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Firm Entry and Exit and Aggregate Growth *

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ABSTRACT

Using plant-level data from Chile and Korea, we find that, during episodes of rapid growth, most of the aggregate productivity growth is due to the entry and exit of firms while, during episodes of slower growth, it is mostly due to growth within and across existing firms. Studies for other countries suggest that this is an empirical regularity. We develop a dynamic general equilibrium model based on Hopenhayn (1992) which incorporates the theory of economic growth proposed by Parente and Prescott (1994) and Kehoe and Prescott (2002). In this model, new firms enter every period with productivities drawn from a distribution whose mean grows over time. After entering, a firm's productivity grows, but not as rapidly as new firms' productivity distribution. In a version of the model calibrated to U.S. plant-level data, we simulate two sets of reforms: a decrease in new firms' costs of entry and a reduction in the barriers to technology adoption for new firms. The model reproduces the regularity that we observe in the data, and confirm that entry and exit of firms is crucial for reforms to generate rapid growth.

* The views expressed here are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System. The authors would like to especially thank James Tybout and INE of Chile for their assistance in acquiring data.

1. Introduction

Researchers developing models in which they analyze the impact of economic reforms on economic growth often justify their assumptions by citing empirical studies that use plant level data to decompose aggregate productivity growth into a component that depends on continuing plants and another component that depends on entry and exit of plants. In the models in which entry and exit play important roles in generating growth in response to reforms, the entry and exit component is often referred to as creative destruction. Two of the widely cited empirical studies are that by Foster, Haltiwanger, and Krizan (2001) — which is usually summarized as establishing that net entry of plants accounts for 25 percent of U.S. productivity growth and is often used to justify models that focus on growth within continuing firms — and that by Brandt, Van Biesebroeck, and Zhang (2012) — which is usually summarized as establishing that net entry of plants accounts for 72 percent of Chinese productivity growth and is often cited as justifying models that focus on entry and exit of firms.

In the first part of this paper, we study plant-level data from Chile and Korea and find that the productivity growth generated by entry and exit is a larger fraction of aggregate growth during periods of fast growth than it is during periods of slower growth. Studies for other countries suggest that this is an empirical regularity. In the second part of the paper, we develop a dynamic general equilibrium model based on Hopenhayn (1992) which incorporates the theory of economic growth proposed by Parente and Prescott (1994) and Kehoe and Prescott (2002). In this model, new firms enter every period with productivities drawn from a distribution whose mean grows over time. After entering, a firm's productivity grows, but not as rapidly as new firms' productivity distribution. In a version of the model calibrated to U.S. plant-level data, we simulate two separate reforms: we decrease new firms' costs of entry and we reduce the barriers to technology adoption for new firms. We show that in both cases the model can reproduce the regularity that we observe in the data. We conclude that the correlation that we identify in the data can be generated by a causal relation that runs in either direction: On one hand, reducing the costs of entry and exit can result in more productivity growth being generated by net entry and can result in higher aggregate growth. On the other hand, reforms that generate higher aggregate growth make it more profitable to enter and result in more productivity growth being associated with net entry. In both cases, the entry and exit of firms is crucial for rapid growth.

How important is entry and exit in determining aggregate productivity growth? We take two steps to answer this question.

First, we decompose aggregate productivity growth in manufacturing in Chile and Korea over periods of fast and slow growth. During 1990–1995, real GDP per worker age person in Chile grew at 6.8 percent per year, while during 2001–2006, it grew at 2.4 percent per year. In South Korea, during 1992–1997, real GDP per working-age person grew at 6.0 percent per year, while during 2002–2007, it grew at 4.0 percent per year. By applying the Foster, Haltiwanger, Krizan (2001) decomposition, henceforth FHK, we determine how the contribution of entry and exit to growth changed over these two time windows. This term is higher if entering plants are relatively productive (compared to the overall industry) and exiting plants are relatively unproductive. The portion related to continuing plants comes from both within-plant productivity increases and the re-allocation of market shares across continuing plants.

Our findings indicate that plant entry and exit played a more important role during periods of fast growth in both countries. In the case of Chile, there was a sharp decline in both the growth rate and the role of entry and exit (from 85 to 35 percent). For Korea, we also find a decline in the growth rate and the role of entry and exit (from 48 to 40 percent). This decline is not as sharp as Chile's, which is consistent with the fact that Korea's decline in output growth was not as large.

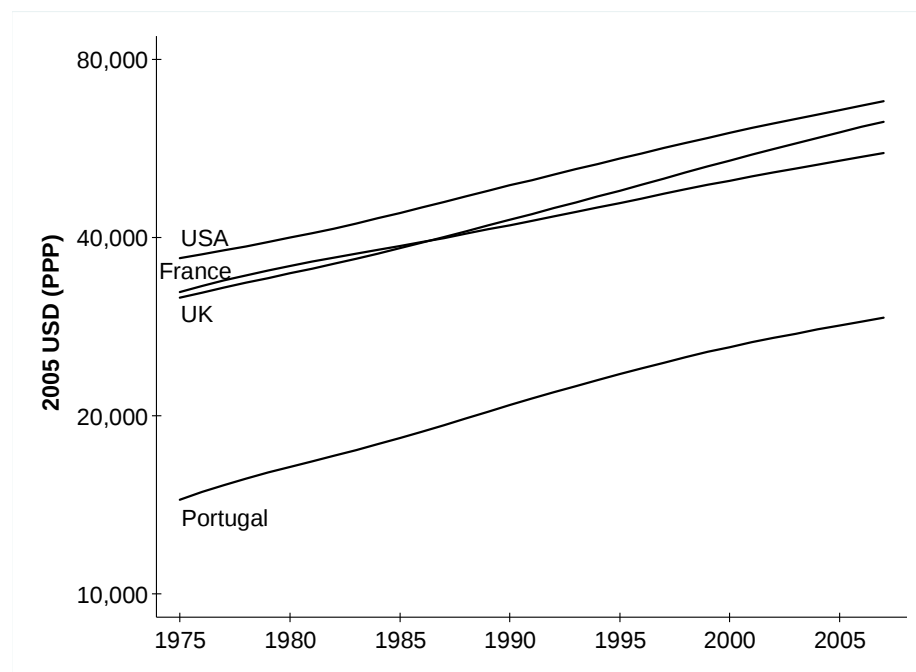
We find evidence that entry, rather than exit, is most important in accounting for productivity growth in Chile and Korea during periods of fast growth. We show that the entry component is larger than the exit component and it tends to have larger fluctuations. Given the importance of the entry term, we further decompose it to determine whether the entry term is driven by more productive entrants, larger entrants, or more entrants. We find that in both Chile and Korea, the largest contributor to changes in the entry term is the change in the relative productivity of entrants. Furthermore, we find that changes in the relative size of entrants and the entry rate play a relatively modest role.

As a second step, we survey papers in the literature that decompose productivity growth using the same methodology as FHK to get a more complete understanding of the relationship between growth and the role of entry and exit. We find that continuing plants consistently account for the bulk of productivity growth in slow-growing countries. A slow-growing country is any country that has a growth rate of approximately 2 percent in real GDP per working-age

person, just as the United States over long periods of times. For countries that grow at faster rates, the entry and exit of plants plays a more important role.

The above facts suggest that the entry of productive plants and the exit of unproductive plants play a role in explaining periods of fast growth. We attempt to account for these facts by building a dynamic general equilibrium model based on Hopenhayn (1992) that incorporates the theory of economic growth proposed by Parente and Prescott (1994) and Kehoe and Prescott (2002). We theorize that income levels are determined by a country's policies and institutions. On the balanced growth path, the growth rate of the economy is determined by technological improvements over time. If a country enacts a reform, it will experience fast growth while transitioning to a higher income level. Once it has converged to a higher income level, it will grow at 2 percent per year.

Figure 1: Trend of real gross domestic product per working age person.



The theoretical framework is consistent with the fact that industrialized countries like the United States and those in Western Europe have grown at 2 percent per year over multiple decades. Despite similar growth rates, they are at different income levels. These facts can be seen in Figure 1, where we plot the trend component of the Hodrick-Prescott filter of real GDP per working-age person for a number of industrialized countries. Furthermore, the pattern of fast

growth followed by 2 percent growth is not uncommon. Eichengreen, Park, and Shin (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.

The model that we construct has three key features. First, there is a new generation of potential entrants each period. These potential entrants draw from an efficiency distribution with a mean that improves each period by growth factor g_e . Second, there are improvements in the efficiency of continuing firms. This productivity growth depends on $\bar{g}$ and ε , which measure an exogenous efficiency improvement and spillovers from the aggregate economy, respectively. Finally, we allow for the endogenous entry and exit of firms.

Our model has a balanced growth path in which the economy grows by the growth factor g_e . This growth factor is the same as that of the mean of the efficiency distribution of entrants. Furthermore, income levels are determined by two distortions. First, there are entry costs that new firms must pay. Secondly, there are barriers to technology adoption for entrants in the spirit of Parente and Prescott (1994). The idea is that there are better technologies that are available but are not adopted due to policies that restrict their adoption. After enacting a reform that removes one of these distortions, an economy will transition to a higher balanced growth path. Finally, we construct our model so that the fraction of aggregate growth due to entry and exit in the FHK decomposition is constant across balanced growth paths.

Next, we want to determine whether the model can quantitatively match the importance of entry and exit during periods of rapid growth. We first calibrate the model to the U.S. economy. We set g_e and $\bar{g}$ to match the long-run growth rate of the United States and the productivity growth accounted for by continuing plants in the FHK decomposition. We also target the size distribution of US establishments as well as the employment share of exiting plants.

After calibrating the model, we consider two distorted economies in which income levels are 20 percent lower than that of the United States. The spirit of the exercise is that these distorted economies are exactly the same as the U.S. economy except for the two policy distortions that we are studying. In the first distorted economy, we raise entry costs by a factor of 2.45. In the second distorted economy, we raise the barriers to technology adoption by a factor of 1.16.

We then remove the distortions in each of the two economies and study the transition path to the higher balanced growth path. We find that in both cases, there is rapid growth that is accompanied by an increase in the contribution of entry and exit to productivity growth. The economy with high entry barriers enjoys a growth rate of 5.5 percent per year for five years, and entry and exit account for 75.5 percent of productivity growth. The economy with the high barriers to technology adoption also enjoys a growth rate of 5.5 percent per year for five years and entry and exit account for 75.5 percent of productivity growth. Along the balanced growth path, these economies grow at 2.0 percent, and net entry accounts for only 25.0 percent of aggregate productivity growth.

