The Dynamics of Development: Innovation and Reallocation

Francisco J. Buera* Roberto N. Fattal-Jaef†

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Abstract

This paper investigates aggregate and firm-level properties of the dynamics of economic development in a number of post-war growth accelerations. We show that while these episodes exhibit gradual and sustained growth in TFP, they differ substantially with respect to the evolution of the firm size distribution. To understand this behavior, we provide a quantitative theory of transitions featuring endogenous innovation, entry and exit, and the dismantling of idiosyncratic distortions, which we calibrate to the experiences of Chile and China. The model features very protracted growth in TFP, and captures key aspects of firm dynamics in the data.

1 Introduction

While elusive for many poor economies, economic development, as defined by a persistent acceleration in the growth rate of per-capita income, has been attained by a number of countries in the post-war period (Haussmann, Pritchett & Rodrik, 2005). Prominent examples are Asian economic miracles and the successful post-communist transitions. At the aggregate level, sustained development episodes are characterized by a gradual and sustained increase in Total Factor Productivity (TFP) (Buera and Shin, 2013, 2015). At the disaggregate level, these episodes feature rich firm dynamics,

*Federal Reserve Bank of Chicago; fjbuera@gmail.com.
†World Bank; rfattaljaef@gmail.com.

which we document in this paper. Our purpose is to provide a quantitative theory connecting these phenomena.

Our baseline economy builds on Lucas (1978), which we extend to incorporate a theory of innovation along the lines of Atkeson and Burstein (2010). There is a large household populated by a continuum of individuals, who are heterogeneous with respect to the ability to operate a firm. Entrepreneurial ability evolves endogenously as a result of entrepreneurs' investments in innovation, and exogenously as a result of productivity shocks. Individuals have a choice between working for a wage or running a firm. We consider an environment perfect insurance, but with idiosyncratic distortions.

We incorporate two distortions to account for the initial differences in TFP across countries and whose (partial) elimination triggers the onset of a growth acceleration. First, in the spirit of Hsieh and Klenow (2009) and Restuccia and Rogerson (2008), we consider idiosyncratic revenue taxes and subsidies affecting the allocation of resources across entrepreneurs and, more importantly, their incentive to innovate. We refer to these as allocative distortions. We use available measures of these distortions, and their dynamics in the aftermath of specific growth acceleration episodes, to discipline their magnitude. Second, as a simple device to model the incentive structure in a communist regime, we assume that entrepreneurial profits, gross of entrepreneurial innovation expenses, are subject to a very progressive profit tax, which distorts innovation and entry decisions.

As we document in this paper, the differential nature of distortions faced by these economies are important determinants of the evolution of the average size of firms. Post-communist transitions are characterized by a decline in the average size of firm, while the average size of firms tend to increase for Asian miracles and other growth accelerations with available data. Notwithstanding this, we find that in both cases transitions are characterized by very protracted increases in TFP, accounting for a substantial fraction of the observed TFP growth. Thus, the aggregate conclusions are robust to the very different triggers of growth accelerations.

We follow a simple two step strategy to quantify the model. First, we calibrate preference and technological parameters that are held constant across economies so that the frictionless version of the model matches data on firms dynamics and income inequality in the US, a relatively undistorted economy. We then use information on the evolution of idiosyncratic distortions in a subset of growth accelerations to discipline, as much as possible, the triggers of reforms.

We consider two specific examples of growth accelerations: Chile in the 80s and

China in the 90s. We assume that firms in Chile are subject to allocative distortions and a uniform profit tax. In particular, we use the level and dynamics of allocative distortions measured by Chen and Irarrazabal (2014) and calibrate the uniform profit tax to match the initial average size of firms. For China, we assume that the economy is subject to both allocative distortions and a very progressive profit tax. We use the level and dynamics of allocative distortions measured by Hsieh and Klenow (2007). The curvature of the profit tax schedule is chosen to capture the egalitarian nature of a communist regime and its scale is set to match the initial large average size of firms in the Chinese manufacturing sector.

We first illustrate the impact of allocative distortions and progressive profit taxes on the initial level of (under)development. Both distortions depress the incentive to innovate, generating losses in TFP of 29% for Chile and 50% for China. They also imply life-cycle profiles for employment and productivity of firms that are flat, consistent with the evidence in Hsieh and Klenow (2014). We decompose the effect of distortions on TFP into two channels: (i) their effect holding fixed the distribution of productivity of firms, which we label as static; (ii) their effect through the change in the distribution of productivity of firms, which we label as dynamic. Interestingly, we find that the dynamic channel explains the majority of the negative impact of allocative distortions on TFP.

