchers discipline the role of entry and exit in models?

In this paper, we argue that entry and exit — creative destruction — is far more important during periods of rapid aggregate growth than it is during periods of slower growth. Our first contribution is empirical. Using plant-level data from Chile and Korea, we find that plant entry and exit accounts for a larger fraction of aggregate productivity growth during periods of faster growth than during periods of slower growth. A meta-analysis of the productivity literature, spanning a number of countries and time periods, supports this empirical regularity. Figure 3, in which we plot output growth rates against the contribution of net entry to aggregate productivity growth, summarizes our findings.

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[1] In the abstract, we refer to production units as firms. When discussing specific data, we refer to a single production unit as a plant and a collection of plants as a firm.

Our second contribution is a dynamic general equilibrium model, based on Hopenhayn (1992), that quantitatively accounts for the relationship between aggregate growth and firm turnover that we find in the data. In the model, new firms enter each period with efficiencies drawn from a distribution whose mean grows over time. Note that we refer to the firm's production function parameter as its efficiency, which is not the same as its measured productivity. After entering, a firm's efficiency grows, but more slowly than the new-firm average. We calibrate the model to U.S. plant-level data and study its response to reductions in policy distortions that generate aggregate output growth. When we reduce either the cost of firm entry or the barriers to technology adoption, firm entry and exit accounts for a larger share of aggregate productivity growth while the economy grows rapidly. Not all reforms, however, generate the observed relationship between aggregate growth and net entry. When we reduce the firm's fixed continuation cost, aggregate productivity falls: A smaller continuation cost allows for less productive firms to enter and prevents less productive firms from exiting.

Chile and South Korea are good candidates for our analysis because both countries have experienced periods of fast and slow aggregate growth. Real GDP per working-age person in Chile grew 4.0 percent per year during 1995–1998, slowing to 2.7 percent per year during 2001–2006. In South Korea, real GDP per working-age person grew 6.1 percent per year in 1992–1997 and slowed to 3.0 percent per year in 2009–2014. Studying periods of slow and fast growth within the same country and same dataset facilitates comparisons.

We use the decomposition in Foster et al. (2001) to measure the contribution of net entry. (In Appendix B, we show that our findings are robust to using other decompositions.) In this decomposition, the net entry term is higher if entering plants are relatively productive compared to the overall industry and exiting plants are relatively unproductive. The continuing plant contribution consists of both within-plant productivity dynamics and the reallocation of market shares across continuing plants.

We find that, in both countries, net entry plays a more important role during periods of fast growth. We further decompose the net entry term and find that the largest contributor to changes in the net entry term is the change in the relative productivity of entering and exiting plants, rather than differences in their market shares.

Our own analysis is limited by the availability of producer-level data. Fortunately, the Foster et al. (2001) decomposition is widely used in the productivity literature. To get a more complete understanding of the empirical relationship between growth and the role of net entry, we survey papers in the literature that use the Foster et al. (2001) decomposition. We find that continuing plants consistently account for the bulk of productivity growth in slow-growing countries and periods. For countries that grow at faster rates, the entry and exit of plants plays a more important role.

Turning to our model, we find three features to be important for generating the relationship between firm entry and exit and aggregate productivity growth. First, in each period, a mass of potential entrants arrive, each of whom draws an efficiency from a distribution with a mean that grows at rate $g_e - 1$. Second, continuing firm efficiency improves with age. This efficiency growth depends on an exogenous growth factor and spillovers from aggregate efficiency growth. Finally, firms optimally choose when to enter and exit production.

The economy is subject to three types of policy distortions. A potential entrant must pay an entry cost in order to draw an efficiency, and, if it chooses to produce, it must pay a fixed cost to continue production in each period. These costs are partly technological and partly the result of policy. We think of these policy-related costs as distortions that can be reduced through economic reform. In the spirit of Parente and Prescott (1994), new firms also face barriers to technology adoption. Better technologies exist but are not used because of policies that restrict their adoption. Our distortions are motivated by the experiences in Chile and Korea, which adopted reforms consistent with lowering entry costs and barriers to technology adoption.

The model has a balanced growth path on which output grows at the same rate as the mean of the efficiency distribution for new entrants, $g_e - 1$, 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. The fraction of aggregate productivity growth that is due to net entry — the focus of our study — is constant across balanced growth paths.

After enacting a reform that decreases the entry cost or the barriers to technology adoption, the economy transits to a higher balanced growth path. During this transition, output grows faster than it does on the balanced growth path, and net entry accounts for a larger share of aggregate productivity growth. In this way, the model qualitatively accounts for the pattern we observe in the data: On the balanced growth path, the output growth rate is relatively low, and so is the contribution of net entry to aggregate productivity growth. During the transition between balanced growth paths, the output growth rate increases, as does the contribution of net entry to aggregate productivity growth.

The model's balanced growth path behavior is consistent with the United States and other industrialized economies that have grown at about 2 percent per year for several decades, despite persistent differences in income levels. Kehoe and Prescott (2002) provide an in-depth discussion of these empirical regularities. In our calibrated model, output grows at about 5 percent per year during the transition between balanced growth paths and 2 percent per year on the balanced growth path. Eichengreen et al. (2012) study episodes of fast growth followed by economic slowdowns and find that, on average, the growth rate slowed from 5.6 to 2.1 percent per year.

To determine whether removing distortions can quantitatively match the importance of entry and exit during periods of rapid growth, we calibrate the model to the U.S. economy. We calibrate the model so that the balanced growth path matches the long-run growth rate of the United States and the share of aggregate productivity growth accounted for by continuing plants. Our calibration focuses on plant-level data, such as the size distribution of U.S. establishments and the employment share of exiting plants.

After calibrating the model, we create three separate distorted economies. The spirit of the exercise is that these distorted economies are exactly the same as the U.S. economy except for the policy distortion that we are studying. We raise one of the three distortions in each economy so that the balanced growth path income level is 15 percent below that of the United States. It is important to note that, in the balanced growth path, these distorted economies grow at 2 percent per year and net entry accounts for 25 percent of aggregate productivity growth. This matches the data well: In our sample, countries we categorize as slow-growing have, on average, annual output growth rates of 2.1 percent and net entry accounts, on average, for 22 percent of aggregate productivity growth.

We then remove the distortion in each economy and study the transition to the higher balanced growth path. When we conduct reforms in the economies with high entry costs and barriers to technology adoption, there is rapid growth in output and aggregate productivity immediately after the reform. During this period, the contribution of entry and exit to productivity increases. When we lower the entry cost, for example, the output growth rate rises to 4.6 percent per year for five years, and entry and exit accounts for 60 percent of productivity growth. In our sample, countries that we categorize as fast-growing had an average output growth rate of 5.8 percent per year, and net entry accounted, on average, for 47 percent of aggregate productivity growth. Decreasing barriers to technology adoption in the model is quantitatively similar.

Not all reforms, however, generate the dynamics consistent with the data. Lowering the fixed continuation cost also leads to rapid output growth, but this rapid growth is accompanied by a decline in aggregate productivity. Lowering the fixed continuation cost allows less productive firms to enter and prevents less productive firms from exiting, which results in a decline in aggregate productivity during periods of fast growth.

Our empirical analysis is broadly related to the productivity decomposition literature, including Baily et al. (1992), Griliches and Regev (1995), Olley and Pakes (1996), Petrin and Levinsohn (2012), and Melitz and Polanec (2015), which develops methodologies for decomposing aggregate productivity. These types of decompositions are often used to study the effect of policy reform (Olley and Pakes 1996; Pavcnik 2002; Eslava et al. 2004; Bollard et al. 2013). Our work is the first to document the relationship between the importance of plant entry and exit and aggregate output growth.

Our modeling approach is related to a series of papers that use quantitative models to study the extent to which entry costs can account for cross-country income differences, such as Herrendorf and Teixeira (2011), Poschke (2010), Barseghyan and DiCecio (2011), Bergoeing et al. (2011), D'Erasmo and Moscoso Boedo (2012), Moscoso Boedo and Mukoyama (2012), D'Erasmo et al. (2014), Bah and Fang (2016), and Asturias et al. (2016). Distortions in our model also drive differences in balanced growth path output levels, but our focus is on the behavior of productivity and entry/exit dynamics during the transition between balance growth paths. Closer to our approach, Garcia-Macia et al. (2016) use a model of firm entry, innovation, and exit to decompose U.S. productivity growth, but their focus is on innovation and the creation of new varieties.