The model quantitatively matches the importance of entry and exit that we see in the data for fast growing economies. The countries experiencing fast growth that we have data for grew at 6.4 percent and net entry accounts for 52 percent of productivity growth on average. The countries experiencing slow growth experienced 2.6 percent growth and net entry accounts for 27 percent of productivity growth.

Furthermore, in both the model and data we find that the entry term is most important in understanding changes in net entry. We also find that in both cases, the relative productivity of entrants plays an important role in explaining changes in the entry term and that the relative size of entrants plays a modest role.

This paper is related to the productivity decompositions developed by FHK and others. These methodologies have become a popular tool to study the determinants of productivity growth originating at the plant level.¹ This is the first paper to our knowledge that has pointed to the consistent relationship that the importance of entry and exit increases during periods of rapid growth. The literature has emphasized other important points about the role of entry and exit in accounting for productivity growth. First, entrants typically have higher productivity than exiting plants. Second, entrants initially have lower productivity than continuing plants, but tend to see substantial productivity growth in subsequent periods.² These results are consistent across

¹ Other decompositions include Baily et al. (1992), Griliches and Regev (1995), Olley and Pakes (1996), Petrin and Levinsohn (2012), and Melitz and Polanec (forthcoming). See for example Foster et al. (2001) and Caves (1998) for productivity decompositions for various countries. Other papers have used them to analyze policy reforms or technological changes, for example: Olley and Pakes (1996), Pavcnik (2002), Eslava et al. (2004), and Collard-Wexler and De Loecker (2014).

² Recent papers indicate that using output measures such as gross output tend to assign lower productivities to entrants relative to quantity based measures of output. The reason is that the evidence points to entrants charging

a series of countries and time periods. See Roberts and Tybout (1997), Caves (1998), Bartelsman and Doms (2000), Tybout (2000), Foster, et al. (2001), and Haltiwanger (2012).

Our empirical findings suggest that models that attempt to explain rapid growth should consider the entry and exit of plants as an important ingredient. We propose a general equilibrium model with entry and exit that quantitatively matches the FHK decompositions during periods of rapid growth. In that sense, our work 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 Asturias et al. (2015), Barseghyan and DiCecio (2011), Bergoeing et al. (2011), D’Erasmus et al. (2011), Herrendorf and Teixeira (2009), Moscoso Boedo and Mukoyama (2012). In contrast to this literature, we create a theory of income differences that matches key facts about productivity growth. The only paper to our knowledge that matches facts from productivity decompositions is Bartelsman et al. (2013). The focus of our paper is very different since it focuses on the role of entry of new plants in explaining periods of fast growth.

2. Productivity Decompositions

In this section, we describe the FHK decomposition, which decomposes a change in aggregate productivity into contributions from the productivity of entering and exiting plants and from changes in productivity in continuing plants. Next, using data from Chile and Korea, we decompose productivity growth during periods of both fast output growth and subsequent periods of slow output growth. We find that, compared to periods of slow output growth, entry and exit account for a larger share of productivity growth during years of fast output growth. Lastly, we analyze previous work on plant entry, exit, and aggregate productivity. This literature was not explicitly focused on the role of entry and exit during different kinds of growth experiences. However, we find that their work supports our finding that fast growing countries tend to have a larger share of productivity growth accounted for by the entry and exit of plants.

2.1. Decomposing Changes in Aggregate Productivity Growth

There is a sizable empirical literature that decomposes changes in aggregate productivity into components that highlight potential sources of productivity increases. These kinds of

lower markups, which lowers gross output measures. The overall picture of the importance of entrants in the growth process remains the same. See Eslava et al. (2004), and Foster, Haltiwanger, and Syverson (2008).

decompositions are useful as they allow us to determine the importance of plant entry and exit in aggregate productivity growth.

To begin, we define the industry-level productivity of industry i at time t , Z_{it} , to be

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

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

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

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

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

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

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

The first component, $\Delta \log Z_{it}^{NE}$, is defined as

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

where N_{it} is the set of entering plants and X_{it} is the set of exiting plants. We define a plant as entering if it is only active at the end of the window, and exiting if it is only active at the beginning of the window. The first term, the entering plant component, positively contributes to growth if entering plants have high productivity compared to the initial industry average. The second term, the exiting plant component, positively contributes to growth if the exiting plants have low productivity compared to the industry average.

The second component, $\Delta \log Z_{it}^C$, is defined as

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

where C_{it} is the set of continuing plants. We define a plant as continuing if it is active in both the beginning and end of the window. The first term, the within-plant component, measures productivity growth due to changes in the productivity of existing plants. The second term, the

reallocation component, measures productivity growth due to the reallocation of output shares among existing plants.

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

$$\log Z_{it} = s_{iNt} \log Z_{iNt} + s_{iCt} \log Z_{iCt},$$

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

$$\log Z_{i,t-1} = s_{iC,t-1} \log Z_{iC,t-1} + s_{iX,t-1} \log Z_{iX,t-1},$$

where $s_{iX,t-1}$ 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 re-write equations (4) and (5) as

$$\Delta \log Z_{it}^{NE} = \underbrace{s_{iNt} (\log Z_{iNt} - \log Z_{i,t-1})}_{\text{entering plants}} - \underbrace{s_{iX,t-1} (\log Z_{iX,t-1} - \log Z_{i,t-1})}_{\text{exiting plants}}. \quad (6)$$

and

$$\Delta \log Z_{it}^C = s_{iCt} (\log Z_{iCt} - \log Z_{i,t-1}) - s_{iC,t-1} (\log Z_{iC,t-1} - \log Z_{i,t-1}) \quad (7)$$

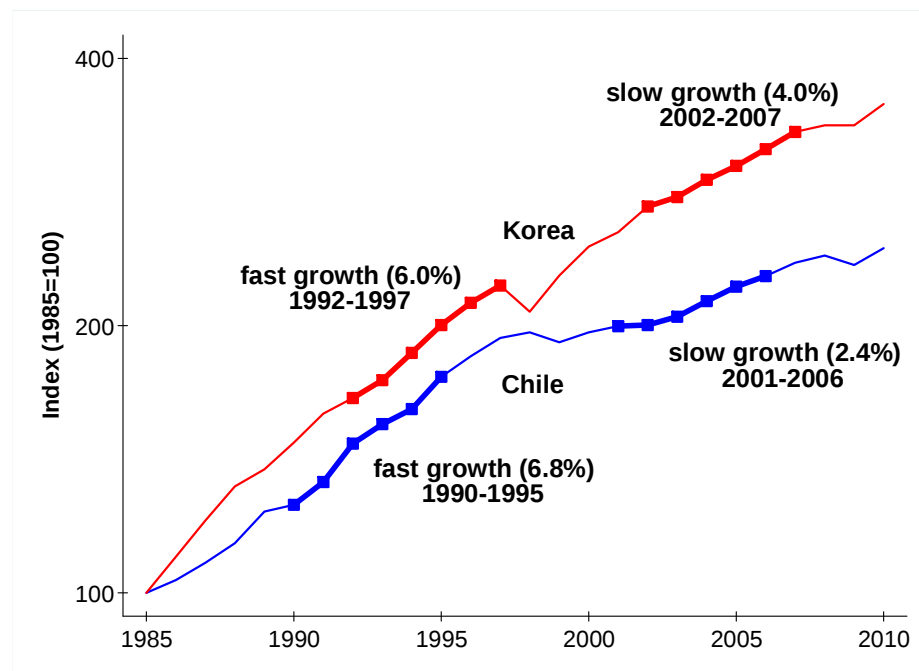
Equations (6) and (7) show that the only statistics needed to calculate the FHK decompositions are the share of output and the weighted productivity of continuing, entering, and exiting plants.

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 slow growth in the 2000s: Chile and Korea. We can see the slowdowns in growth in Figure 2. The GDP per working-age person in Chile grew at an annualized rate of 6.8 percent during the years 1990-1995 and in Korea it grew at 6.0 percent during the years 1992–

1997. The growth in Chile slowed to 2.4 percent during the years 2001-2006.³ In Korea, the slowdown was less dramatic, declining to 4.0 percent during the years 2002-2007. Using this data, 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 this approach of looking across two periods in the same country is that we can avoid cross-country differences and use consistent datasets.

Figure 2: GDP per working-age person in Chile and Korea.



We use manufacturing plant-level data for Chile and Korea to decompose changes in productivity during the period of fast growth and the subsequent slowdown. For Chile, we use the Encuesta Nacional Industrial Anual (ENIA) dataset provided by the Chilean statistical agency, the Instituto Nacional de Estadística (INE). The dataset is made up of two panels that cover all manufacturing establishments in Chile with more than 10 employees. One panel covers 1986–1996 and the other covers 1995–2006. For Korea, we use the Mining and Manufacturing Surveys provided by the Korean National Statistical Office for the years 1992, 1997, 2002, and

³ De Gregorio (2004) characterizes the years 1985-1997 as the “golden period” and the following years as ones of “slower growth.” The slowdown in growth coincided with the East Asian crisis and a domestic liquidity crisis in 1998.

2007. The data cover all establishments with more than 10 employees. The full details of the decompositions can be found in the appendix.

The first step in the decomposition is to estimate plant-level productivity. We assume that plant e in industry i operates the production function,

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

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 measure possible. For the Chilean data, depending upon the window, this is 4-digit ISIC Revision 2 or Revision 3. For the Korean data, depending upon the window, this is 4-digit ISIC Revision 3 or Revision 4.⁴ To get a sense of the level of disaggregation, note that ISIC Revision 2, Revision 3, and Revision 4 have 81 industries, 127 industries, and 138 industries, respectively.

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 for the Chilean data and the number of employees of the plant for the Korean data. Following FHK, the coefficients β_j^i are the industry-level factor cost shares, averaged over the beginning and end of each time window.

We calculate the industry-level productivity, $\log Z_{it}$, for industry i in each year using (1), and decompose these changes into net entry and continuing terms using (4) and (5). To compute 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 beginning and end of each time window. We follow the same process to compute the aggregate entering, exiting, and continuing terms.

⁴ The Korean data are classified under a national system that is similar to ISIC Rev. 3 and 4.

Table 1: Importance 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)
1990–1995	Chile	6.8	4.9	84.6
1992-1997	Korea	6.0	3.6	47.9
2001–2006	Chile	2.4	3.1	34.9
2002-2007	Korea	4.0	3.3	40.0

A summary of the Chilean and Korean productivity decompositions can be found in Table 1.⁵ From 1990–1995, Chilean manufacturing productivity experienced a growth rate of 4.9 percent (annual) compared to 3.1 percent growth during the 2001–2006 period. In these two periods, we see a stark difference in the contribution of net entry to aggregate productivity growth. During the transition period, net entry accounts for 84.6 percent of aggregate productivity growth, while it accounts for only 34.9 percent during the period with slower output growth. It is interesting to note that after Chile’s slow down, the country’s growth rate and contribution of net entry are similar to that of the United States.