We then turn to the main goal of the paper, investigating the macro and firm-level features of development dynamics. As idiosyncratic distortions are gradually dismantled, and the progressivity of profit taxes is suddenly eliminated in the case of China, innovation investment rises, both on impact and further along the transition. This results in a sustained, but significantly protracted, rise in TFP. Over the sample period, the model account for over 30% of the TFP growth for Chile, and over 50% of TFP growth for China. An important implication of the quantitative theory is that the impact of reforms is very protracted. The half life of the transition of GDP is 24 years and 14 years for Chile and China, respectively. The faster, but still protracted, transition of the Chinese case is explained by the fact that we assume the sudden elimination of the progressive profit taxes, together with the gradual decline in allocative distortions suggested by the data.[1] Finally, consistent with the data, along the transition the average size of firms increases for Chile, while it decreases substantially for the case of China.

[1] As a comparison, the half-life of a transition in a Neoclassical growth model with comparable physical capital shares following a sudden increase in TFP is around 6 years.

We conclude the analysis of the development dynamics with two additional exercises. First, we explore the implications of the theory for the evolution of the cross-sectional employment-age relationship. Along the transition, the cross-sectional employment-age relationship is the product of age and cohort effects, and therefore it is natural to ask about the relative importance of these forces. We find that the cross-sectional employment-age relationship converges slowly to its new stationary equilibrium. This result raises a word of caution when using a stationary model to make inferences about the nature of underlying distortions, specially when studying economies undergoing a growth acceleration episode.

Finally, we use the theory to forecast the evolution of the Chinese economy under two alternative time path of idiosyncratic distortions. First, we project the time path of TFP in China under the assumption that allocative distortions do not decline after 2011. We contrast this path with the evolution of an economy where allocative distortions continue to decline at the same pace as in our sample, until idiosyncratic distortions are eliminated. In the second case, TFP growth would be on average 0.5 percent higher over a period of 30 years. While in the first case the average size of firms stabilizes 10 years after the beginning of the reform, in the alternative case it takes over 60 years for the average size of firms in China to rise, and converge to the value observed in the US.

2 Related Literature

Our study provides a unified framework for thinking about the long run implications of various types of allocative distortions, and for investigating the micro and macro behavior of the economy along development paths. It is therefore related to the large body of studies that have made contributions to each of these areas in isolation.

Our work is related to the burgeoning empirical and quantitative literature on misallocation and productivity, of which Hsieh and Klenow (2009), Bartlesman, Haltiwanger, and Scarpetta (2008), and Restuccia and Rogerson (2008) are salient examples. We connect to this literature from two dimensions. First, we appeal to it as motivation for assigning a prominent role to resource misallocation in the construction of an initial allocation with low productivity and income per capita in the model. We take direct summary statistics about the degree of resource misallocation in developing countries from the empirical branch of the literature, and use them to discipline the extent of misallocation in the model at the onset of our transition experiments, and their dynamics afterwards. Secondly, we contribute to the quantitative side of the literature, investigating the extent to which the dynamic responses from firms, such as innovation, entry, and exit, complement the static allocative responses in shaping long run losses in productivity and in explaining the speed of transition to the equilibrium with fewer distortions.[2]

The second feature of our work connects us with the literature on neoclassical transition dynamics. Christiano (1989) and King and Rebelo (1993) were the first to emphasize the shortcomings of the frictionless neoclassical model when it comes to reproducing features of transition dynamics in miracle economies. In the data, transition dynamics of fast growing economies are characterized by sustained growth in income per-capita and total factor productivity, delayed but protracted investment surges, and hump-shaped interest rate dynamics. These features cannot be jointly reproduced by the many extensions to the canonical neoclassical growth model, unless one introduces an exogenous path of TFP that accompanies the convergence in capital stocks, as shown for the case of Japan by Chen, İmrohoroğlu, and İmrohoroğlu (2006). Our contribution is to develop a model that can account endogenously for the joint dynamics of investment rates and TFP, and at the same time delivers rich firm-level implications that can be validated against firm-level data.

Two papers in the literature stand out for their proximity with ours. Buera and Shin (2013) develops a theory of transitions featuring heterogeneous entrepreneurs, entry and exit to production, and credit market imperfections. Motivated by the experience of seven Asian economies, the authors show that in the presence of financial frictions that delay capital reallocation, transition paths triggered by the removal of idiosyncratic distortions are characterized by investment and interest rate dynamics that are closer to the data. The model also yields an endogenous path for TFP, although on this front the model's convergence is substantially faster than in the data. Our relationship to this paper is twofold. On one hand, we take the paper's historical accounts of growth accelerations in fast growing economies as providing empirical support for the idea that reforms that remove allocative distortions occurred at the beginning of these growth accelerations. Secondly, our model provides a complementary mechanism through which macroeconomic dynamics can depart from those of the standard neoclassical model. Rather than emphasizing frictions to factor reallocation, we show that the interaction