In Section 2, we use productivity decompositions to document the positive relationship between the importance of firm net entry in aggregate productivity growth and the aggregate growth rate in the economy. Section 3 lays out our dynamic general equilibrium model, and Section 4 discusses the existence and characteristics of the model's balanced growth path. In Section 5 we show how our calibrated model replicates the empirical relationship we find in Section 2. Section 6 concludes.

2. Productivity Decompositions

In this section, we decompose changes in aggregate productivity in Chile and Korea into contributions from the productivity of entering and exiting plants and from changes in the productivity of continuing plants. We find that, compared to periods of slow output growth, the net entry of plants accounts for a larger share of productivity growth during years of fast output growth. We then analyze previous work on plant entry and exit and aggregate productivity. This literature was not explicitly focused on the role of entry and exit during different kinds of growth experiences. We find, however, that previous studies support our finding that fast-growing countries tend to have a larger share of productivity growth accounted for by the entry and exit of plants.

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, both output growth rates and the contribution of net entry are continuous (see Figure 3).

2.1. Decomposing Changes in Aggregate Productivity Growth

Our aggregate productivity decomposition follows Foster et al. (2001). We define the industry-level productivity of industry i at time t, Z_{it}, to be

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

where s_{eit} is the share of plant *e*'s gross output in industry i and z_{et} is the plant's productivity. The industry's productivity change during the *window* of $t-1$ to t is

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

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

$$\Delta \log Z_{it} = \Delta \log Z_{it}^{NE} + \Delta \log Z_{it}^{C} , \tag{3}$$

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

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

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

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

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

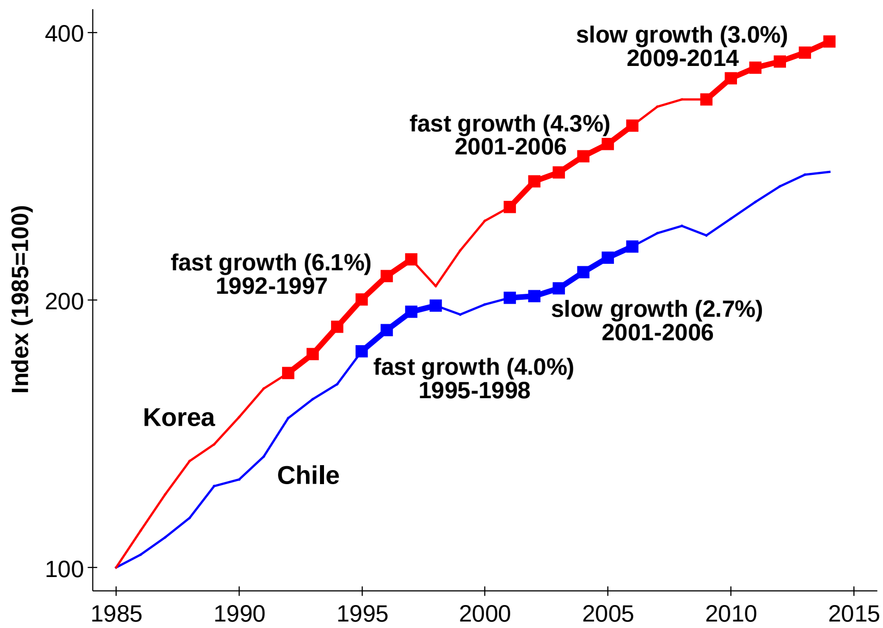
$$\Delta \log Z_{it}^{C} = \underbrace{\sum_{e \in C_{it}} s_{ei,t-1} \Delta \log z_{et}}_{\text{within}} + \underbrace{\sum_{e \in C_{it}} \left(\log z_{et} - \log Z_{i,t-1} \right) \Delta s_{et}}_{\text{reallocation}}, \tag{5}$$

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

2.2. The Role of Net Entry in Chile and Korea

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

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



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

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

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

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

To define an industry, we use the most disaggregated classification possible. For the Chilean data, this is 4-digit International Standard Industrial Classification (ISIC) Revision 3.

For the Korean data, depending upon the sample window, this is a Korean national system that is based on 4-digit ISIC Revision 3 or Revision 4. To get a sense of the level of disaggregation, note that ISIC Revisions 3 and 4 have, respectively, 127 and 137 industries.

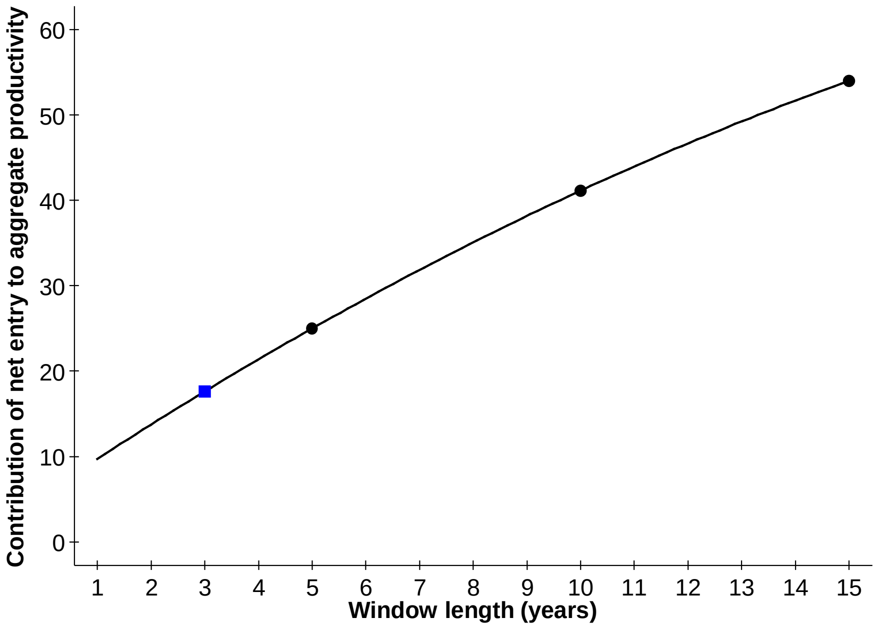
We construct measures of real factor inputs for each plant. Gross output, intermediate inputs, and capital are measured in local currencies, and we use price deflators to build the real series. For labor, we use man-years in the Chilean data and number of employees in the Korean data. Following Foster et al. (2001), the coefficients β_j^i are the industry-level factor cost shares, averaged over the beginning and end of each time window.

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

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

We use our calibrated model (discussed in Sections 3–5) to convert each measurement into 5-year equivalent windows. To do so, we compute the contribution of net entry generated by the model (on the balanced growth path) using window lengths of 5, 10, and 15 years. The contribution of net entry to aggregate productivity growth in the model is 25.0 percent when measured over a 5-year window, 41.1 percent when measured over a 10-year window, and 54.0 percent when measured over a 15-year window. Using these points, we fit a quadratic equation that relates the importance of net entry to the window length, which we plot in Figure 2. We use the fitted curve to adjust the measurements that do not use 5-year windows.

Figure 2: Net entry under various windows in the model.



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

We summarize the Chilean and Korean productivity decompositions in Table 1. We find that periods with faster output growth are accompanied by larger contributions of net entry to aggregate productivity growth. From 1995 to 1998, Chilean manufacturing productivity experienced annual growth of 3.3 percent compared to 1.9 percent growth during the 2001–2006 period. During the period of fast growth for Chile, net entry accounts for 50.4 percent of aggregate productivity growth, whereas it accounts for only 22.8 percent during the period with slower growth. In Korea, the manufacturing sector experienced annual productivity growth of 3.6 percent during 1992–1997 and 3.3 percent during 2001–2006, compared to 1.5 percent during 2009–2014. During the periods of fast growth, net entry accounts for 48.0 percent of aggregate productivity growth in 1992–1997 and 37.3 percent in 2001–2006, compared to only 25.1 percent in 2009–2014.

Table 1: Contribution of net entry in productivity decompositions.

Period	Country	GDP per 15–64 annual growth (percent)	Aggregate productivity annual growth (percent)	Contribution of net entry (percent)
1995–1998	Chile	4.0	3.3	50.4*
2001–2006	Chile	2.7	1.9	22.8
1992–1997	Korea	6.1	3.6	48.0
2001–2006	Korea	4.3	3.3	37.3
2009–2014	Korea	3.0	1.5	25.1

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

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

As a next step, we decompose both the entering and exiting terms in (4) into the productivity differences of entering and exiting firms and their market shares. Appendix C contains additional details regarding this decomposition. We report the decompositions in Table 2. The entering term increases during periods of fast growth. The relative productivity of entrants increases during periods of faster growth in both countries, but market share patterns are less clear. Entrant market shares rise in Korea and fall in Chile. The exiting term tends to be more negative during periods of fast growth. Exiting firm market shares tend to be larger in Korea in times of fast growth, whereas market shares are relatively unchanged in Chile.