In the case of Korea, the manufacturing sector experienced productivity growth of 3.6 percent (annual) during 1992–1997 compared to 3.3 percent during 2002–2007. During the period of faster output growth, net entry accounts for 47.9 percent of aggregate productivity growth, while it accounted for only 40.0 percent during the slower growth period. The reduction in the contribution of net entry is less stark than in Chile, which is consistent with the fact that the decline in Korea’s growth rate was less sharp.

Table 2: FHK entering and exiting terms.

Period	Country	Aggregate productivity growth (percent)	Entering (percent)	Exiting (percent)
1990–1995	Chile	27.1	20.8	2.2
1992-1997	Korea	19.2	5.2	4.0
2001–2006	Chile	16.4	5.9	-0.2
2002-2007	Korea	17.5	2.2	4.9

⁵ We report all of the FHK decomposition terms for Chile and Korea in the appendix.

We further decompose the FHK net entry term in two steps. First, we decompose net entry into the entry and exit terms, as reported in Table 2. Note that this table reports total productivity change over the window and not the annualized growth as in Table 1. We find that the entry component is most important in understanding changes in the net entry term, by observing that the entry term tends to be the largest component of net entry, and that the entry term covaries more with aggregate productivity growth. For example, in Chile the entry term dropped from 20.8 percent to 5.9 percent while aggregate productivity growth dropped from 27.1 percent to 16.4 percent. In the case of Korea, the entry term decreased from 5.2 percent to 2.2 percent while the aggregate productivity growth decreased from 19.2 to 17.5 percent. Second, we decompose changes in the entry term. Examination of equation (4) shows that there are two reasons why the entry term can increase. First, the productivity of entrants can increase while leaving their output shares constant. Second, the output share accounted for by entrants can increase while productivities remain constant. The second component can be the result of entrants becoming larger or an increase in the number of entrants. The following decomposition allows us to consider these three forces separately:

$$\Delta \log Z_t^N = \underbrace{\frac{\Delta \log Z_t^N}{S_{Nt}}}_{\text{relative productivity of entrants}} \times \underbrace{\frac{S_{Nt}}{E_t}}_{\text{relative size of entrants}} \times \underbrace{E_t}_{\text{entry rate}}, \quad (9)$$

where $\Delta \log Z_t^N$ is the entering term reported in Table 2, S_{Nt} is the share of gross output accounted for by entrants in the aggregate, and E_t is the entry rate in the aggregate (the number of entrants divided by the number of plants at the end of the time window). We interpret the first term, $\Delta \log Z_t^N / S_{Nt}$, to be a measure of the relative productivity of entrants. The reason is that $\Delta \log Z_t^N$ is the contribution of entry in the aggregate and it is necessary to adjust this for the gross output share of entrants. We see from equation (6) that at the industry-level this term must be divided by the output share accounted for by entrants to arrive at the expression of the relative productivity. The second term is the relative size of entrants since a value of one implies that the average entrant has the same market share as the average continuing firm.

Table 3: FHK entry term decomposed

Period	Country	Aggregate productivity growth (percent)	Entering (percent)	Entry rate (percent)	Relative size of entrants	Relative productivity of entrants (percent)
1990–1995	Chile	27.1	20.8	55.6	1.01	37.0
1992–1997	Korea	19.2	5.2	70.3	0.55	13.8
2001–2006	Chile	16.4	5.9	40.9	0.95	15.2
2002–2007	Korea	17.5	2.2	62.8	0.44	8.0

The results of this decomposition are reported in Table 3. We find that the relative productivity of entrants is the main component in accounting for the change in the FHK entering term. The 253 percent increase in the entering term in Chile was accompanied by a 143 percent increase in the relative productivity of entrants, a 36 percent increase in the entry rate, and a 6 percent increase in the relative size of entrants. Likewise, the 136 percent increase in the entering term in Korea was accompanied by a 73 percent increase in the relative productivity of entrants, a 12 percent increase in the entry rate, and a 25 percent increase in the relative size of entrants.

In the appendix, we consider alternative productivity decompositions described in Griliches and Regev (1995) and Melitz and Polanec (forthcoming). Our finding that net entry is a more important contributor to aggregate productivity during periods of fast growth is robust to these alternative methods.

2.3. The Role of Net Entry in the Cross-section

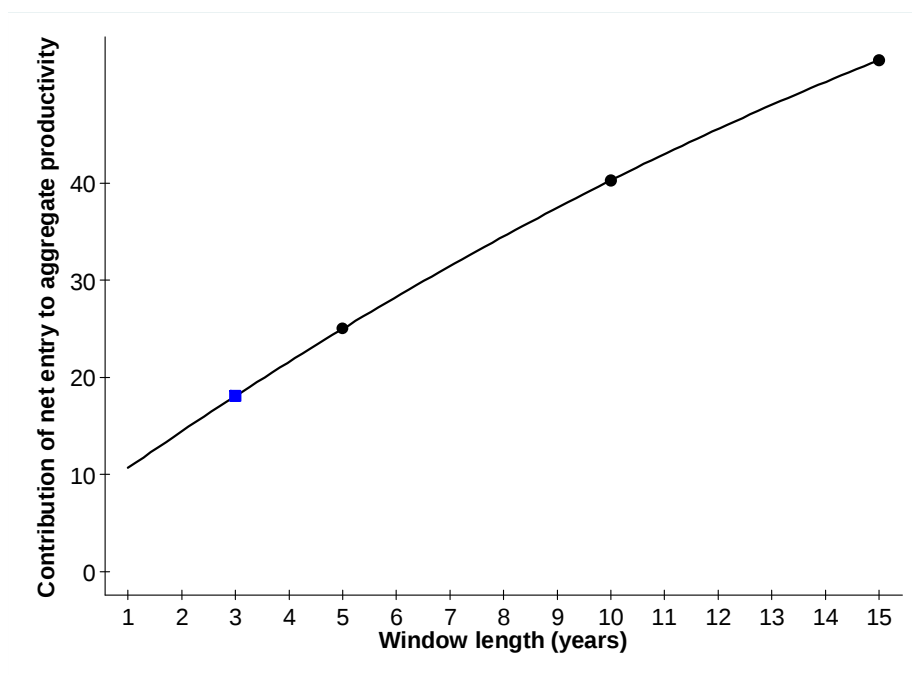
In section 2.2 we studied the contribution of net entry to aggregate productivity growth within countries that experienced both fast growth and a subsequent slowdown. This is an ideal situation; by studying the same country, we eliminate problems that might arise from cross-country differences. We would 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 growing relatively slowly (Portugal, the United Kingdom, and the United States) and countries 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 as weights, and the FHK decomposition make their calculations comparable to ours for Chile and Korea.

Before we compare the decompositions in the different studies, we must make an adjustment for the varying lengths of the time windows considered. In our calculations for Chile and Korea, we use five-year windows, but, for example, the analysis of Portuguese plants in Carreira and Teixeira (2008) use a three-year window. The length of the sample window is important, as longer sample windows increase the importance of net entry in productivity growth.

We use the calibrated model described in Sections 3–5 to make these adjustments. To do so, we compute the contribution of net entry generated by the model in 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 five-year window, 40.3 percent when measured over a ten-year window, and 52.7 percent when measured over a fifteen-year window. Using these points, we then fit a quadratic equation that relates net entry with the window length, which is plotted in Figure 3.

Figure 3: Net entry under various windows in the model.



We are now ready to adjust the calculations reported in the literature that do not use five-year windows. In the case of a 3-year window, the quadratic fit implies that net entry is 18.1 percent (the blue square in Figure 3). Thus, we arrive at an adjustment factor of 1.38 ($=25.0/18.1$) and a 5-year net entry contribution of 21 percent for Portugal ($=15*1.38$).

Table 4 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 five-year equivalents. In the first panel of Table 4, we gather results from countries that could be considered on a balanced growth path — countries with relatively high levels of GDP per working age person and moderate growth rates. In the combined set of countries, the contribution of net entry ranges from 12 percent to 40 percent, with an average of 27 percent. Our findings are consistent with the survey in Caves (1998; pg. 1973) which finds similar results for industrialized countries.

In the second panel of Table 4, we gather the results from countries that could be considered out of balanced growth. In particular, these countries have relatively low GDP per working age person and high growth rates. In the combined set of countries, the contribution of net entry to aggregate productivity growth ranges between 39 and 85 percent, with an average of 52 percent.

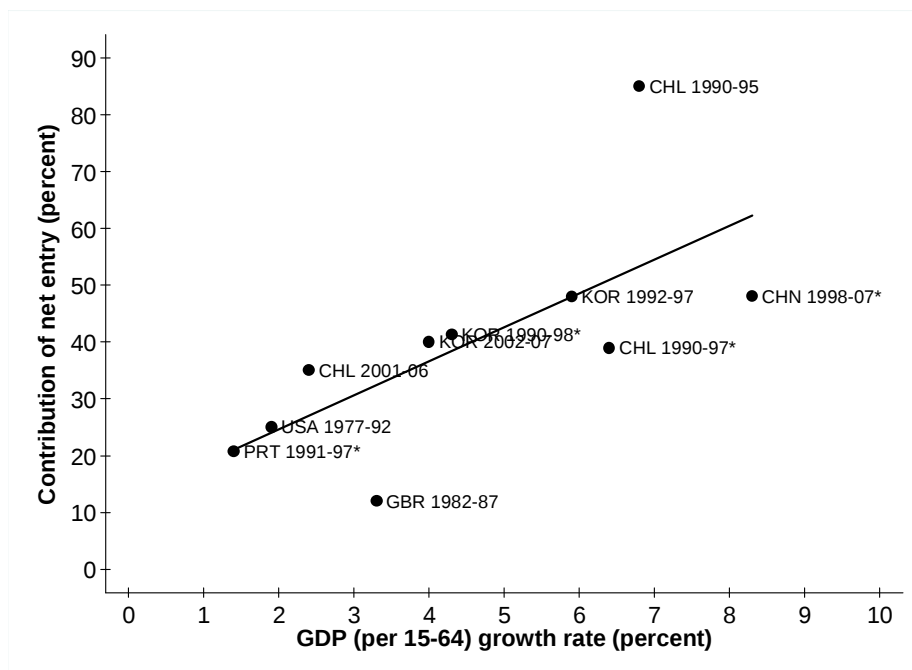
In Figure 4, we summarize the findings in a scatterplot. On the vertical axis, we plot the contribution of net entry and on the horizontal axis we plot the economy's growth rate. The figure shows a clear positive correlation: The net entry of plants is more important for aggregate productivity growth during periods of rapid GDP growth. Combining our results with the literature yields a more complete picture of the relationship between aggregate productivity growth and the contribution of net entry to productivity growth.