[2]Some example of studies that have investigated the role of entry, exit, and innovation in amplifying or mitigating the long run productivity losses from idiosyncratic distortions are Bhattacharya et. al. (2013), Da-Rocha et. al. (2014), Hsieh and Klenow (2014), and Akcigit, Alp, and Peters (2016)

between the economy's incentives to accumulate tangible capital, through household's investment decisions, and intangible capital, from firms' innovation efforts, can generate transition paths for output, investment, and TFP similar to those in the data in a frictionless setup. Furthermore, because innovation outcomes are risky, the productivity distribution of firms reflects the increased innovation efforts by firms with a lag, which allows the model to generate sustained and protracted increases in TFP, a weakness of the theories based on barriers to factor reallocation.

The consideration of tangible and intangible forms of capital relates our paper to the work of Atkeson and Kehoe (2005). The authors develop a theory of development in which life-cycle dynamics are driven by age-dependent, exogenous stochastic accumulation of organizational capital and in which entering firms embody the best available technology. The trigger of development in their model stems from a sudden permanent improvement in the technologies embodied in new plants. Despite the resemblance of our model to theirs, there are several points of departure. First, as in the data, life-cycle dynamics of firms in the frictionless steady state of our model are different from those of the distorted equilibrium. In turn, these differences are generated endogenously, from a theory of innovation that connects firm growth to allocative frictions. Secondly, the predictions about entry along the transition path in our model differ from those in Atkeson and Kehoe (2005). Entry is inefficiently encouraged by subsidies in the pre-reform steady state of our economy, which implies that our development paths are characterized by reductions in entrepreneurship, and increases in the average firm size. Lastly, because of our focus on growth accelerations, we follow a different strategy for parameterizing the pre-reform stationary equilibrium, appealing to firm-level data in low income countries to discipline the choice of distortions that hinder output and productivity.

3 Motivating Facts

We set the stage for the quantitative model by presenting a number of facts regarding macroeconomic and microeconomic features of transitions around the world. We consider separately two types of convergence episodes: sustained growth accelerations in the post-war period, identified by appealing to the methodology of Hausmann et.al.

(2005)[3], and post-communist transitions[4]. As we shall explain in greater detail below, we proceed in this way because of the fundamental differences in the adjustments occurring at the micro-level between these episodes, differences that we want to carefully account for in the theory that we develop later.

Our interpretation about the triggers of development dynamics is that they arise as a result of large scale reforms that produce significant changes in the business environments in which firms operate. This view may sound more acceptable for the case of post-communist transitions than for accelerations since, by definition, a liberalization as dramatic as the adoption of a market-based allocation mechanism constitutes an evident change in the incentives for business formation, resource allocation, and firm growth. There is, however, substantial evidence supporting the view that large-scale economic reforms also help explain the beginning of take-offs in growth accelerations. Buera and Shin (2013), for instance, summarize policy changes around the start of the growth accelerations of Asian Miracles, among the most prominent examples of accelerations during the 1960-2000 period, and find that the dates in which these policy changes were implemented coincide with most of the take-off dates identified using statistical methods. To reinforce our interpretation, we present direct data on measures of resource misallocation for two salient examples of accelerations and post-communist transitions, Chile and China, and show that these measures indeed decline throughout the period in which growth is taking place. We present this data when we discuss the calibration of reforms in the model.