Table 2: Entering and exiting terms decomposed multiplicatively.

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

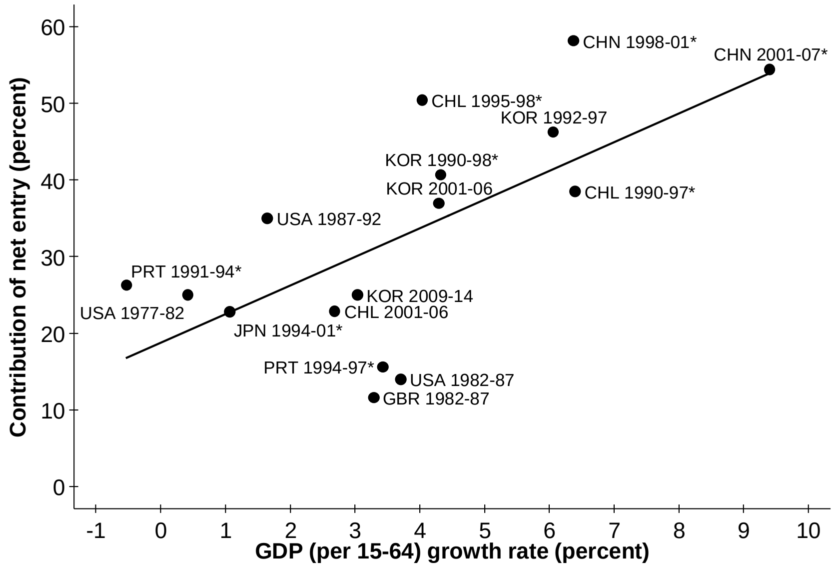
*Measurements adjusted to be comparable with the results from the 5-year windows.

2.3. The Role of Net Entry in the Cross Section

In Section 2.2 we studied the contribution of net entry to aggregate productivity growth in Chile and Korea, countries that experienced both fast growth and a subsequent slowdown. This is an ideal situation because we eliminate problems that might arise from cross-country differences. We would like to study the determinants of productivity growth in as many countries as possible, but access to plant-level data constrains the set of countries that we are able to consider. Fortunately, several researchers have used the same methodology that we describe in Section 2.1 to study countries that are growing relatively slowly (Japan, Portugal, the United Kingdom, and the United States) and countries that are growing relatively fast (Chile, China, and Korea). These studies are not focused on the questions that we ask here, but their use of TFP as the measure of productivity, gross output production functions, gross output as weights, and the Foster et al. (2001) decomposition make their calculations comparable to ours for Chile and Korea.

Table 3 summarizes our findings as well as those in the literature. The fifth column in the table contains the contributions of net entry to aggregate productivity growth as reported in the studies, and the sixth column contains the adjusted 5-year equivalents. In the first panel of Table 3, we gather results from countries with moderate output growth rates. In this set of countries, the contribution of net entry ranges from 12 percent to 35 percent, with an average of 22 percent.

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



* denotes 5-year equivalents

In the second panel of Table 3, we gather the results from countries with relatively high output growth rates. In this set of countries, the contribution of net entry to aggregate 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, and on the horizontal axis we plot the economy's output growth rate. The figure shows a clear positive correlation: The net entry of plants is more important for aggregate productivity growth during periods of rapid GDP growth. Combining our results with studies from the literature yields a more complete picture of the relationship between aggregate productivity growth and the contribution of net entry.

Table 3: Productivity decompositions.

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

Notes: The third column reports annual growth rates of real GDP per working-age person (in percent) over the period of study. The fourth column reports the sample window's length. The fifth column reports the contribution of net entry (in percent) during the sample window using the decomposition described in (3). The sixth column reports the net entry contribution (in percent) normalized to 5-year sample windows. The seventh column reports the source of the information. All studies use TFP as the measure of productivity, use the gross output production function, and use gross output shares as weights. 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 construct a general equilibrium model of firm entry and exit based on Hopenhayn (1992). We model a continuum of firms in a closed economy. These firms are heterogeneous in their marginal efficiencies and produce a single good in a perfectly competitive market. Time is discrete and there is no aggregate uncertainty.

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

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

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

3.1. Households

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

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

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

3.2. Incumbent Producers

In each period t, potential entrants pay a fixed entry cost, κ_t, to draw a marginal efficiency, x, from the distribution $F_t(x)$. 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. Potential entrants that choose to operate may exit for exogenous reasons (with probability δ), or they may endogenously exit when the firm's value is negative.

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

$$y = x\ell^{\alpha}, \tag{8}$$

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

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

where f_t is the continuation cost, which is denominated in units of the consumption good. Both the entry cost, $\kappa_t = \kappa g_e^t$, and the continuation cost, $f_t = fg_e^t$, 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.[2] We assume that the cost of entry, $\kappa = \kappa^T\left(1+\tau^{\kappa}\right)$, is composed of two parts. The first, κ^T, is technological and is common across all countries. The second, $\tau^{\kappa} \geq 0$, is the result of policy. The continuation cost is defined analogously as $f = f^T\left(1+\tau^f\right)$. The solution to (9) is given by

[2]This formulation is similar to Acemoglu et al. (2003), who assume that fixed costs are proportional to the frontier technology.

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

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

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

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

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

$$g_{ct} = \overline{g}g_t^{\varepsilon}, \tag{12}$$

where $\overline{g}$ is a constant, g_t is average efficiency growth, and ε measures the degree of spillovers from the aggregate economy to the firm. These spillovers are not important for our theory, but they are important for our quantitative results.

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

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

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

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

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, $\kappa_t = \kappa g_e^t$, a potential entrant draws its efficiency, x, from a Pareto distribution,

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

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

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

$$E_x\left[V_t(x)\right] = \kappa_t . \tag{16}$$

We refer to the mass of draws taken from the distribution as *potential entrants* because some of the efficiencies drawn are not large enough to justify operating.

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

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

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

$$\eta_t = \sum_{i=1}^{\infty} \eta_{it} . \tag{18}$$

3.4. Equilibrium

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

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

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

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

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

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

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

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

4. Balanced Growth Path

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

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

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

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

Proposition 1. *A balanced growth path exists.*

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

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

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

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

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

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

where ξ and ω are positive constants that do not depend on κ, f, and φ. The cutoff efficiency to operate is given by

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

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

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

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

$$w_t(\kappa, f, \varphi) = \alpha Y_t(\kappa, f, \varphi), \tag{28}$$

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

The bond price is $q_{t+1} = \beta / g_e$. Finally,

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

where ν is a positive constant. Appendix D contains further details. □

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

The balanced growth path has the interesting feature that, although there is efficiency growth among continuing firms, long-run output growth in the economy is solely driven by the improving efficiency of new entrants, g_e. Furthermore, if two economies have the same g_e, they will grow at the same rate, regardless of their entry costs and barriers to technology adoption. The cross-country differences in entry costs and barriers to technology adoption manifest as differences in the level of output on the balanced growth path.

4.1. The Impact of Reform

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

Consider an economy that decreases its entry cost, κ. The associated decrease in $\lambda(\kappa, f, \varphi)$, which captures the decrease in the fixed costs relative to output, increases both the mass of operating firms and the mass of potential entrants. The increase in the mass of operating firms increases output. From (23) and (25), we see that the mass of potential entrants increases more than the mass of operating firms, which increases the cutoff efficiency in (26). The indirect effects, summarized by $\lambda(\kappa, f, \varphi)$, cancel out, and the direct effect of κ on the mass of entrants remains. The increase in the cutoff efficiency increases output.

When a country lowers the barriers to technology adoption, φ, it also increases the mass of operating firms and the mass of potential entrants through the induced decrease in $\lambda(\kappa, f, \varphi)$. As in the reform to κ, the increase in the mass of operating firms increases output. The effect of φ on the efficiency threshold, however, is different from that in the κ reform. Since the change in φ only effects μ and η indirectly through $\lambda(\kappa, f, \varphi)$, the mass of potential entrants and the mass of operating firms grow at the same rate and do not affect the efficiency threshold. The efficiency threshold changes only through the direct effect of φ. Firms have access to a better technology distribution, which increases the efficiency threshold, thereby increasing output.