Table 4: Productivity decompositions.

Country	Period	GDP/WAP growth rate	Window	Net entry contribution	Net entry contribution, 5-year equivalent	Source
United States	1977–1992	1.9	5 years*	25	25	Foster et al. (2001)
United Kingdom	1982–1987	3.3	5 years	12	12	Disney et al. (2003)
Portugal	1991–1997	1.4	3 years*	15	21	Carreira and Teixeira (2008)
Chile	2001–2006	2.4	5 years	35	35	
Korea	2002–2007	4.0	5 years	40	40	
Average		2.6			27	
China	1998–2007	8.3	9 years	72	48	Brandt et al. (2012)
Chile	1990–1997	6.4	7 years	49	39	Bergoeing and Repetto (2006)
Korea	1990–1998	4.3	8 years	57	41	Ahn et al. (2004)
Chile	1990–1995	6.8	5 years	85	85	
Korea	1992–1997	6.0	5 years	48	48	
Average		6.4			52	

*Averaged over multiple windows. The second column describes the period studied. The third column reports annual growth rates of 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 five-year sample windows. The measure of productivity is TFP and the weights are gross output shares.

Figure 4: The contribution of net entry and GDP growth.



3. Model

In this section, we construct a general equilibrium model of firm entry and exit based on Hopenhayn (1992). We model a closed economy in which there is a continuum of firms. 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.

The model incorporates the theory of economic growth proposed by Parente and Prescott (1994) and Kehoe and Prescott (2002). In particular, all countries grow at the same rate when they are on the balanced growth path. The level of this balanced growth path depends on the distortions in the economy. We incorporate two distortions that we interpret as being the result of government policy. First, firms face entry costs that are not technological in nature. Second, new firms face barriers that prevent them from adopting the most efficient technology. If a reform is enacted, the economy will transition to a higher balanced growth path.

There are three key features in the model. First, the efficiency distribution of new entrants exogenously improves each period. Second, the efficiency of existing firms also improves. This improvement in efficiency is determined by both an exogenous component and by spillovers from the rest of the economy. Finally, firm entry and exit are endogenous in the model.

There are two points to make in terms of linking the previous empirical work and the model. 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. Thus, for every firm in the model we find its productivity using the same process as described in section 2.2. We use this measure of productivity to calculate aggregate productivity and the FHK decompositions. Second, the empirical work from the previous section makes use of plant-level data. We will treat a plant in the data as being equivalent to a firm in our model since we abstract from multi-plant firms.

3.1. Households

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

$$\begin{aligned} \max \quad & \sum_{t=0}^{\infty} \beta^t \log C_t \\ & P_t C_t + q_{t+1} B_{t+1} = w_t + B_t + D_t \\ & C_t \geq 0, \text{ no Ponzi constraint, } B_0 \text{ given,} \end{aligned} \tag{10}$$

where $\beta \in (0,1)$ is the discount factor, C_t is household consumption, P_t is the price of the good, q_{t+1} is the price of the one-period bond, B_{t+1} are the holdings of one-period bonds purchased by the household, w_t is the wage, and D_t are aggregate dividends paid by firms. We normalize $P_t = 1$ for all t .

3.2. Producers

In each period, potential entrants pay a fixed entry cost, κ_t , at time t in order to draw a marginal efficiency, x , from a distribution, $F_t(x)$. This entry cost is paid by the household, entitling it to future dividends of firms that operate. Upon seeing their efficiency, potential entrants choose whether or not to operate. Once in operation, a firm dies exogenously with probability δ , and a firm will voluntarily exit once its 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, $y = x\ell^\alpha$, where ℓ is the amount of labor used by the firm and $0 < \alpha < 1$. Conditional on operating, firms choose the amount of labor to hire to maximize dividends, $d_t(x)$,

$$d_t(x) = \max x \ell_t(x)^\alpha - w_t \ell_t(x) - f_t, \quad (11)$$

where f_t is the fixed cost of operation, which is denominated in units of the consumption good. The fixed cost grows at the same rate as the productivity of potential entrants, $f_t = f g_e^t$. As we will see in the next section, this formulation implies that the continuation cost is a constant of output per capita and thus ensures the existence of a balanced growth path.⁶ The solution to (11) is given by

$$\ell_t(x) = \left(\frac{\alpha x}{w_t} \right)^{\frac{1}{1-\alpha}}. \quad (12)$$

Notice that labor demand is increasing in the efficiency of the firm.

At the beginning of each period, an operating firm chooses whether to produce in the current period or to exit. If the firm chooses to exit, its dividends are zero and the firm cannot re-enter in subsequent periods. Thus, a firm with efficiency x chooses whether to operate or exit the market

$$V_t(x) = \max \{d_t(x) + q_{t+1}(1-\delta)V_{t+1}(g_{e,t+1}x), 0\}, \quad (13)$$

where $g_{ct}-1$ is an operating firm's efficiency growth rate from $t-1$ to t . This efficiency growth rate is characterized by,

$$g_{ct} = \bar{g} g_t^\varepsilon, \quad (14)$$

where $\bar{g}$ is a constant, $g_t = \hat{x}_t / \hat{x}_{t-1}$ is aggregate efficiency growth, and ε measures the degree of spillovers from the aggregate economy to the firm.

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

$$V_t(\hat{x}_t) = 0. \quad (15)$$

It is also useful to define the minimum efficiency of firms in cohort 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 value of the firm is greater than zero. For all firms age $j \geq 2$ it is characterized by

⁶In the balanced growth path, this formulation is similar to Acemoglu et al. (2003) who assume that fixed costs are proportional to the frontier technology.

$$\hat{x}_{jt} = \max \left\{ \hat{x}_t, \hat{x}_{j-1,t-1} g_{ct} \right\}. \quad (16)$$

Notice that if some firms in a given age cohort choose to exit, then $\hat{x}_{jt} = \hat{x}_t$. If no firms choose to exit, then the minimum efficiency evolves with the efficiency of the operating firms adjusted for productivity growth, $\hat{x}_{jt} = \hat{x}_{j-1,t-1} g_{ct}$.

A potential entrant pays a fixed entry cost, $\kappa_t = \kappa g_e^t$, which is denominated in units of the consumption good. The entry cost is composed of two parts, $\kappa = \kappa^T (1 + \tau)$, where κ^T is the technological cost that is common across countries and $\tau \geq 0$ is the policy induced cost. Upon paying the fixed entry cost, a potential entrant draws an efficiency x from a Pareto distribution

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

for $x \geq g_e^t / \varphi$, where φ characterizes the barriers to technology adoption in the spirit of Parente and Prescott (1994), and γ is the tail parameter of the efficiency distribution. The parameter φ governs the extent to which new firms can adopt the technology of the leader country. The mean of this distribution is proportional to g_e^t / φ . Thus, raising barriers to technology adoption lowers the mean and the mean of the distribution grows at rate $g_e - 1$ in each period.

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

$$E_x[V_t(x)] = \kappa_t. \quad (17)$$

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

The mass of firms of age j at time t in operation, η_{jt} , is

$$\eta_{jt} = \mu_{t+1-j} (1 - \delta)^{j-1} \left(1 - F_{t+1-j} \left(\hat{x}_{jt} / \tilde{g}_{jt} \right) \right), \quad (18)$$

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

$$\eta_t = \sum_{i=1}^{\infty} \eta_{it}. \quad (19)$$

3.3. Equilibrium

The economy's initial conditions are: 1) the measure of firms operating in period zero for ages $j = 1, \dots, \infty$, given by $\{\mu_{t-j+1}, \hat{x}_{j0}, g_{c,t-j+1}\}_{j=1}^{\infty}$ and 2) the bond holdings of households B_0 .

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

1. Given $\{w_t, D_t, q_{t+1}\}_{t=0}^{\infty}$, $\{C_t, B_{t+1}\}_{t=0}^{\infty}$ solves the household's problem (10).
2. Given $\{w_t, Y_t\}_{t=0}^{\infty}$, $\{\ell_t(x)\}_{t=0}^{\infty}$ satisfies (12) and solves the producers' problem (11) for all $x \geq \hat{x}_t$.
3. The mass of potential entrants is characterized by the free-entry condition in (17).
4. The mass of operating firms is characterized by (18) and (19).
5. The labor market clears for all $t \geq 0$

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

6. Entry-exit thresholds $\{\hat{x}_{jt}\}_{t=0}^{\infty}$ satisfy conditions (15) and (16) for all $j = 1, \dots, \infty$ and $t \geq 0$
7. The bond market clears for all $t \geq 0$, $B_{t+1} = 0$.
8. The goods market clears

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

9. Dividend payments satisfy

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

4. Balanced Growth Path

In this section, we define a balanced growth path for the model described in section 0 and prove its existence. We also conduct comparative statics exercises to show how the level of the balanced growth path depends on entry costs and barriers to technology adoption.

Definition. A *balanced growth path* is a sequence of final good output $\{Y_t\}_{t=0}^{\infty}$, household consumption $\{C_t\}_{t=0}^{\infty}$, wages $\{w_t\}_{t=0}^{\infty}$, dividends $\{D_t\}_{t=0}^{\infty}$, minimum efficiencies of operating firms $\{\{\hat{x}_{jt}\}_{j=1}^{\infty}\}_{t=0}^{\infty}$, measures of potential entrants $\{\mu_t\}_{t=0}^{\infty}$, measures of operating firms $\{\{\eta_{jt}\}_{j=1}^{\infty}\}_{t=0}^{\infty}$, and bond prices $\{q_{t+1}\}_{t=0}^{\infty}$, such that

1. $Y_{t+1}/Y_t = C_{t+1}/C_t = w_{t+1}/w_t = D_{t+1}/D_t = \hat{x}_{j,t+1}/\hat{x}_{jt} = g_e$ for all $t \geq 0$ and $j = 1, \dots, \infty$,
2. $q_{t+1} = \beta / g_e$ for all $t \geq 0$, and
3. $\mu_t = \mu$ and $\eta_t = \eta$.

Proposition 1. A *balanced growth path* exists.