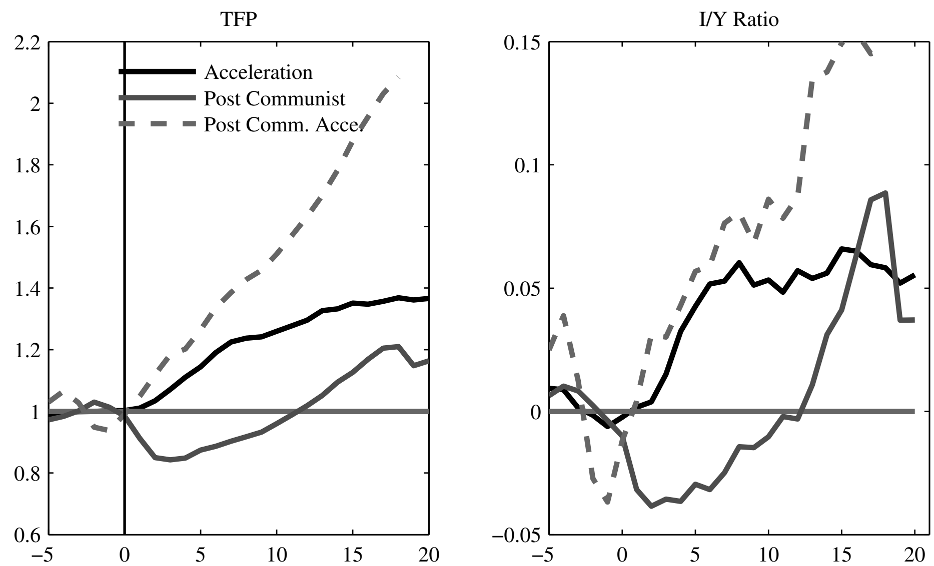
[3]In Hausmann et.al. (2005) a growth acceleration starts in year t only if the following three conditions are met: (1) the average growth rate in the seven ensuing years (years t through $t+6$) is above 3.5 percent; (2) the average growth rate in the seven ensuing years is at least two percentage points higher than in the preceding seven years (years $t-7$ to $t-1$); and (3) the output per capita in the ensuing seven years is above the previous peak. If more than one contiguous years satisfy all three conditions, the start of the growth acceleration is chosen to be the one for which a trend regression with a break in that year provides the best fit among all eligible years, in terms of the F-statistic. A *sustained* growth acceleration is one for which the average growth rate in the decade following a growth acceleration (years $t+7$ through $t+16$) is above 2 percent. We use the growth acceleration data from Buera and Shin (2013) who apply Haussmann et al. methodology to an updated sample (Penn World Tables 8.0).

[4]The complete list of post-communist countrie and the list of acceleration episodes picked up by the methodology is presented in the appendix.

3.1 Aggregate and Firm-Level Features of Accelerations and Post-Communist Transitions

Consider first the behavior of aggregate variables. Figure 3.1 shows the average behavior of TFP and investment rates in our selection of growth-accelerations and post-communist transitions. The left panel plots the average dynamics of TFP. In the vertical axis, units are measured relative to the average value of TFP in the 5 years preceding the take-off[5]. For post-communist countries, we assume that all transitions to start in 1990, so the corresponding line illustrates the ratio between the average of TFP across countries relative to the average value between 1985 and 1990.

Figure 3.1: Macroeconomic Features of Acceleration Episodes and Post-Communist Transitions



The left panel plots TFP dynamics for the simple average of post-communist transitions and acceleration episodes. The right panel illustrates the average of investment rates. The horizontal axes measure years with respect to the beginning of each episode, which we label period 0. For post-communist transitions we date such period to be 1990, while for growth accelerations, period 0 is given by the country's specific date which we identify, using the Hausmann et.al. (2005) methodology, as the start of the growth take-off. TFP dynamics are measured relative to the TFP level in period 0, while the investment rates are expressed as absolute deviations from the period 0 levels. A complete list of countries in each group is presented in the appendix.

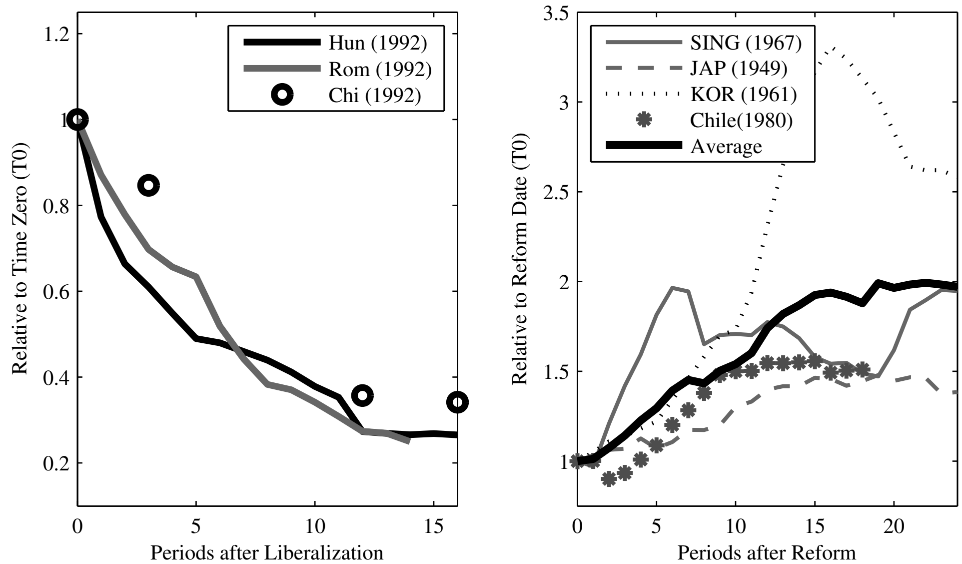
[5]Since accelerations occur at different dates in each country, we construct a measure the average TFP dynamics as follows. For each country, we construct the time series of TFP during the acceleration years and we express them relative to the average value of TFP in the 5 years preceding the start of the acceleration; and then we average across countries.