As in the other two reforms, lowering the fixed continuation cost, f, increases the mass of operating firms and the mass of potential entrants through a decrease in $\lambda(\kappa, f, \varphi)$. The increase in the mass of operating firms increases output. In this case, the mass of potential entrants grows less than the mass of operating firms — lowering the continuation cost encourages firms to stay in the market — so the efficiency threshold falls. The lower efficiency threshold decreases output. The two effects, the increase in the mass of operating firms and the decrease in the efficiency threshold, have opposing influences on output, but it is straightforward to show that the increase in the mass of operating firms dominates the change in the efficiency threshold. A decrease in f increases output.

5. Quantitative Exercise

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, which we take to be the frontier economy ($\varphi = 1$) and on a balanced growth path. We then create three distorted economies that have income levels that are 15 percent below that of the United States by increasing entry costs, barriers to technology adoption, and the continuation cost. Finally, we introduce a reform into each of these distorted economies to determine whether the reforms can quantitatively match the relationships that we observe in the data regarding output growth, productivity growth, and the importance of entry and exit.

5.1. Measuring Productivity

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

$$k_{t+1} = \kappa_t + f_t - \left(f_t - (\kappa_{t+1} - \kappa_t) \right) + f_{t+1} = \kappa_{t+1} + f_{t+1}. \tag{31}$$

This formulation implies that all firms have the same capital stock, which keeps the model tractable. The complete details are available in Appendix E. In Appendix F, we also report the results from a model in which labor is an amalgam of variable labor and variable capital. Our main findings are robust to this alternative calibration.

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

$$\log z_t(x) = \log y_t(x) - \alpha_{\ell t} \log \ell_t(x) - \alpha_{kt} \log(k_t) \tag{32}$$

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

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. The depreciation rate is constant in the balanced growth path (BGP) but not in the transition. In Appendix E, we provide the derivation of the aggregate depreciation rate. Once we measure firm productivity, we calculate aggregate productivity and the Foster et al. (2001) (FHK hereafter) 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 (8) into (32) and use the fact that $\alpha_{\ell t} = \alpha$ to obtain

$$\log z_t(x) = \log x - \alpha_{kt} \log(\kappa_t + f_t)\,. \tag{33}$$

Thus, measured productivity and efficiency are tightly linked, the only difference being the last term, which is common across all firms. Note that, in models of monopolistic competition with constant markups or in models that do not have fixed costs, measured productivity is generally constant across firms in the cross section. In our model, the fixed component of a firm's capital stock generates dispersion in firm productivity.

5.2. Calibration

We choose parameters so that the model matches key features of the U.S. economy, paying particular attention to the size distribution of establishments and the importance of net entry in U.S. aggregate productivity growth. We think of the U.S. economy as being distortion-free, $\tau^f = \tau^\kappa = 0$ and $\varphi = 1$, so the calibration identifies the model's technological parameters. We summarize the parameters in Table 4. A period in the model is five years, the same length as the time window for the productivity decompositions.

We set the fixed continuation cost, f^T, so that the model matches the average establishment size in the United States of 14.0 employees, as found in U.S. Census Bureau (2011) for 1976–2000. Barseghyan and DiCecio (2011) survey the empirical literature on fixed entry and continuation costs, and find that the average entry-continuation cost ratio is 0.82. We set κ^T so that the ratio of the entry cost to the annual fixed continuation cost, $\kappa^T / (f^T / 5)$, is 0.82.

Table 4: Calibrated parameters.

Parameter		Value	Target
Operating cost (technological)	f^T	0.46×5	Average U.S. establishment size: 14.0
Entry cost (technological)	κ^T	0.38	Entry cost / continuation cost: 0.82
Tail parameter	γ	6.10	S.D. of U.S. establishment size: 89.0
Firm growth	$\overline{g}$	1.006^5	Effect of continuing firms on growth: 75 percent
Death rate	δ	$1-0.963^5$	Exiting plant employment share: 19.3 percent
Entrant productivity growth	g_e	1.02^5	BGP growth rate: 2 percent
Discount factor	β	0.98^5	Real interest rate: 4 percent
Returns to scale	α	0.67	BGP labor share: 0.67

We cannot calibrate ε, which characterizes the relationship between continuing-plant and aggregate efficiency growth, so we estimate ε directly from the plant-level data. In the data, we observe an increase in the productivity growth of continuing plants when there is an increase in industry-level productivity growth. To quantify this relationship, take the logarithm of (12),

$$\log g_{ct} = \log \overline{g} + \varepsilon \log g_t \,, \tag{34}$$

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

$$\log g_{ct,i} = \beta_0 + \varepsilon \log g_{it} + \upsilon_{it} \,, \tag{35}$$

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 υ_{it} is an error term. In the data, a continuing plant is one that is present at both the beginning and the end of the sample window. Although ε governs the growth rate of continuing-firm efficiency, we use productivity data to estimate (35). Since productivity is a linear transformation of efficiency, the estimated ε is correct, but the constant term in the regression is not an estimate of $\overline{g}$.

Table 5: Productivity spillover estimates.

	Chile	Korea

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

Notes: Estimates of (35) using plant-level data from Chile and Korea. Standard errors are reported in parentheses. ***Denotes p<0.01.

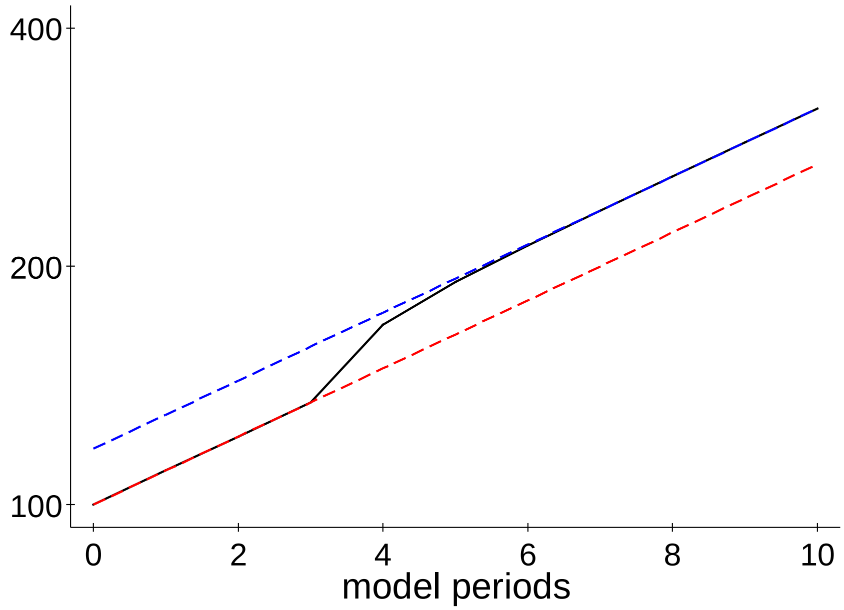
Ideally, we would like to estimate (35) using data for U.S. plants, but without access to those data, we use data from Chile and Korea. The OLS estimates of ε range from 0.38 to 0.70 for Korea and 0.72 to 0.83 for Chile (Table 5). We use the average over the five estimates, $\varepsilon = 0.64$. In Appendix F, we explore the robustness of our results to changing this parameter.

5.3. Simulating Policy Reforms

In this section, we consider policy reforms that move the economy to a higher balanced growth path by lowering entry costs, barriers to technology adoption, or the firm continuation cost. The goal of these experiments is to understand the kinds of reforms that can quantitatively account for the contribution of entry and exit to productivity growth during periods of rapid aggregate growth.

We 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 cost, τ^{κ}, so that output on the balanced growth path is 15 percent lower than in the nondistorted economy. In the second and third distorted economies, we raise the barriers to technology adoption, φ, and the policy-related portion of the fixed continuation cost, τ^{f}, so that output on the balanced growth path is 15 percent lower than in the nondistorted economy. This requires setting $\kappa = 0.74$, $\varphi = 1.12$, and $f = 0.90 \times 5$ in the three distorted economies (the benchmark values of these parameters are reported in Table 4).

Figure 4: Output per worker (entry cost reform).