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

$$\eta = \frac{\gamma(1-\alpha)-1}{\lambda f \gamma} \quad (20)$$

where $\lambda = \varphi^{1/\alpha} (\kappa / \kappa^T)^{1/(\gamma\alpha)}$ is the ratio of the economy's output and that an economy with $\tau = 1$ and $\varphi = 1$. The mass of potential entrants is

$$\mu = \frac{\xi}{\lambda \kappa \gamma \omega}, \quad (21)$$

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

$$\hat{x}_t = \frac{g_e^t}{\varphi} \left(\frac{\omega}{\eta} \mu \right)^{\frac{1}{\gamma}}. \quad (22)$$

We notice that the cutoffs are increasing at rate $g_e - 1$. This fact implies that the other aggregate variables related to income also grow at the same rate since

$$Y_t = [(1 - \alpha) / (\lambda f)]^{(1 - \alpha)} \hat{x}_t, \quad (23)$$

$$w_t = \alpha [(1 - \alpha) / (\lambda f)]^{(1 - \alpha)} \hat{x}_t, \quad (24)$$

$$D_t = (1 - \alpha - \eta \lambda f - \mu \lambda \kappa) [(1 - \alpha) / (\lambda f)]^{(1 - \alpha)} \hat{x}_t. \quad (25)$$

The bond price is $q_{t+1} = \beta / g_e$. The appendix contains further details. $\square$

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.

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 productive firms increase the demand for labor as seen in equation (12), increasing the wage and the cutoff needed to operate. Thus, unproductive firms from previous generations are replaced by more productive firms.

Proposition 1 allows us to conduct further comparative statics and better understand the mechanisms through which lowering distortions raises output. For comparative statics it is useful to know that both ω and ξ do not depend on the policy variables κ and φ . First, consider an economy with lower entry costs. The lower entry costs induce more potential entrants. As can be seen in equation (22), this increase in the mass of potential entrants results in higher efficiency cutoffs. The change in the mass of potential entrants has two separate sources. The first is a direct effect: higher entry costs κ result in a larger mass of potential entrants μ . The second is an indirect effect: an increase in κ reduces λ , which subsequently increases the mass of potential entrants. The indirect effect is related to the general equilibrium effects

induced by the policy. This effect comes from the fact that higher income levels imply that fixed costs, relative to income per capita, is lower. Thus, the gains from reforming entry barriers are not technological in nature but are derived from increasing the mass of potential entrants through the direct and indirect effects.

Lowering barriers to technology adoption operates through a different channel. In contrast to lowering entry costs, changes in φ do not directly affect the mass of potential entrants. Rather, efficiency cutoffs increase in equation (22) since new firms have access to the improved technology. This access to an improved technology results in a lowering of λ , which subsequently induces a higher μ through general equilibrium effects.

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 and on a balanced growth path. Next, we use the model to analyze the effects of policy reforms and determine whether the model can quantitatively match the relationship between output growth and the importance of entry and exit in aggregate productivity growth that we observe in the data.

5.1. Measuring Productivity

First, we need to define the capital stock of firms in the model so that we can measure productivity in the same manner as described in section 2.2. Investment is counted as the entry cost, κ_t , that firms pay to take a productivity draw and the fixed cost to operate each period, f_t . The depreciation of capital for a continuing firm consists of the operating fixed cost minus the costs of upgrading capital. Thus, the total depreciation of capital for a continuing firm is $f_t - (\kappa_{t+1} - \kappa_t)$. The depreciation rate and investment described above imply that the capital stock of a continuing firm is $k_t = \kappa_t + f_t$.

We are now in a position to measure the productivity of firms in the model. The productivity z of a firm with efficiency x is given by

$$\log z_t(x) = \log y_t(x) - \alpha \log \ell_t(x) - \alpha_{kt} \log(k_t),$$

where α_{kt} is the capital share and

$$\alpha_{kt} = \frac{R_t K_t}{Y_t},$$

where $R_t = 1/q_t - 1 + \delta_{kt}$, and δ_{kt} is the aggregate depreciation rate. See the appendix for the full discussion of how we construct capital and the aggregate depreciation rate of capital. Note that depreciated capital in the economy also includes the capital of firms that die and the entry costs of potential entrants that do not enter. The depreciation rate is constant in the balanced growth path but not in the transition.

Once we measure firm productivity, we also calculate aggregate productivity and the FHK decompositions generated by the model as described in equations (4) and (5).

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 on U.S. aggregate productivity growth. We summarize the parameters in Table 5. The time window for the decompositions are 5 years, and one model period is also 5 years.

Table 5: Calibrated parameters.

Parameter		Value	Target / Source
Operating cost	f	0.53 x 5	Average U.S. establishment size: 16.0
Entry cost (technological)	κ^T	0.44	Entry cost / fixed cost: 0.82
Tail parameter	γ	6.11	Std. of U.S. establishment size: 91.2
Firm growth	$\bar{g}$	1.009 ⁵	Effect of continuing firms on growth: 75 percent
Death rate	δ	1 – 0.965 ⁵	Exiting plant employment share: 17.7 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 set the fixed operating cost, f , so that the model matches the average establishment size in the U.S. of 16.0 employees (1981-2000, United States Census, *Statistics of U.S. Businesses*). To pin down the entry cost, we set κ^T so that the ratio of the entry cost to the

annual fixed operating cost, $\kappa^T / (f / 5)$, is equal to 0.82. Barseghyan and DiCecio (2011) report this fact based on the average ratio of entry costs to fixed operating costs from empirical studies.

We set the tail parameter γ to match the standard deviation of establishment size in the United States, which has an average value of 91.2 between 1981 and 2000. We set $\bar{g}$, which determines the efficiency growth rate of continuing firms, to match the fact that the contribution of continuing firms on productivity growth in the United States is 0.75, as documented by FHK. The exogenous death rate, δ , is set so that exiting plants destroy 17.7 percent of employment every five years in the United States, as documented by Dunne et al. (1989). We set g_e , which governs the efficiency growth of new entrants, to an annualized value of 1.02. Proposition 1 indicates that at this value the economy will grow at two percent annually, which is consistent with the average GDP growth rate in the United States over the last century. We set the discount factor, β , to match a four percent annual real interest rate. Finally, the production function curvature, α , is set to 0.67, to be consistent with the fact that the labor share in the balanced growth path is 0.67.

We will now discuss parameters that we did not calibrate. First, we consider the United States to be the frontier economy so we set $\varphi = 1$ and $\tau = 0$. Second, we use data to estimate the parameter ε , which characterizes the relationship between continuing-plant and aggregate efficiency growth. In the data, we observe an increase in the productivity growth of continuing plants when there is an increase in (industry-level) aggregate productivity growth. Taking the log of (14) yields

$$\log g_{ct} = \log \bar{g} + \varepsilon \log g_t \quad (26)$$

which gives us an equation that we can estimate using plant-level data. We estimate the following equation using OLS

$$\log g_{ct,i} = \beta_0 + \varepsilon \log g_{it} + \nu_{it} \quad (27)$$

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 of industry i , and ν_{it} is an error term. A continuing plant is one which is present at both the beginning and the end of the sample window. Ideally, we would like to estimate (27) using data for U.S. plants, but without access to

those data, we use the data from Chile and Korea. The OLS estimates of ε range from 0.42 to 0.65 for Korea and 0.29 to 0.73 for Chile. We use the average over the four estimates, $\varepsilon = 0.52$.

5.3. Simulating policy reforms

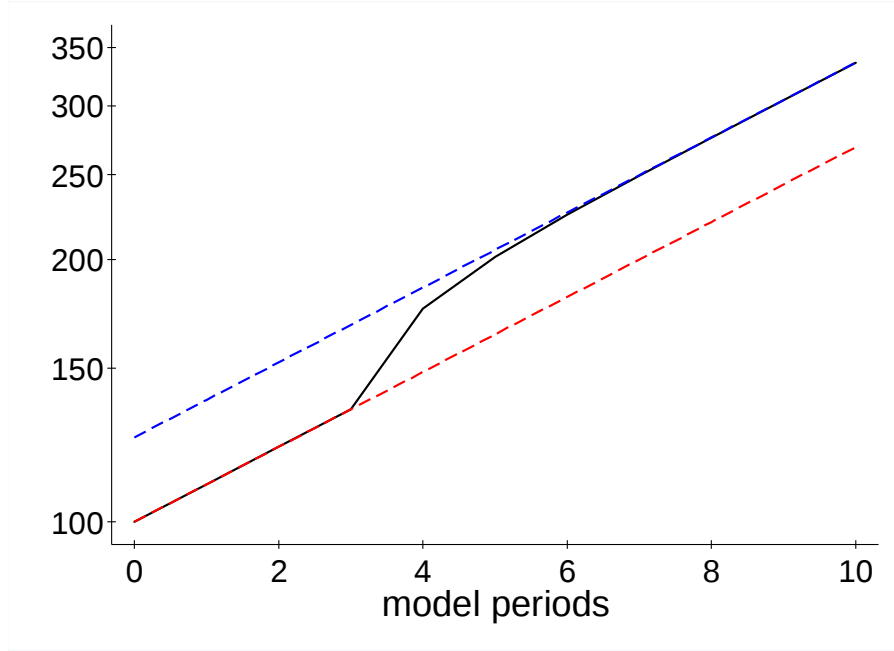
In this section we consider policy reforms that move the economy to a higher balanced growth path through the lowering of entry costs and the barriers to technology adoption. The goal of these experiments is to evaluate the model's ability to quantitatively account for the contribution of entry and exit to productivity growth during periods of slow and fast growth.

We consider two separate distorted economies. In the first, we raise the policy related portion of entry costs, $1 + \tau$, so that income on the balanced growth path declines by 20 percent. In the second distorted economy, we raise the barriers to technology adoption, φ , so that income declines by the same amount. We raise κ by a factor of 2.45 and φ by a factor of 1.16 in the first and second distorted economies respectively. The spirit of the exercise is that these economies have the same technology and preferences as the U.S. economy except for the policy variables of interest.

In the next step, we eliminate the distortions in each economy and study the transition to the new balanced growth path. 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.

In the discussion that follows regarding Figure 5 - Figure 9, we will first focus on the reform that reduces entry costs. In Figure 5, we plot income for an economy that conducts the hypothetical reform in period 4, where a period in the model is five years. As shown in the graph, the economy quickly transitions 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 period of the reform, the economy grows 5.5 percent annually for 5 years and this growth quickly declines in subsequent periods to 2.0 percent upon converging to the new balanced growth path.

Figure 5: Output per worker after reform of entry costs.