Despite the initial slump in the case of post-communist transitions, both TFP and investment rate increase over time. This pattern of behavior has been noted before in the literature as a challenge for the standard neoclassical growth model, the workhorse model to study transitions, since that model is silent about TFP dynamics and predicts a decreasing path of convergence in the investment rate towards an equilibrium with a higher capital stock. In this context, one of the goals of our paper is to attempt to reconcile theory and data, by developing a quantitative model of transitions with endogenous TFP and investment rate dynamics[6].

While exhibiting similar characteristics in the aggregate, acceleration episodes and post-communist transitions differ notably in the adjustments taking place at the micro level, in particular regarding the size distribution of firms. To see this, the figure below reproduces the dynamics of the average size of a manufacturing firm, in terms of employment, for the subset of countries for which we were able to gather time-series average size data. We consider three post-communist cases, Hungary, Romania, and China, and four acceleration episodes, Singapore, Japan, Chile, and Korea. The former group of countries is plotted in the left panel, and the latter group in the right one.

[6]Christiano (1989), King and Rebelo (1993), Chen et.al. (2006), and Buera and Shin (2013) are salient examples of papers that have noted the conflict between the neoclassical growth model and macroeconomic data on transitions, and developed extensions of the neoclassical model to bridge the gap between the two. See the literature review for a more thorough explanation of how our paper relates to this literature.

Figure 3.2: Average Size Dynamics during Acceleration Episodes and Post-Communist Transitions



Left panel illustrates average size dynamics for post-communist countries. Acceleration episodes are plotted on the right. Horizontal axes measure years after period 0, which corresponds to the year of reforms in the case of accelerations, and the first available year with firm level data in the case of post-communist transitions. Given the substantial differences in average size dynamics across growth accelerations, we also plot the behavior of the simple average of average size dynamics across these episodes. In all cases, the vertical axes measure the ratio of the average size relative to period 0

The figure shows a divergence in the behavior of average firm size across episodes. While the average size increases by a factor of two 20 years into an acceleration path, the typical firm shrinks by almost 70% in the post-communist case.

Several authors studied the behavior of the industrial sector in post-communist economies and emphasized the declining role played by large state-owned enterprises in favor of small privately owned businesses. Maddison (1998) is perhaps the most eloquent of these explorations, showing data about the re-organization of production in China and the economies of former Soviet Union countries[7]. Our contribution is to extend this analysis to a more recent period, and to revisit the previous findings through the lens of newer datasets.

[7]The following quote from Maddison (1998) illustrates this point: *"There has been a huge expansion in industrial activity outside the state sector. In 1978 there were 265 000 collectives. By 1996 there were l.6 million. The number of private enterprises rose from zero to 6.2 million. The bulk of these are small scale operations, most of them in rural areas, and run by individuals, townships and village level governments. A major reason for the success of these new firms is that their labour costs are much lower than in state enterprises, their capitalization is much more modest, and they are freer to respond to market demand. Many benefit from special tax privileges granted by local authorities."*

Similarly, the fact that average firm size tends to increase with development has also been noted before in the literature. In fact, our data for average size dynamics during accelerations draws exactly from that in Buera and Shin (2013). What has not been equally emphasized before is the notion that divergences from this average behavior can be determined by the nature of the underlying transformations taking place in the economy and that one such transformation that differs from the average is a post-communist liberalization.

This section presented facts regarding macroeconomic and microeconomic aspects of transition dynamics in the data. We showed that both in post-communist liberalizations and in acceleration episodes, aggregate dynamics follow a similar behavior, with TFP and investment rates increasing over time. At the micro level, however, the experiences of these countries are divergent. While accelerations are characterized by a protracted increase in the average size of a firm, firm size decreases in post-communist transitions. Combined, these facts play two essential roles in the design and validation of our quantitative theory. First, they tell us that our recreation of initial conditions before reforms needs to take into account the fundamental differences in the distortions that inhibit economic development in each case. In addition, it sets the bar for the kind of dynamics that we should expect our model to deliver. We present the theory with which we confront these challenges in the section below.

4 Model

We propose an economy populated by a single household composed of a continuum of agents. These agents are heterogeneous with respect to their ability to operate a production technology and run a business. The head of the household makes an occupational choice on behalf of each agent, choosing either to assign her to entrepreneurship and earn a risky profit, or make her participate in the labor force, in exchange for a fixed wage. Each individual commits to participate in a risk-sharing agreement that insulates individual consumption from fluctuations in idiosyncratic income. In addition to occupational choices, the head of household chooses aggregate consumption and investment in order to maximize lifetime utility.