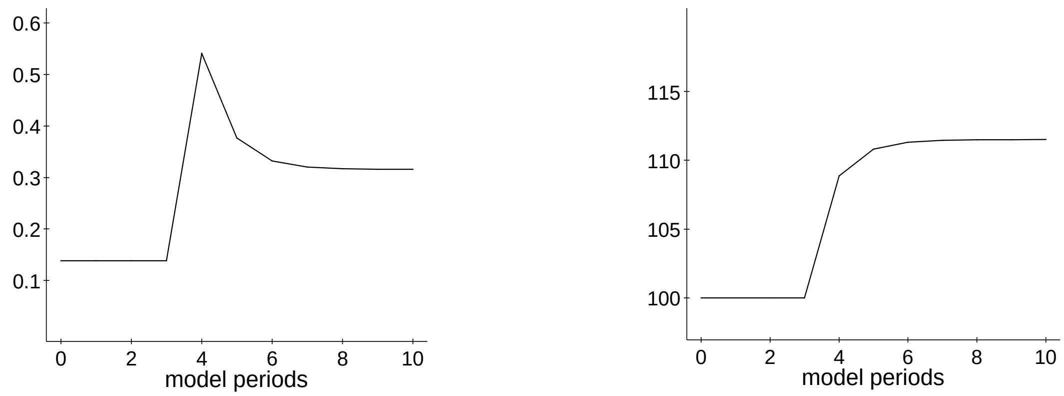
In each distorted economy, we institute a *reform* by eliminating the distortion, and we study the economy's transition to the new balanced growth path.[3] We begin with the reform that reduces entry costs. In Figure 4, we plot output in the economy if it reduces the entry cost in period 4. The economy quickly transits from one balanced growth path to another. Within two model periods, the economy is very close to converging to the new balanced growth path. In the initial 5-year period of reform, output grows 4.6 percent annually. The output growth rate quickly declines in subsequent periods before returning to the 2 percent annual growth rate on the new balanced growth path.

To understand the mechanisms at work in the model, we plot key economic variables during the transition. In Figure 5(a), we plot the mass of potential entrants. The smaller entry cost increases the value of a firm, leading to a permanent increase in the mass of potential entrants. The increase in the mass of potential entrants leads to more entry, which increases the demand for labor, thereby increasing the wage (Figure 7a). Rising wages decrease profits, and some low-efficiency firms will no longer find it optimal to produce.

[3] We compute this transition under the assumption that the economy converges to a new balanced growth path within 40 model periods (or 200 years), and then verify that this is the case.

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

(a) Mass of potential entrants **(b) Detrended efficiency thresholds**

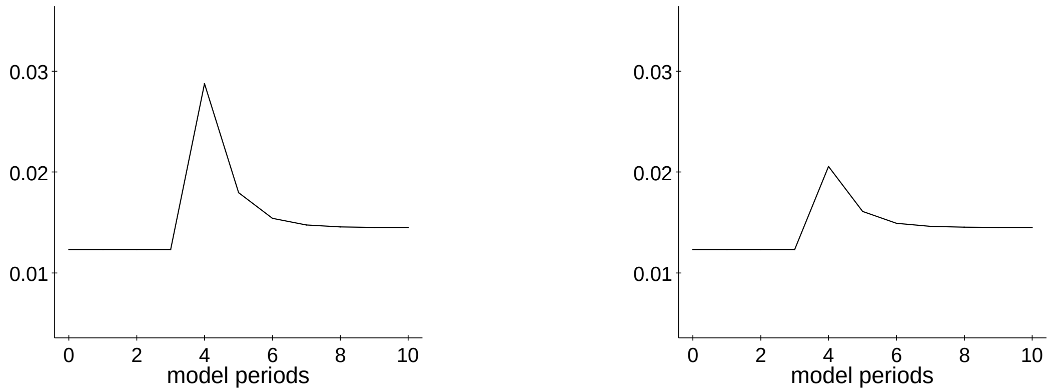


The stronger competition for labor increases the threshold efficiency level. In this reform, we have exit in each cohort, so the threshold efficiency level is the same for all incumbents and entrants. Any firm with efficiency less than $\hat{x}_t$ will not produce. In Figure 5(b), we plot the detrended efficiency threshold, normalizing the first period value to 100. The series has been detrended by dividing the threshold by g_e^t so that the detrended efficiency threshold is constant when the economy is on the balanced growth path.

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 permanentaly higher on the new balanced growth path. The increase in the mass of potential entrants and the resulting increase in the efficiency threshold change the composition of operating firms. As relatively inefficient firms exit and relatively efficient firms enter, aggregate productivity rises. This reallocation is strongest during the transition, which is also when aggregate productivity grows the fastest. This is the mechanism that drives the increased importance of entry and exit for aggregate productivity growth during periods of fast output growth.

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

(a) Mass of entering firms **(b) Mass of exiting firms**



Other model variables, such as consumption and interest rates, exhibit patterns similar to the neoclassical growth model. We plot consumption and interest rates in Figure 8. To understand their behavior, recall that creating new firms is investment: The household foregoes consumption to create long-lived firms that generate output. Decreasing κ decreases the cost of this investment, increasing the demand for potential entrants. The increase in potential entrants increases the interest rate during the reform, and consumption falls. As the investment boom subsides, consumption rises to its new balanced growth path value.

Figure 7: Wages and output (entry cost reform).

(a) Detrended wage **(b) Detrended output**

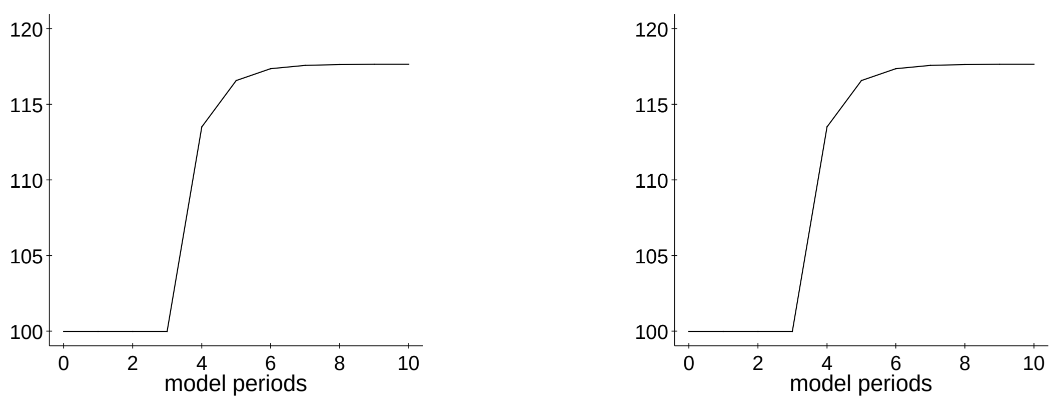


Figure 8: Consumption and interest rates (entry cost reform).

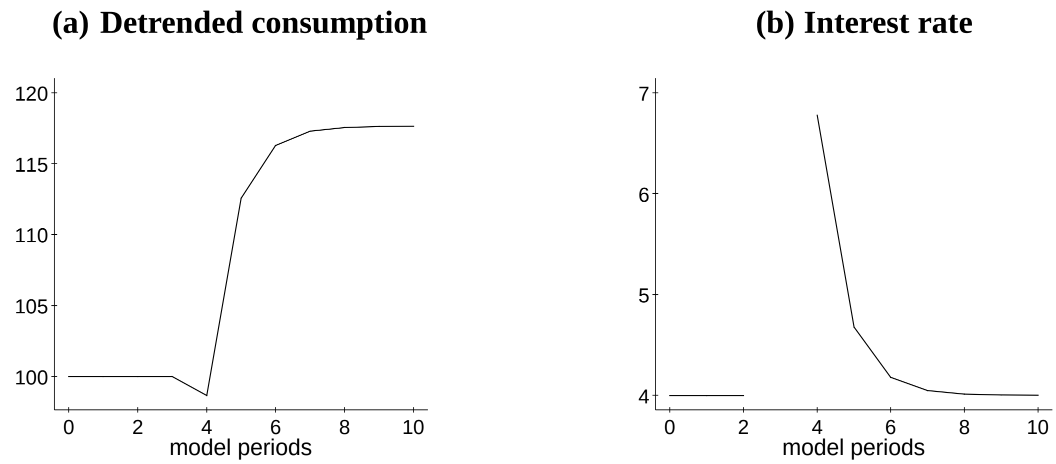


Table 6 reports the output and productivity growth rates and the contribution of net entry to productivity growth when we decrease the entry cost in the model. Before the reform, the economy is on a balanced growth path in which output grows at 2 percent per year and net entry contributes 25 percent of aggregate productivity growth. These outcomes are the result of our calibration. During the reform period, output grows at an annualized rate of 4.6 percent, before returning to 2 percent on the new balanced growth path. During the reform, there is a surge in the contribution of net entry, from 25.0 percent in the initial balanced growth path to 59.7 percent. Increases in the aggregate capital stock imply that increases in productivity growth rates are smaller than in output growth rates.