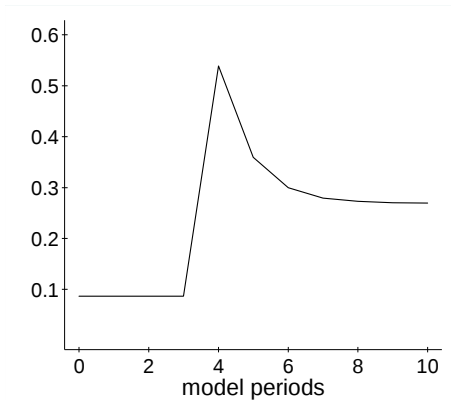


To understand the mechanisms at work in the model, we plot key economic variables during the transition. First, there is a permanent increase in the mass of potential entrants since the decline in entry barriers increases the value of a firm. Figure 6(a) shows the increase in the mass of potential entrants. The increase in the mass of potential entrants subsequently increases the cutoff efficiency. Figure 6(b) shows the increase in the detrended efficiency thresholds. The series has been detrended by dividing the variables by g_e^t so that the detrended efficiency thresholds are constant if the economy is on the balanced growth path. We also normalize the first period values to 100.

The increase in the mass of potential entrants and the resulting increase in the efficiency thresholds lead to a change in the composition of operating firms. There is an increase in the entry rate, as shown in Figure 7(a), and an accompanying increase in the exit rate, as shown in Figure 7(b). These more-productive firms draw resources away from less-productive firms. This effect occurs through rising wages, which forces out relatively inefficient firms through reductions in profitability. This is the same mechanism at work, for example, in Hopenhayn (1992). Figure 8 shows the increase in wages and output during the transition.

Figure 6: More potential entrants increases efficiency thresholds

(a) Mass of potential entrants



(b) Detrended efficiency thresholds

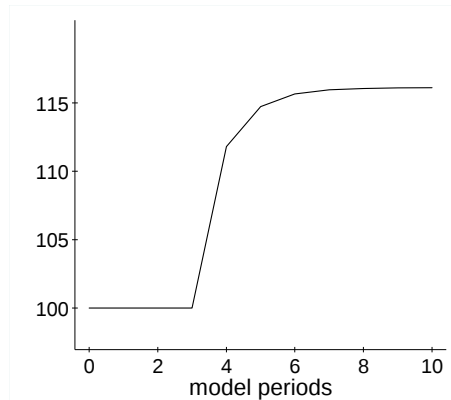
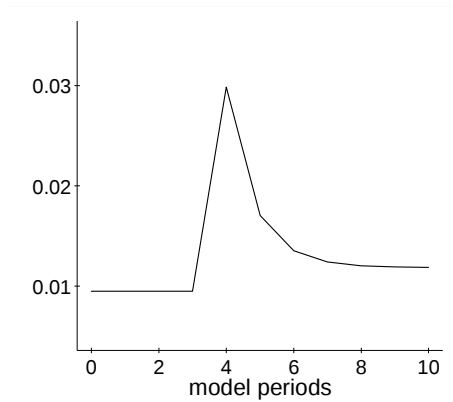
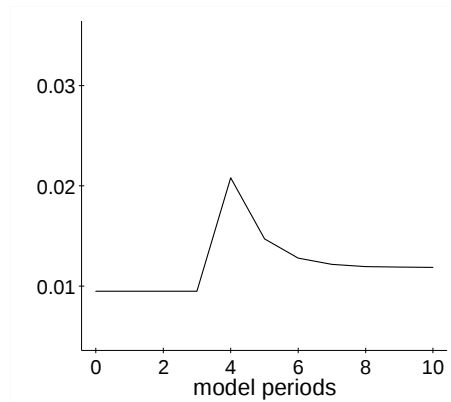


Figure 7: Efficient firms enter and inefficient firms exit

(a) Mass of entering firms



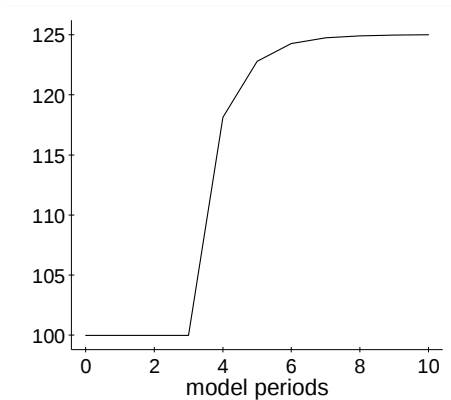
(b) Mass of exiting firms



Other key variables such as consumption and interest rates exhibit patterns similar to the neoclassical growth model. Figure 9(a) shows that consumption initially declines after the reform and then subsequently increases. The reason is that the demand for investment from potential entrants increases which increases interest rates, as shown in Figure 9(b). The sharp initial rise in interest rates imply that consumers reduce consumption initially in order to increase investment to potential firms.

Figure 8: More efficient firms increase wages and output

(a) Detrended wage



(b) Detrended output

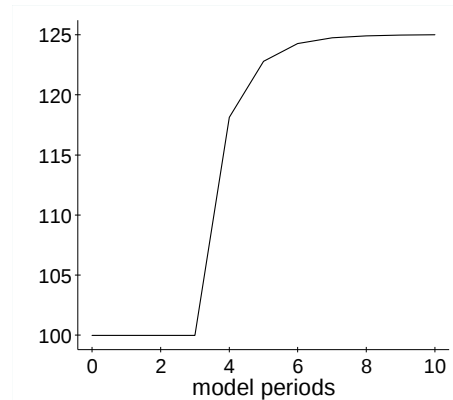
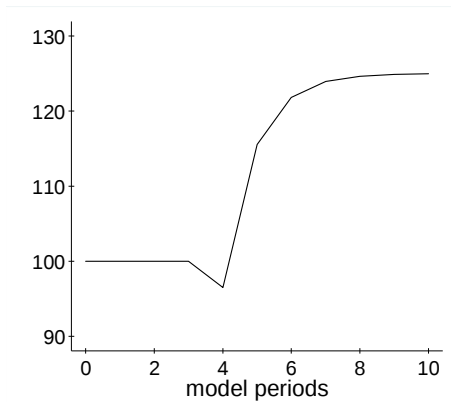
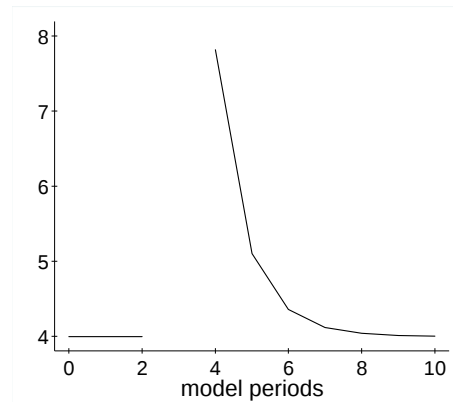


Figure 9: Consumption and interest rates

(a) Consumption



(b) Interest rate



Other key variables such as consumption and interest rates exhibit patterns similar to the neoclassical growth model. Figure 9(a) shows that consumption initially declines after the reform and then subsequently increases. The reason is that the demand for investment from potential entrants increases which increases interest rates, as shown in Figure 9(b). The sharp initial rise in interest rates imply that consumers reduce consumption initially in order to increase investment to potential firms.

The figures that characterize the key economic variables for the reform to barriers to technology adoption are similar. The only difference is that the mass of potential entrants, in Figure 6(a), increases by less and then decreases to the same level upon converging to the new

balanced growth path. This result is expected given Proposition 1 since the reform to barriers to technology adoption has only an indirect effect on the mass of potential entrants.

Table 6 reports the growth rates and the contribution of net entry through time in the case of the reform to entry costs. During the reform period, the economy grows at an annualized rate of 5.5 percent, and then growth quickly declines. There is a surge in the contribution of net entry, from 25.0 percent in the initial balanced growth path to 75.5 percent. Productivity increases are smaller than output growth since there is also aggregate capital growth. The results for the case of the φ reform are very similar. In the case of both reforms, output and aggregate productivity growth are identical. Furthermore, the contribution of net entry is the same up to the first decimal place.

Table 6: FHK decompositions, κ reform in model.

Model periods (5 years)	Entry cost	Output growth (percent, annualized)	Aggregate productivity growth (percent, annualized)	Contribution of net entry (percent)
0-3	1.09	2.0	1.3	25.0
4 (reform)	0.44	5.5	3.1	75.5
5	0.44	2.8	1.4	46.4
6	0.44	2.2	1.3	32.0
7+	0.44	2.0	1.3	25.0

Next, we want to examine whether the model can quantitatively match the contribution of net entry that we observe in the data during the periods of fast growth. Table 7 shows the productivity growth and the contribution of net entry in the data as well as those in the model BGP and after the reforms in the two distorted economies. Since Table 4 has multiple observations for countries that are in fast growth and slow growth, we report the average annual output growth and the average contribution of net entry over all fast-growing countries and all slow-growing countries. Overall, the model successfully generates rapid growth with a high contribution of net entry, although we do observe that the contribution of net entry in the model is higher than what we observe in the data.

Table 7: Contribution of net entry, model and data.

	Output growth (percent, annualized)	Contribution of net entry (percent)
Data fast growth	6.4	52.2
Model reform (κ)	5.5	75.5
Model reform (φ)	5.5	75.5
Data slow growth	2.6	26.6
Model BGP	2.0	25.0

We can further analyze the results of the model by decomposing all of the FHK terms. In Table 8, we extend the results reported in Table 2 to include the model output. We see that, as in the data, the entry term is most important in understanding the large changes in aggregate productivity.

Table 8: FHK decompositions, model and data.

Period	Country	Fast /slow growth	Aggregate productivity growth (percent)	Entering (percent)	Exiting (percent)
1990–1995	Chile	Fast	27.1	20.8	2.2
1992-1997	Korea	Fast	19.2	5.2	4.0
4 (reform κ)	Model	Fast	16.4	8.3	4.1
4 (reform φ)	Model	Fast	16.4	8.3	4.1
2001–2006	Chile	Slow	16.4	5.9	-0.2
2002-2007	Korea	Slow	17.5	2.2	4.9
3 (BGP)	Model	Slow	6.7	1.3	0.4

Like before, we use equation (9) to decompose the FHK entry term into three components: the entry rate, the relative size of the average entrant, and the relative productivity of entrants. In Table 9 we extend the results of Table 3 to include the decomposition implied by the model. First, we find that the model implies that the average size of entrants does not change. We find that in the case of the reform to entry costs, the entry rate increases by 166 percent and the relative productivity of entrants increases by 145 percent. Thus, we find that in both the model and data, the increase in the relative productivity of entrants plays a key role and that the average size of entrants plays a small role in explaining changes in the entry term.

Table 9: Entry term decomposed, model and data.