There are endogenous and exogenous forces for firm dynamics and resource reallocation. The endogenous component stems from entrepreneur's investments in a risky innovation technology that controls the expected evolution of entrepreneurial ability over time, and their entry and exit decisions. The exogenous element results from idiosyncratic productivity shocks around the expected path. It is the endogenous decision of entrepreneurs to innovate together with the decision to enter and exit entrepreneurship that connects the life cycle and the size distribution of firms with policies and distortions to factor allocation.

We first present the details of the frictionless economy, which we take as a reference for the calibration of preferences and technological parameter values which are kept constants across countries. These parameters are calibrated to match data on the dynamics of firms and income inequality in the US, a relatively undistorted eocnomy. Then we introduce an extension with distortions and calibrate it using information from growth accelerations.

4.1 Consumption and Savings Problem

The assumption of perfect sharing of idiosyncratic risk allows us to separate the consumption/investment decision from the choices about occupations.

Taking wages and occupational choices as given, the household chooses consumption and investment in order to solve the following problem:

$$\max{}_{\{c_t, k_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}$$

subject to

$$c_t + k_{t+1} = w_t L_t^s + \Pi_t + (1 + r_t) k_t.$$

Aggregate labor supply and aggregate profits, L_t^s and Π_t respectively, are defined as follows:

$$L_t^s = \int (1 - o_t(z)) \, dM_t(z)$$

and

$$\Pi_t = \int o_t(z) \, \pi_t(z) \, dM_t(z)$$

where $o_t(z)$ is the outcome of the occupational choice of a household member with productivity z, being equal to 0 if she is a worker, and 1 is she is an entrepreneur; and $M_t(z)$ denotes the endogenous distribution of agents over productivity levels. All these objects will be characterized in detail below.

4.2 Occupational Choice

We assume that the head of household chooses occupations for its members every period. Furthermore, we assume that movements in and out of entrepreneurship are costless. Therefore, the decision to allocate an individual into working for a wage or becoming an entrepreneur amounts to comparing the values associated with each activity.

When selected into entrepreneurship, agents produce the final good combining their own idiosyncratic productivity, z, together with capital and labor into a Cobb-Douglas production function with decreasing returns to scale[8]:

$$y_t(z) = z^{(1-\alpha-\theta)} k_t(z)^{\alpha} \, l_t(z)^{\theta}$$

We assume that there are perfectly flexible labor and capital rental markets every period, so that both capital and labor can be adjusted freely in response to changes in aggregate or idiosyncratic conditions. It follows that capital and labor choices are determined by the following static maximization problem:

$$\pi_t(z) = \max{}_{l,k} \left\{ z^{(1-\alpha-\theta)} k^{\alpha} l^{\theta} - w_t l - (r_t + \delta) k \right\}$$

which yields the following expressions for optimal capital and labor demands:

$$l_t(z) = \left(\frac{\alpha}{r_t + \delta} \right)^{\frac{\alpha}{1-\alpha-\theta}} \left(\frac{\theta}{w_t} \right)^{\frac{1-\alpha}{1-\alpha-\theta}} z$$

$$k_t(z) = \left(\frac{\alpha}{r_t + \delta} \right)^{\frac{1-\theta}{1-\alpha-\theta}} \left(\frac{\theta}{w_t} \right)^{\frac{\theta}{1-\alpha-\theta}} z$$

The indirect profit function associated with optimal capital and labor demands is given by:

$$\pi_t(z) = \left(\frac{\alpha}{r_t + \delta} \right)^{\frac{\alpha}{1-\alpha-\theta}} \left(\frac{\theta}{w_t} \right)^{\frac{\theta}{1-\alpha-\theta}} (1 - \alpha - \theta) \, z$$

Besides production decisions, entrepreneurs make investments in innovation. We adopt a process of technology upgrading and downgrading similar to that in Atkeson

[8]The introduction of the productivity term raised to the $(1 - \alpha - \theta)$ power is a normalization that simplifies the description of the stochastic process for productivity. As we will show below, firms' capital and labor demands become proportional to z when productivity is introduced in this way in the production function. This allows us to map the space of productivity levels z directly into the space of labor and capital demands.

and Burstein (2010). Specifically, we assume that the growth rate of idiosyncratic productivity follows a simple binomail process, with an expected rate of growth that is determined by the firm's investments in innovation, and an exogenous standard deviation.