Table 6: Productivity decompositions (entry cost reform).

Model periods (five years)	Entry cost	Output 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	2.7	59.7
5	0.38	2.5	1.4	36.9
6	0.38	2.1	1.3	28.1
7+	0.38	2.0	1.3	25.0

Our second reform, lowering the barrier to technology adoption (φ), generates outcomes almost identical to lowering κ. Output and aggregate productivity growth after reform to φ are identical to those during and after the reform to entry costs, and the contribution of net entry is the same to the first decimal place. The figures that characterize the key economic variables for the reform to barriers to technology adoption are similar to those in Figures 4–8. The only substantial difference is that the mass of potential entrants in Figure 5(a) increases less after the reform to φ. As seen in (25), lowering κ directly affects the mass of potential entrants. This is in addition to the indirect general equilibrium effects that operate through λ. Lowering φ, however, works only through general equilibrium effects; there is no direct effect on entry.

Our last reform is to decrease the fixed continuation cost that firms pay each period. We report the results of this reform in Table 7. There is a surge in output growth immediately after the reform, but this reform leads to a decline in aggregate productivity. The lower operating cost discourages inefficient firms from exiting and allows less efficient firms to enter. Note the contrast between lowering entry costs and lowering continuation costs. The former generates more potential entrants, thereby raising the efficiency threshold needed to operate. The latter discourages unproductive firms from exiting once they are operating. In the data, we observe that periods of higher output 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 continuation cost.

Table 7: Productivity decompositions (continuation cost reform).

Model periods (five years)	Operation cost	Output 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	89.2
5	2.32	2.8	1.1	37.0
6	2.32	2.2	1.2	28.5
7+	2.32	2.0	1.3	25.0

5.4. Net Entry in the Model and the Data

In this section, we examine the extent to which reforms to entry costs and barriers to technology adoption quantitatively match the contribution of net entry to aggregate productivity that we observe in the data during periods of fast output growth. In Table 8, we report output growth rates and the contribution of net entry to productivity growth in the data and model. Since Table

3 has multiple observations for countries that are experiencing fast and slow growth, we report the average annual output growth and the average contribution of net entry over all the fast-growing economies and all the slow-growing economies.

The model successfully matches the patterns we find in the data. During periods of slow growth, which correspond to the balanced growth path in our model, the model is calibrated to generate the output growth rate and the net entry contribution that we observe in the U.S. data. We have not used any of the model's transition path behavior in the calibration, so the net entry contribution following reform is informative about the model's performance. During reform, output in the model grows at 4.6 percent, compared to 5.8 in the data. The contribution of net entry during this period is 60 percent in the model, compared to 47 percent in the data.

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

	Output growth (percent, annualized)	Contribution of net entry to productivity growth (percent)
Data fast growth	5.8	47
Model reform (κ)	4.6	60
Model reform (φ)	4.6	60
Data slow growth	2.1	22
Model BGP	2.0	25

We further analyze the model's outcomes by decomposing the entering and exiting terms in (4) into components that correspond to the relative productivity of entrants or exiters and their gross output shares. In Table 9, we report the decomposition from our model as well as the data that we reported 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; in the data, entrants are 17 percent more productive. The entrants' market share is 0.42 in the model, compared to 0.30 in the data. Exiting firms are 10 percent less productive than the average firm in the model and 12 percent less productive in the data. The exiting firms' market share is 0.27 in the model and 0.26 in the data.

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

	Entering term			Exiting term		
	Entering term	Relative productivity entrants	Entrant market share	Exiting term	Relative productivity exiters	Exiter market share
Fast growth						
Data	4.8	16.8	0.30	−3.1	−11.7	0.26
Model reform (κ)	5.9	14.1	0.42	−2.5	−9.5	0.27
Model reform (φ)	5.9	14.1	0.42	−2.5	−9.5	0.27
Slow growth						
Data	0.9	2.2	0.31	−1.2	−4.8	0.23
Model BGP	1.4	6.7	0.20	−0.3	−1.6	0.19

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

During periods of slower output growth, the average entrant is 7 percent more productive than the average firm, compared to 2 percent in the data. The entrants' market share in the model is 0.20, compared to 0.31 in the data. In the exiting term, the pattern is reversed: The model generates exiters that are 2 percent less productive than the average firm, compared to 5 percent in the data. The market share of exiters is similar in the model (0.19) and the data (0.23). Our simple model of firm dynamics captures the characteristics of entering and exiting firms reasonably well, and we leave to future research a more nuanced model of firm entry and exit.

5.5. Policy Reforms in Chile and Korea

Both Chile and Korea underwent policy changes close to the periods of fast growth that are consistent with lowering barriers to technology adoption and entry costs. 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. Chile relaxed foreign direct investment (FDI) restrictions in 1993, which reduced the barriers to technology adoption, as it improves access to foreign technologies. Chile also conducted financial reforms in 1993 and 1997. Reforms to the financial system make it easier for firms to finance large up-front costs and, in that sense, lower barriers to technology adoption and entry costs. Finally, the government privatized and deregulated services in 1993 and 1997, which can be interpreted as a decrease in the barriers to technology adoption and entry costs. Similarly, for Korea, the government relaxed FDI restrictions in 1991, 1992, 1995, and 1998, lowering the barriers to technology adoption, and reformed the financial sector in 1993, 1994, 1998, and 2004, lowering the barriers to technology adoption and entry costs. Finally, the government instituted pro-competitive reforms in 1990, 1993, 1994, 1999, and 2004, which allow for greater competition and lower barriers to entry. See Appendix G for details of the reforms in each country.

6. Conclusion

In this paper, we use productivity decompositions to study the relationship between aggregate productivity growth and the importance of plant entry and exit. In the data, we show that the entry and exit of plants contribute more to aggregate productivity growth during periods of faster output growth than during periods of slower output growth. We first study two countries — Chile and Korea — that experienced rapid growth followed by an economic slowdown. We find that, in both countries, the slowdown in growth was also accompanied by a decline in the contribution of plant entry and exit to aggregate productivity growth. Adding to our evidence from Chile and Korea, we collect the results from productivity growth studies in other countries that use the same decomposition methodology that we do. In this broad group of countries, we find that fast-growing countries have larger contributions to aggregate productivity from the entry and exit of plants. This relationship is summarized in Figure 3.

Given our empirical findings, we build a dynamic general equilibrium model with firm entry and exit to examine whether it can quantitatively replicate these relationships. The model is based on Hopenhayn (1992) and incorporates key features of the theories of economic growth proposed by Parente and Prescott (1994) and Kehoe and Prescott (2002). In the model, aggregate growth is driven by the productivity growth of new firms, the productivity growth of incumbent firms, and the endogenous exit of less productive firms. We calibrate the model to U.S. plant-level data. We then create three distorted economies that have income levels that are 15 percent lower than that of the United States by increasing entry costs, barriers to technology adoption, and the fixed continuation cost. We find that if we eliminate the distortions in the economies with entry costs and barriers to technology adoption, the model can replicate the increase in the productivity growth rate and the increasing importance of firm entry and exit. These findings suggest that the entry of productive firms and the exit of unproductive firms play a key role in understanding rapid output growth, but this is less important during times of moderate output growth.

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Appendix A: Data Appendix

Data Description for Chilean Productivity Decompositions

We use the ENIA (Encuesta Nacional Industrial Anual) dataset provided by the Chilean statistical institute INE (Instituto Nacional de Estadística). The dataset is a panel of all manufacturing establishments in Chile with more than 10 employees covering 1995–2006. The data use 4-digit ISIC Rev. 3 industry classification system.[4]

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

$$\log y_{eit} = \log z_{eit} + \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit}, \tag{A36}$$

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

We construct gross output and factor inputs in the same manner as Liu and Tybout (1996) and Tybout (1996). Gross output is the sum of total income (sales of goods produced; goods shipped to other establishments; resales of products; and work, repairs and installations for third parties), electricity sold, buildings produced for own use, machinery produced for own use, vehicles produced for own use, goods produced that go to inventory (final inventory of goods in process plus final inventory of goods produced minus initial inventory of goods in process minus initial inventory of goods produced). For intermediate inputs, we include the purchases of intermediates (materials, fuels, goods purchased for resale, cost of work done by third parties, water, greases, and oil), electricity, and the materials used from inventories (initial inventories minus final inventories). We use gross output and intermediate input deflators at the 4-digit level (ISIC Rev. 3) to convert these variables into 1995 pesos. These deflators were created by INE to be used with the ENIA plant-level data.[5] For the labor input, we use man-years, adjusted for labor quality (between blue-collar and white-collar workers) using relative wages.