Period	Country	Fast/slow growth	Aggregate productivity growth (percent)	Entering (percent)	Entry rate (percent)	Relative size of average entrants	Relative productivity of entrants (percent)
1990–1995	Chile	Fast	27.1	20.8	55.6	1.01	37.0
1992–1997	Korea	Fast	19.2	5.2	70.3	0.55	13.8
4 (reform κ)	Model	Fast	16.4	8.3	50.6	1.00	16.4
4 (reform φ)	Model	Fast	16.4	8.3	50.6	1.00	16.4
2001–2006	Chile	Slow	16.4	5.9	40.9	0.95	15.2
2002–2007	Korea	Slow	17.5	2.2	62.8	0.44	8.0
3 (BGP)	Model	Slow	6.7	1.3	19.0	1.00	6.7

6. Conclusion

In this paper, we use FHK productivity decompositions to study the relationship between aggregate productivity growth and the importance of plant entry and exit. We empirically show that during periods of rapid growth the entry and exit of plants contributes more to aggregate productivity growth. To do so, we first study two countries that experienced rapid growth followed by an economic slow-down: Chile and Korea. In both of these countries, we found that the slow-down in growth was also accompanied by a decline in the contribution of entry and exit. Second, we conduct a survey of the literature for studies that use FHK decompositions to study productivity growth across countries, and after making adjustments to window lengths necessary to make comparisons, we find that fast-growing countries saw a larger contribution from entry and exit of plants.

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 entrants, 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 two distorted economies that have income levels that are 20 percent lower than the United States by raising entry costs in the first economy and barriers to technology adoption in the second economy. We find that if we eliminate the distortions in these

economies, the model can replicate the large increases in productivity growth and the increasing importance of entry and exit. These findings suggest that the entry of productive new firms and the exit of unproductive old firms play a key role in explaining rapid growth, but is less important during times of moderate growth.

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Appendix for “Firm Entry and Exit and Aggregate Growth”

By Jose Asturias, Sewon Hur, Timothy J. Kehoe, and Kim J. Ruhl

Section 1: 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. One dataset covers 1986–1996 and the other one covers 1995–2006.

We use 4-digit ISIC industries, which is the highest level of disaggregation. For the 1986–1996 data, we use ISIC Rev. 2 codes and for the 1995–2006 data we use ISIC Rev. 3 codes.⁹

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

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

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 .

Constructing Real Gross Output and Factor Inputs

We constructed the gross output and factor inputs in the same manner as in Liu and Tybout (1996) and Tybout (1996). We now describe in detail how the real variables were constructed for the dataset that spans 1986–1996 and 1995–2006.

For the dataset that spans 1995–2006, we used gross output and intermediate input deflators broken down at the 4-digit level (ISIC Rev. 3) to put these variables into 1995 pesos. These deflators were by created INE to be used with the ENIA plant-level data.¹⁰

We now describe the construction of the real capital stock for the dataset that covers 1995–2006. We consider three types of capital: buildings, machinery, and vehicles. When a plant enters, we use the reported book value of each type of capital for that year. We use an

⁹ To give a sense of the level of disaggregation, we report the number of industries in each classification system. ISIC Rev. 2 has 81 industries and ISIC Rev. 3 has 127 industries.

¹⁰ For more details, see http://www.ine.cl/canales/chile_estadistico/estadisticas_economicas/industria/series_estadisticas/series_estadisticas_enia.php.

investment deflator provided by the Central Bank of Chile to put the value of capital stock into 1995 pesos. We use the investment deflator to put reported investment for each type of capital into 1995 pesos. For subsequent years, we use the perpetual inventory method. The movement of capital type j is characterized by

$$k_{etj} = (1 - \delta_j) k_{e,t-1,j} + i_{etj} \quad (28)$$

where k_{etj} is the real capital stock, δ_j is the rate of depreciation for capital j and i_{etj} is real investment. We use depreciation rates of 5 percent for buildings, 10 percent for machinery, and 20 percent for vehicles. Investment in capital type j is the addition of new capital j subtracted from sales of capital j . If we ever have the case that k_{etj} in equation (28) is negative, then we set it equal to zero.

Once we have computed the real capital stock series for each type of capital, we sum the value of the buildings, machinery and vehicles to arrive to the plant's total capital stock

$$k_{et} = \sum_j k_{etj}.$$

We now discuss the preparation of the real variables for the dataset that covers 1986–1996. There are two steps that needs to be taken to prepare the deflators. The deflators created for the ENIA plant-level data uses industry classification system ISIC Rev. 3 compared to the dataset that uses ISIC Rev. 2. Thus, the first step is to convert the deflators from ISIC Rev. 3 to ISIC Rev. 2. We use a concordance table provided by the United Nations Statistics Division that maps each Rev. 2 industry code to corresponding Rev. 3 codes. If a Rev. 2 industry code has more than one Rev. 3 corresponding industry, we take the average of these deflators. The final product of this step is a 4-digit gross output and intermediate input deflator at the 4-digit level using ISIC Rev. 2 for the years 1992–1996.

The next step is to extend the series to 1986. We use information from the Anuario de Cuentas Nacionales 1999 issued by the Central Bank that reports nominal and real gross output for each industry broken down at the 2-digit level using ISIC Rev. 2. We create a deflator for 1986–1992 period that we splice together with the one for 1992–1996.

We will now discuss the construction of the real capital stock for the dataset that covers 1986–1996. The book value for each type of capital is only reported for 1992 and onwards. If a

plant enters in 1992 or after, we use the real book value of capital in the year that it entered. Then, we use the perpetual inventory method for the following years.

If a plant enters before 1992 and operates in 1992, then we start with the real book value of capital in 1992 and calculate the capital stock for subsequent years using the perpetual inventory method. For the years preceding 1992, we re-arrange equation to get

$$k_{e,t-1,j} = \frac{k_{etj} - i_{etj}}{1 - \delta_j} \quad (29)$$

which allows us to calculate the capital stock of capital type j for the preceding years. If we ever have the case that k_{etj} in equation (29) is negative, then we set it equal to zero.

If a plant enters before 1992 and exits before 1992, we must estimate the real capital stock of the plant based on the real capital stock that we have calculated for other plants. To do this, we estimate the following regression for 1991 for each type of capital j

$$\log k_{e,1991,j} = \alpha_0 + \alpha_1 \log \ell_{eit} + FE_i,$$

where FE_i is an industry dummy at the 4-digit level. If a plant is missing real capital stock in the year 1991, then we use the estimated capital stock j

$$\hat{k}_{e,1991,j} = e^{\hat{\alpha}_0 + \hat{\alpha}_1 \log \ell_{eit} + FE_i}.$$

For the preceding years we use equation to find the real capital stock. We repeat this process for 1990 and for the previous years.

Constructing Factor Cost Shares

To find the parameters β_k^i , β_ℓ^i and β_m^i of the production function, we use industry cost shares for each input. The cost shares that we calculate are at 4-digit industry-level for each input and we take the average over the beginning and end of the period.

For cost of labor we use total employee remuneration and for intermediate inputs the total reported cost on intermediate inputs. We do not have a direct measure of the user cost of capital in order to compute the cost share of capital. Thus, we use the no-arbitrage relationship to find the user cost of capital j as follows

$$R_{ij} = 1 + r_t - (1 - \delta_j) \frac{P_{t+1,j}}{P_{tj}} ,$$

where R_{ij} user cost of capital, P_{tj} is the price of a unit of capital in period t , and r_t is the real interest rate. This is similar to the strategy followed by Young (1995). To determine r_t , we use the economy-wide real interest rate and to determine P_{t+1} / P_t we use an investment deflator.

Calculating FHK Productivity Decompositions

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

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

We can thus calculate the industry-level productivity Z_{it} for industry i for all years using equation (1). Furthermore, we decompose these changes in industry-level productivity using equations (2), (3), (4), and (5). To find aggregate 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.

Additional details

There are a few additional details to note. First, if a plant changes industry classification, then we consider it to be an exiting plant in the old industry and an entering plant in the new industry.

Secondly, we exclude plants for which we cannot calculate productivity, mainly consisting of plants that report not using either of the three input factors. These plants consist of 4.89 percent of gross output in 2006.

Thirdly, we exclude a handful of industries due to lack of appropriate data. These include:

- We exclude 4-digit industries for which INE does not report deflators. These industries account for 0.78 percent of gross output in 2006. Their ISIC Rev. 3 classifications are: 1712, 1820, 2213, 2310, 2696, 2891, 2892, 2914, 2915, 2923, 2926, 2927, 2929, 3000, 3420, 3511, 3512, 3520, 3530, 3592, 3691
- We exclude 4-digit industries for which we cannot calculate cost shares at the beginning and end of the period. This arises from the fact that in one of the two years we did not have any plants present so that we could calculate the cost shares. In

2001–2006 window these industries include ISIC Rev. 3 categories 2230, 2430, 3140, and 3220, which account for 0.01 percent of gross output in 2006. In the 1990–1995 window these industries include ISIC Rev. 2 categories 3118 and 3853, which account for 1.31 percent of gross output in 1995.

- We exclude the category 39 ISIC Rev. 2 (other manufacturing industries) for 1990–1995. We only have 2 digit deflators for 1990 and 1991 and this category includes miscellaneous industries that are not necessarily related as they are in other industries. This industry accounts for 0.22 percent of gross output in 1995.

Section 2: Data Description for Korean Productivity Decompositions

We use the Mining and Manufacturing Survey purchased from the Korean National Statistical Office for the years 1992, 1997, 2002, and 2007. This dataset is a panel and covers all manufacturing establishments in Korea with more than 10 employees. Furthermore, each plant has industry classifications at the 5-digit level using the Korean Standard Industrial Classification (KSIC Rev. 6 for 1992 and 1997, Rev. 8 for 2002, and Rev. 9 for 2007 and 2012).¹¹ We use KSIC Rev. 6 for the 1992-1997 window and KSIC Rev. 9 for the 2002-2007 window, all at the 4-digit level, as the main unit of industry analysis.

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

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

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 factor elasticity of input j in industry i .

For gross output, we use sales 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.¹² Labor is expressed in number of total workers.¹³ 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

$$k_{et} = \sum_j k_{eitj} .$$

¹¹ 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.

¹² The producer price indices are in product codes, which are converted to KSIC codes using the concordances in the online appendix.

¹³ For 1992, 1997, and 2002, total workers include self-employed workers, unpaid family workers, production workers, and non-production workers. For 2007, total workers include self-employed workers, unpaid family workers, everyday workers, temporary workers, and unpaid workers.