Let Δ denote the change in the logarithm of productivity that a firm can experience from one period to the other. Entrepreneurs use a research technology that yields a probability p of a technological upgrade (and probability $1-p$ of a downgrade) in return to investing $\chi(p,z)$ units of labor. We assume a convex function for the cost of innovation of the following form:

$$\chi_t(p,z) = z \times \mu\left(e^{\phi p} - 1\right)$$

Notice that the innovation cost is scaled by the current productivity of the entrepreneur. As we will explain below, this is an important assumption that allows the model to be consistent with innovation patterns of large firms in the U.S, which is our target economy for the calibration of parameters that are kept constant across economies. We will also explain the relevance of the scale parameter μ and the elasticity parameter ϕ to replicate of properties of the size distribution and firm life-cycle dynamics in the U.S.[9]

Taking capital and labor demands from the static profit maximization problem, entrepreneurs' innovation decision solves the following optimization problem:

$$\begin{aligned} v_t^E(z) &= max_p \Bigg\{ \pi_t(z) - w_t \chi(p,z) \\ &\quad + \left(\frac{1}{1+r_{t+1}}\right)\left[p v_{t+1}\left(z e^{\Delta}\right) + (1-p) v_{t+1}\left(z e^{-\Delta}\right)\right] \Bigg\} \end{aligned}$$

with $v_t^E(z)$ standing for the value of an entrepreneur with productivity z in period t, and $v_t(z)$ denoting the value of an individual in period t with productivity z, facing the decision to become an entrepreneur or working for a wage. We will come back to this value below, once we characterize the value of a worker.

Unlike entrepreneurs, we abstract from modeling workers' efforts and investments in developing entrepreneurial ability. We assume that while working for a wage, agents

[9] The process for idiosyncratic productivity can be interpreted as a binomial approximation to a geometric Brownian motion, with an exogenous standard deviation Δ, and endogenous drift $(2p_t(z) - 1)\Delta$.

get a random draw of entrepreneurial ability from a known stationary distribution $F(z)$ that they can exploit the following period if they find it profitable to do so. In particular, we assume that an individual in the labor force with current entrepreneurial ability z gets to keep it for the following period with probability ψ, and gets a random draw from the distribution $F(z)$ with probability $(1-\psi)$. The same process governs the evolution of entrepreneurial ability of agents that join the labor force after having exited from operating a business. These agents will keep their accumulated stock of knowledge with probability ψ, and will get random draws with probability $(1-\psi)$.

Our probabilistic representation of the arrival of entrepreneurial ideas among workers allow us to be consistent with two key properties about the behavior of entrants in the data: 1) the rate of establishment entry and exit, and 2) the average size of entrants relative to incumbents. We will see below that consistency with these facts is important for the properties of firm's life-cycle dynamics, and for shaping the responses to reforms.

It follows from the above that the value of a worker is simply defined by the wage rate in the period, plus the discounted expected value of resetting occupations in the following period:

$$v_t^{\omega}(z) = w_t + \left(\frac{1}{1+r_{t+1}}\right)\left[\psi v_{t+1}(z) + (1-\psi)\int v_{t+1}(z')\,dF(z')\right]$$

with the value of an agent before making an occupational choice given by

$$v_t(z) = \max{}_{o_t(z)} o_t(z)\, v_t^E(z) + (1-o_t(z))\, v_t^{\omega}(z)\,.$$

4.2.1 Aggregation and Definition of Equilibrium

At any given point in time, all individuals in the economy will be distributed over the space of entrepreneurial productivities. We denote the fraction of individuals with productivity less than or equal to z with $M_t(z)$. We need to characterize the evolution of this distribution in order to be able to aggregate individual decisions and compute equilibrium prices.

Say we start with a given distribution $M_t(z)$ at the beginning of period t. Entrepreneurs move across productivity levels in accordance to their innovation decisions, while workers do so in response to the stochastic process of productivity. Combining these processes leads to the following law of motion for the distribution of agents across productivity levels:

$$
\begin{aligned}
M_{t+1}(z) \quad = \quad & M_t(z) + \int_z^{ze^{\Delta}} (1 - p_t(x))\, o_t(x)\, dM_t(x) - \int_{ze^{-\Delta}}^{z} p_t(x)\, o_t(x)\, dM_t(x) \\
& - (1-\psi) \int_0^z (1 - o_t(x))\, dM_t(x) \\
& + (1-\psi) F(z) \int_0^{\infty} (1 - o_t(x))\, dM_t(x) \qquad (4.1)
\end{aligned}
$$

The second two terms refer to the individuals that worked as entrepreneurs in period t and transition to (remain in) the set with productivity in $[0, z]$ after a period. Those with productivity level $x \in \left(z, ze^{\Delta}\right]$ downgrade to $xe^{-\Delta} < z$ with probability $1 - p_t(x)$, and those with productivity level $x \in \left(ze^{-\Delta}, z\right]$ upgrade to $xe^{\Delta} > z$ with probability $p_t(x)$. The last two terms refer to workers. A fraction $1 - \psi$ of workers with ability less than z get a new productivity. Among all the workers that get a new productivity, a fraction $(1 - \psi)F(z)$ have a new draw less than or equal to z.