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[4] To give a sense of the level of disaggregation, ISIC Rev. 3 has 127 industries.

[5] For more details, see http://www.ine.cl/canales/chile_estadistico/estadisticas_economicas/industria/series_estadisticas/series_estadisticas_enia.php.

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

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

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

$$R_{jt} = \max\left\{1 + r_t - (1-\delta_j)\frac{P_t}{P_{t+1}}\frac{P_{t+1,j}^K}{P_{tj}^K}, \delta_j\right\}, \tag{A37}$$

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

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

$$\log z_{eit} = \log y_{eit} - \left(\beta_k{}^i \log k_{eit} + \beta_\ell{}^i \log \ell_{eit} + \beta_m{}^i \log m_{eit}\right). \tag{A38}$$

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

Data Description for Korean Productivity Decompositions

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

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

$$\log y_{eit} = \log z_{eit} + \beta_k^i \log k_{eit} + \beta_\ell^i \log \ell_{eit} + \beta_m^i \log m_{eit}, \tag{A39}$$

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

For gross output, we use production value reported in Korean won. We use producer price indices (obtained from the Bank of Korea, henceforth BOK), broken down at the 4-digit level, to put this series into real 2010 Korean won. For labor, we use the number of production workers plus a quality-adjusted estimate of nonproduction workers. As in Bailey et al. (1992), the adjustment is made using the relative earnings of nonproduction workers, calculated separately for each plant.[7] For the capital stock, we consider three types of capital: buildings and structures, machinery and equipment, and vehicles and ships. We use the average reported book value of each type of capital at the beginning and end of each year, deflated by the GDP deflator for gross fixed capital formation (BOK). Once we have computed the real capital stock series, we sum the value of buildings and structures, machinery and equipment, and vehicles and ships to obtain the total capital stock of the plant,

$$k_{et} = \sum_j k_{eitj} \,. \tag{A40}$$

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

[6] 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.

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

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

$$\underbrace{D}_{\text{industry codes}\times\text{years}} = \exp\left[\underbrace{I}_{\text{industry codes}\times\text{product codes}} \cdot \log\left(\underbrace{P}_{\text{product codes}\times\text{years}}\right)\right], \tag{A41}$$

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

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

$$R_{jt} = \max\left\{1 + r_t - (1-\delta_j)\frac{P_t}{P_{t+1}}\frac{P^K_{t+1,j}}{P^K_{tj}}, \delta_j\right\}, \tag{A42}$$

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

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

$$\log z_{eit} = \log y_{eit} - \left(\beta^i_k \log k_{eit} + \beta^i_\ell \log \ell_{eit} + \beta^i_m \log m_{eit}\right). \tag{A43}$$

Appendix B: Sensitivity of Empirical Results

Alternative Decompositions for Chile and Korea

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

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

$$\log Z_{it} = s_{it}^{N} \log Z_{it}^{N} + s_{it}^{C} \log Z_{it}^{C}, \tag{A44}$$

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

$$\log Z_{i,t-1} = s_{i,t-1}^{C} \log Z_{i,t-1}^{C} + s_{i,t-1}^{X} \log Z_{i,t-1}^{X}, \tag{A45}$$

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

Second, we rewrite (4) and (5) as

$$\Delta \log Z_{it}^{NE} = \underbrace{s_{it}^{N}\left(\log Z_{it}^{N} - \log Z_{i,t-1}\right)}_{\text{entering}} - \underbrace{s_{i,t-1}^{X}\left(\log Z_{i,t-1}^{X} - \log Z_{i,t-1}\right)}_{\text{exiting}} \tag{A46}$$

and

$$\Delta \log Z_{it}^{C} = s_{it}^{C}\left(\log Z_{it}^{C} - \log Z_{i,t-1}\right) - s_{i,t-1}^{C}\left(\log Z_{i,t-1}^{C} - \log Z_{i,t-1}\right). \tag{A47}$$

Equations (A46) and (A47) show that the only statistics needed to calculate the net entry and continuing plant components of the FHK decompositions are the share of output and the weighted productivity of continuing, entering, and exiting plants.

The MP decomposition rewrites the continuing and net entry terms as

$$
\begin{aligned}
\Delta \log Z_{it}^{C} &= Z_{it}^{C} - Z_{i,t-1}^{C} \\
\Delta \log Z_{it}^{NE} &= s_{it}^{N}\left(\log Z_{it}^{N} - \log Z_{it}^{C}\right) - s_{i,t-1}^{X}\left(\log Z_{i,t-1}^{X} - \log Z_{i,t-1}^{C}\right).
\end{aligned}
\tag{A48}
$$

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 will affect the net entry term.

Lastly, we can write the GR decomposition as

$$
\begin{aligned}
\Delta \log Z_{it}^{C} &= s_{it}^{C}\left(\log Z_{it}^{C} - \log \overline{Z_{it}}\right) - s_{i,t-1}^{C}\left(\log Z_{i,t-1}^{C} - \log \overline{Z_{it}}\right) \\
\Delta \log Z_{it}^{NE} &= s_{it}^{N}\left(\log Z_{it}^{N} - \log \overline{Z_{it}}\right) - s_{i,t-1}^{X}\left(\log Z_{i,t-1}^{X} - \log \overline{Z_{it}}\right)
\end{aligned}
\tag{A49}
$$

where

$$
\log \overline{Z_{it}} = \frac{\log Z_{it} + \log Z_{i,t-1}}{2}. \tag{A50}
$$

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 10 and Table 11. We see that the pattern of high contributions of net entry during the fast growth years, followed by lower contributions of net entry, still holds under all of the decompositions. For Chile, the contribution of net entry goes from 23.5 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 10: Chilean contribution of net entry.

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

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

Table 11: Korean contribution of net entry.

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

We calculate these decompositions using output from the model. The results can be found in Table 12. 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), which finds that the contribution of net entry to productivity growth is similar under both FHK and GR in U.S. manufacturing data. We find that both the MP and GR decompositions show an increase in the net entry component after the reforms.

Table 12: Model output contribution of net entry.

Periods	FHK	GR	MP
Reform (lower entry costs)	59.7	42.9	24.5
Reform (lower φ)	59.7	42.9	24.5
BGP	25.0	15.3	5.8

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

In our baseline specification, we use industry-level cost shares to remain consistent with FHK. As a robustness check, we use the Wooldridge (2009) extension of the Levinsohn and Petrin (2003) method (WLP) for estimation of the production function. With the new elasticities of the production function, we find the plant-level productivities and compute the FHK productivity decompositions. The contribution of net entry and productivity growth is reported in Table 13. As before, we find a similar pattern in which the contribution of net entry is higher during periods of fast growth.

Table 13: Importance of net entry in productivity decompositions (WLP).

Period	Country	GDP per 15–64 annual growth (percent)	Aggregate productivity annual growth (percent)	Contribution of net entry (percent)
1995–1998	Chile	4.0	4.4	73.7*
2001–2006	Chile	2.7	3.4	45.4
1992–1997	Korea	6.1	4.3	39.1
2001–2006	Korea	4.3	3.5	39.2
2009–2014	Korea	3.0	1.4	23.4

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

Alternative Weighting Across Plants

In our baseline specification, we use gross output as weights to calculate industry productivity and then to aggregate changes in industry productivity. This methodology is consistent with that of FHK. As a robustness check, we redo the exercise using value added as weights. The results, reported in Table 14, show that the pattern still holds: the contribution of net entry is higher during periods of fast growth.

Table 14: Importance of net entry in productivity decompositions (VA weights).