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 deflators constructed using the input-output matrix (BOK) broken down at 2-4-digit levels to put this series into real 2010 Korean Won. We build two sets of deflators; one based on KSIC Rev. 6 using the input-output matrix for 1995, and one based on KSIC Rev. 9 using the input-output matrix for 2011. We obtain the matrix of intermediate deflators $\underline{D}$, by:

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

where I is the input-output matrix and P is the matrix of the producer price indices by year. Essentially, the deflator for an industry i is the geometric mean of the price indices of its inputs, weighted by the input coefficients in that industry given by the input-output matrix,

$$D_{it} = \exp \left[\sum_{j=1}^N I_{ij} \log(P_{jt}) \right] = \prod_{j=1}^N P_{jt}^{I_{ij}}.$$

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 period of growth. For labor, 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 follows

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

where r_t is the real interest rate, P_{jt} is the deflator for fixed capital formation, and δ_j is the depreciation rate of capital j . 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 estimated productivity of plant e in industry i at time t is

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

Section 3: 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 (forthcoming), henceforth GR and MP respectively.¹⁴ In particular, we decompose productivity growth over the same windows using 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.

The MP decomposition re-writes the continuing and net entry term as

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

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. For example, consider a world in which all plants have the same productivity and that they all grow at the same rate. If there is any sort of entry then FHK decomposition assigns a positive value to net entry since new entrants are more productive than plants last period. On the other hand, the MP decomposition assigns zero to net entry.

Lastly, we can write the GR decomposition as

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

where

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

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 due to the averaging over time.

¹⁴ We do not consider the Bailey, Hulten, and Campbell (1992) since FHK is a refinement of that decomposition.

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 contribution of net entry still holds under all of the decompositions. For Chile, the contribution of net entry goes from 65.9 percent to 23.1 percent using GR and 63.4 percent to -16.9 percent using MP. In the case of Korea, the contribution of net entry goes from 42.7 percent to 31.2 percent using GR and 3.1 percent to -11.1 percent using MP.

Table 10: Chilean contribution of net entry

Periods	FHK	GR	MP
1990–1995	84.6	65.9	63.4
2001–2006	35.0	23.1	-16.9

Table 11: Korean contribution of net entry

Periods	FHK	GR	MP
1992–1997	47.9	42.7	3.1
2002–2007	40.0	31.2	-11.1

We calculate these decompositions using output from the model. The results can be found in . 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 contribution of net entry to productivity growth is similar under both FHK and GR in US manufacturing data.

Table 12: Model output contribution of net entry

Periods	FHK	GR	MP
Reform (lower entry costs)	75.5	57.1	35.7
Reform (lower φ)	75.5	57.1	35.7
BGP	25.0	16.2	7.4

We find that both the MP and GR decompositions show an increase in the net entry component after the reforms. The magnitude of these increases is similar to what we see in Chile and Korea.

Section 4: Spillover Parameter ϵ

The relationship between the productivity growth of continuing firms and industry productivity in the model is

$$g_{ct} = g_w^{1-\epsilon} g_t^\epsilon,$$

where g_{ct} is the productivity growth of continuing firms, g_w is the within firm productivity growth, and g_t is the industry-wide productivity growth. We take the log of both sides and we get

$$\log g_{ct} = (1-\epsilon) \log g_w + \epsilon \log g_t,$$

which gives us an equation that we can estimate using our data.

We estimate the following regression

$$\log g_{ct,i} = \beta_0 + \beta_1 \log g_{it} + \eta_{it},$$

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 productivity growth of industry i , and η_{it} is an error term.¹⁵ A continuing plant is one which is present both the beginning and end of a time window. Note that β_1 gives us our estimate of the spillover parameter ϵ .

Table 13: Estimates of spillover parameter ϵ

Country	Window	β_1
Chile	1990-1995	0.29
	2001-2006	0.73
Korea	1992-1997	0.42
	2002-2007	0.65
AVERAGE		0.52

The results are reported in for Chile and Korea for both windows. The OLS estimate of $\hat{\beta}$ ranges from 0.42 to 0.65 for Korea and 0.29 to 0.73 for Chile. We use $\epsilon = 0.52$, which is the average over the four estimates.

¹⁵ Note that if we use the notation of the appendix where we describe alternative decompositions, then $\log g_{ct,i} = \log Z_{i,C,t} - \log Z_{i,C,t-1}$.

Section 5: Proof of Proposition 1

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

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

Next, using the zero profit condition, we can derive:

$$w_t = \alpha \left(\frac{1-\alpha}{\lambda f} \right)^{1-\alpha} \hat{x}_t \quad (30)$$

The labor market clearing condition gives

$$1 = \left(\frac{w_t}{\alpha} \right)^{\frac{1}{\alpha-1}} \frac{\gamma(1-\alpha)}{\gamma(1-\alpha)-1} \hat{x}_t^{\frac{1}{1-\alpha}} \eta_t \quad (31)$$

Substituting (30) into (31) we obtain the expression for the mass of operating

$$\eta = \frac{\gamma(1-\alpha)-1}{\gamma\lambda f} \quad (32)$$

Using equation (19) and applying the BGP conditions ($\mu_t = \mu$, $Y_{t+1}/Y_t = g_e$, $g_{ct} = g_w^{1-\varepsilon} g_e^\varepsilon$), we obtain the expression for the entry-exit threshold

$$\hat{x}_t = \frac{g_e^t}{\varphi} \left(\frac{\omega\mu}{\eta} \right)^{\frac{1}{\gamma}} \quad (33)$$

where

$$\omega = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\frac{g_e}{g_c} \right)^{\gamma(1-i)} \quad (34)$$

The free entry condition in equation (17) can be re-written as

$$\kappa_t = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\prod_{s=1}^{i-1} q_{t+s} \right) \int_{\hat{x}_{t+i-1} \prod_{s=1}^{i-1} g_{c,t+s}^{-1}}^{\infty} \pi_{t+i-1} \left(\prod_{s=1}^{i-1} g_{c,t+s} x \right) dF_t(x) \quad (35)$$

Evaluating the integral in (35) and substituting (31) we obtain

$$\kappa_t = \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\prod_{s=1}^{i-1} q_{t+s} \right) \varphi^{-\gamma} g_e^{\gamma t} \hat{x}_{t+i-1}^{-\gamma} \prod_{s=1}^{i-1} g_{c,t+s}^{\gamma} \left\{ \frac{w_{t+i-1}}{\alpha} \frac{1-\alpha}{\eta} - f_t \right\} \quad (36)$$

Substituting $Y_{t+i-1} = w_{t+i-1} / \alpha$ and (32) into (36), we obtain

$$w_t \lambda \kappa = \frac{g_e^{\gamma t}}{\gamma \eta} \sum_{i=1}^{\infty} (1-\delta)^{i-1} \left(\prod_{s=1}^{i-1} q_{t+s} g_{c,t+s}^{\gamma} \right) w_{t+i-1} \hat{x}_{t+i-1}^{-\gamma} \quad (37)$$

Substituting (33) into (37) and applying the BGP conditions ($w_{t+1} / w_t = g_e$, $q_{t+1} = \beta / g_e$, $g_{ct} = g_c$), we obtain

$$\mu = \frac{\xi}{\gamma \lambda \kappa \omega} \quad (38)$$

where

$$\xi = \sum_{i=1}^{\infty} \beta^{i-1} (1-\delta)^{i-1} \left(\frac{g_e}{g_c} \right)^{\gamma(1-i)} \quad (39)$$

Finally, the ratio of output per capita to that of an economy with $\tau = 0$ and $\varphi = 1$ is given by

$$\lambda = \varphi^{\frac{1}{\alpha}} \left(\frac{\kappa}{\kappa^T} \right)^{\frac{1}{\gamma \alpha}}$$

Thus, our guess has been verified and all optimality conditions are satisfied. This concludes the proof of Proposition 1. $\square$

Section 6: Additional Tables

Table 14: Full FHK decompositions, model vs. data.

Period	Country	Fast/slow growth	Aggregate productivity growth (percent)	Entering (percent)	Exiting (percent)	Within (percent)	Reallocation (percent)
1990–1995	Chile	Fast	27.1	20.8	2.2	4.2	-0.1
1992-1997	Korea	Fast	19.2	5.2	4.0	8.1	1.9
4 (reform κ)	Model	Fast	16.4	8.3	4.1	7.4	-3.3
4 (reform φ)	Model	Fast	16.4	8.3	4.1	7.4	-3.3
2001–2006	Chile	Slow	16.4	5.9	-0.2	4.4	6.3
2002-2007	Korea	Slow	17.5	2.2	4.9	8.6	1.9
3 (BGP)	Model	Slow	6.7	1.3	0.4	5.1	-0.1

Table 15: FHK exit term decomposed, model vs. data.

Period	Country	Fast/slow growth	Aggregate productivity growth (percent)	FHK Exiting (percent)	Exit rate	Relative size of average exiter	Relative productivity of exiter
1990–1995	Chile	Fast	27.1	2.2	30.2	0.4	-20.4
1992-1997	Korea	Fast	19.2	4.0	70.0	0.5	-13.8
4 (reform κ)	Model	Fast	16.4	4.1	35.2	0.9	-11.6
4 (reform φ)	Model	Fast	16.4	4.1	35.2	0.9	-11.6
2001–2006	Chile	Slow	16.4	-0.2	41.1	0.6	0.6
2002-2007	Korea	Slow	17.5	4.9	58.7	0.5	-19.6
3 (BGP)	Model	Slow	6.7	0.4	19.0	0.9	-2.1

Section 7: 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.

Investment for a firm is κ_t when it enters and f_t when it pays the continuing fixed cost each period. The depreciation for continuing firms is the operating cost minus the cost of upgrading capital, which is $f_t - (\kappa_{t+1} - \kappa_t)$. This implies that the capital stock for a continuing firm is $k_t = \kappa_t + f_t$.

We also need to define the aggregate depreciation rate and the aggregate capital stock. Aggregate investment is $\mu_t \kappa_t + \eta_t f_t$ and the aggregate capital stock is $\eta_t (\kappa_t + f_t) + (\mu_t - \eta_t) \kappa_t$. The depreciation of capital is the sum of the capital of firms that die, entry costs of potential entrants who do not enter, and $f_t - (\kappa_{t+1} - \kappa_t)$ for continuing firms as discuss above. We find that the aggregate depreciation rate is

$$\tilde{\delta}_{kt} = 1 - \frac{\eta_{t+1}(\kappa_{t+1} + f_{t+1}) + (\mu_{t+1} - \eta_{t+1})\kappa_{t+1}}{\eta_t(\kappa_t + f_t) + (\mu_t - \eta_t)\kappa_t} + \frac{\mu_t \kappa_t + \eta_t f_t}{\eta_t(\kappa_t + f_t) + (\mu_t - \eta_t)\kappa_t}.$$

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