Period	Country	GDP per 15–64 annual growth (percent)	Aggregate productivity annual growth (percent)	Contribution of net entry (percent)
1995–1998	Chile	4.0	4.2	59.1*
2001–2006	Chile	2.7	1.7	−9.4
1992–1997	Korea	6.1	3.9	45.9
2001–2006	Korea	4.3	4.0	35.8
2009–2014	Korea	3.0	1.9	20.7

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

Appendix C: Net Entry Term Further Decomposed

We now describe the decomposition of the entering and exiting terms. To do so, we aggregate the net entry term in equation (A46) in the following manner:

$$\sum_{i=1}^{I}\left[w_{it}\Delta\log Z_{it}^{NE}\right]=\sum_{i=1}^{I}\left[w_{it}s_{it}^{N}\left(\log Z_{it}^{N}-\log Z_{i,t-1}\right)\right] -\sum_{i=1}^{I}\left[w_{it}s_{i,t-1}^{X}\left(\log Z_{i,t-1}^{X}-\log Z_{i,t-1}\right)\right], \tag{A51}$$

where I is the number of industries and w_{it} is the weight given to industry i when aggregating. Thus, we have the following decomposition:

$$\sum_{i=1}^{I}\left[w_{it}\Delta\log Z_{it}^{NE}\right]=\underbrace{\sum_{i=1}^{I}\left[\frac{w_{it}s_{it}^{N}}{\sum_{j=1}^{I}w_{jt}s_{jt}^{N}}\left(\log Z_{it}^{N}-\log Z_{i,t-1}\right)\right]}_{\text{average relative productivity of entrants}}\underbrace{\sum_{j=1}^{I}w_{jt}s_{jt}^{N}}_{\text{average entrant market share}} -\underbrace{\sum_{i=1}^{I}\left[\frac{w_{it}s_{i,t-1}^{X}}{\sum_{j=1}^{I}w_{jt}s_{j,t-1}^{X}}\left(\log Z_{i,t-1}^{X}-\log Z_{i,t-1}\right)\right]}_{\text{average relative productivity of exiters}}\underbrace{\sum_{j=1}^{I}w_{jt}s_{j,t-1}^{X}}_{\text{average exiter market share}}, \tag{A52}$$

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

Appendix D: Proof of Proposition 1

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

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

$$w_t = \alpha \left(\frac{1-\alpha}{\lambda f} \right)^{1-\alpha} \hat{x}_t \,, \tag{A53}$$

where

$$\lambda = g_e^t / Y_t \,, \tag{A54}$$

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

$$1 = \left(\frac{w_t}{\alpha} \right)^{\frac{1}{\alpha-1}} \frac{\gamma(1-\alpha)}{\gamma(1-\alpha)-1} \hat{x}_t^{\frac{1}{1-\alpha}} \eta_t \,. \tag{A55}$$

Substituting (A53) into (A55) we obtain the expression for the mass of operating firms

$$\eta = \frac{\gamma(1-\alpha)-1}{\gamma \lambda f} \,. \tag{A56}$$

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

$$\hat{x}_t = \frac{g_e{}^t}{\varphi} \left(\frac{\omega \mu}{\eta} \right)^{\frac{1}{\gamma}} , \tag{A57}$$

where

$$\omega = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\frac{g_e}{g_c} \right)^{\gamma(1-i)} \,. \tag{A58}$$

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

$$\kappa_t = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\prod_{s=1}^{i-1} q_{t+s} \right) \int_{\hat{x}_{t+i-1} \prod_{s=1}^{i-1} g_{c,t+s}^{-1}}^{\infty} d_{t+i-1} \left(\prod_{s=1}^{i-1} g_{c,t+s} x \right) dF_t(x) \,. \tag{A59}$$

Evaluating the integral in (A59) and substituting (A55), we obtain

$$\kappa_t = \sum_{i=1}^{\infty}(1-\delta)^{i-1}\left(\prod_{s=1}^{i-1} q_{t+s}\right)\varphi^{-\gamma} g_e^{\gamma t}\hat{x}_{t+i-1}^{-\gamma}\prod_{s=1}^{i-1} g_{c,t+s}^{\gamma}\left\{\frac{w_{t+i-1}}{\alpha}\frac{1-\alpha}{\eta} - f_t\right\}. \tag{A60}$$

Substituting $Y_{t+i-1} = w_{t+i-1}/\alpha$ and (A56) into (A60), we obtain

$$w_t\lambda\kappa = \frac{g_e^{\gamma t}}{\gamma\eta}\sum_{i=1}^{\infty}(1-\delta)^{i-1}\left(\prod_{s=1}^{i-1} q_{t+s} g_{c,t+s}^{\gamma}\right) w_{t+i-1}\hat{x}_{t+i-1}^{-\gamma}. \tag{A61}$$

Substituting (A57) into (A61) and applying the BGP conditions ($w_{t+1}/w_t = g_e, q_{t+1} = \beta/g_e$, $g_{ct} = g_c$), we obtain

$$\mu = \frac{\xi}{\gamma\lambda\kappa\omega}, \tag{A62}$$

where

$$\xi = \sum_{i=1}^{\infty}\beta^{i-1}(1-\delta)^{i-1}\left(\frac{g_e}{g_c}\right)^{\gamma(1-i)}. \tag{A63}$$

Finally, substituting $Y_t = w_t/\alpha$ into (A54) and applying the BGP conditions, we obtain

$$\lambda = \left(\frac{f}{1-\alpha}\right)^{\frac{\gamma(1-\alpha)-1}{\alpha\gamma}}\varphi^{\frac{1}{\alpha}}\left[\frac{\kappa}{\xi}\frac{\gamma(1-\alpha)-1}{1-\alpha}\right]^{\frac{1}{\alpha\gamma}}, \tag{A64}$$

which is increasing in κ , φ , and f .

Thus, our guess has been verified and all optimality conditions are satisfied. □

Appendix E: Measuring Capital in the Model

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

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

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

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

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

then the subsequent capital stock is

$$k_t = k_t + f_t \ ,$$

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

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

This expression implies that the total depreciation of capital at the firm level is the continuation cost minus any increase in the fixed capital stock. The fact that all firms have the same capital stock allows us to keep the model 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 $\eta_t(\kappa_t + f_t) + \left(\mu_t - \eta_{1t}\right)\kappa_t$. The depreciation of capital is the sum of the capital of firms that die, entry costs of potential entrants who do not enter, and $f_t - (\kappa_{t+1} - \kappa_t)$ for continuing firms as discussed above. We find that the aggregate depreciation rate is

$$\delta_{kt} = 1 - \frac{\eta_{t+1}(\kappa_{t+1} + f_{t+1}) + \left(\mu_{t+1} - \eta_{1t+1}\right)\kappa_{t+1}}{\eta_t(\kappa_t + f_t) + \left(\mu_t - \eta_{1t}\right)\kappa_t} + \frac{\mu_t \kappa_t + \eta_t f_t}{\eta_t(\kappa_t + f_t) + \left(\mu_t - \eta_{1t}\right)\kappa_t}. \qquad \text{(A65)}$$

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

Appendix F: Sensitivity Analysis of Quantitative Results

In this section we report results of sensitivity analysis for the quantitative exercise. These results are reported in Table 15. First, we vary the spillover parameter, ε, from 0.38 to 0.83. These are the minimum and maximum values that we found in the Chilean and Korean data as reported in Table 5. We find that, as in the baseline calibration, there is an increase in the net entry term immediately after the reform. The contribution of net entry ranges from 46.9 to 73.9 percent.

As a final robustness check, we also calibrate the model so that labor is interpreted to be an amalgam of variable labor and variable capital. The new interpretation of α is that it is the span-of-control parameter in Lucas's (1978) model. Consequently, we use a value of 0.85 for this parameter; see, for example, Gomes and Kuehn (2014) and Atkeson and Kehoe (2005). Given the new value of α, we recalibrate all other parameters. The main findings reported in Table 15 are also robust to this alternative calibration.

Table 15: Contribution of net entry (percent).

Robustness	Parameter (baseline value)	BGP	Reform
Low spillovers	$\varepsilon = 0.38$ (0.64)	25.0	73.9
High spillovers	$\varepsilon = 0.83$ (0.64)	25.0	46.9
Variable capital	$\alpha = 0.85$ (0.67)	25.0	73.8
Baseline		25.0	59.7

Appendix G: Reforms in Chile and Korea

Table 16 describes the reforms conducted in Chile (enacted 1993−1997) and Korea (enacted 1990−1995 and 1998−2004).

Table 16: 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	FDI reforms	“raise the ceiling on foreign equity ownership of	Chung (2007),

(1995)		listed corporations"	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