A *competitive equilibrium* in this economy is given by sequences of choices by the head of the household $\{c_t, k_{t+1}, o_t(z)\}_{t=0}^{\infty}$; sequences of entrepreneurs' decisions $\{l_t(z), k_t(z), p_t(z)\}$; sequences of interest rates and wage rates $\{r_t, w_t\}$; and a distribution of agents over productivities $\{M_t(z)\}$; such that given an initial capital stock K_0 and a given distribution of talent draws for workers $F(z)$, household's and firm's decision solve their dynamic optimization problems and capital and labor markets clear

$$
\int \left[l_t(z) + z\mu e^{\phi p_t(z)}\right] o_t(z)\, dM_t(z) = \int (1 - o_t(z))\, dM_t(z)
$$

and

$$
\int k_t(z)\, o_t(z)\, dM_t(z) = K_t,
$$

and the distribution of entrepreneurial productivity evolves according to (4.1).

Similarly, a *long run equilibrium* of this economy is one where individual decisions, aggregate quantities, and prices are constant, and the distribution of productivities is stationary.

Output and Productivity A well known property of our model with decreasing returns to scale and frictionless factor markets is that the production side of the economy aggregates into the following aggregate production function:

$$Y_t = \left[\int o_t(z)\, z dM_t(z)\right]^{(1-\alpha-\theta)} (K_t^s)^{\alpha} \left(L_{p,t}^s\right)^{\theta}$$

where $L_{p,t}$ stands for aggregate labor demand for the production of the final good only:

$$L_{p,t} = \int l_t(z)\, o_t(z)\, dM_t(z)$$

Measured TFP, in turn, can be computed from the following expression:

$$\begin{aligned} TFP_t &= \left[\int o_t(z)\, z dM_t(z)\right]^{(1-\alpha-\theta)} \left(L_{p,t}^s\right)^{\theta} \\ &= \left[\frac{\int o_t(z)\, z dM_t(z)}{\int o_t(z)\, dM_t(z)}\right]^{(1-\alpha-\theta)} \left(\int o_t(z)\, dM_t(z)\right)^{1-\alpha-\theta} \left(L_{p,t}^s\right)^{\theta}. \end{aligned}$$

Notice that we have made an adjustment to our measure of TFP_t so as to make it comparable with that in income accounting studies. The expression reflects the fact that output is deflated using the entire labor force, which has a unit measure, regardless of occupation, while in the model only a subset of the agents are involved in the production of goods. The other fraction, workers in innovation, make intangible contributions that we assume go unmeasured in GDP.

4.3 Introducing Distortions

The goal of the paper is to study transitions from low to high levels of economic development. To do this, we first need to take a stand about the forces that drag on economic development in the initial allocation and the changes in the economic environment that reverse them. Motivated by the empirical literature on misallocation, our approach is to give a prominent role to allocative distortions in understanding the former and to interpret the latter as an outcome of reforms that liberalize the economy from these distortions. A second decision we need to make refers to the specific type of distortions that we shall feed into the model in order to generate allocations similar to those of acceleration economies prior to take-off and resembling those of communist regimes. Lastly, we must identify a strategy to discipline the parameterization of these distortions from the data.

We interpret the initial condition of an economy prior to engaging in an acceleration episode as an equilibrium in which factors of production are misallocated across firms due to distortions in the labor, capital, and product markets. The burgeoning literature that we summarized in Section 2 provides robust evidence about the pervasiveness of resource misallocation in under-developed countries. To fully account for this feature, we introduce a distribution of idiosyncratic wedges that we calibrate to replicate properties of the distribution of wedges in the data. That is, we do not take a stand on what the specific frictions are, whether they operate more predominantly through labor, capital, or product markets, but we rather follow the tradition of the literature in modeling the distortion in reduced form, through a productivity-dependent revenue tax. We calibrate them to reflect the degree of misallocation that we observe in economies before taking off.

Constructing an initial allocation representing a communist regime is more challenging given the inherent differences in the process of decision making in central planning economies relative to a market economy. Given our goal of understanding successful transitions *out* from communism, we side-step this difficulty by focusing on recreating an allocation that resembles that of a communist regime within the context of a market economy with distortions, rather than doing so within a fully-specified model of the political economy of a communist regime.

There are three distinguishing features of a centrally planned economy that we take into account when constructing a communist allocation: apprehension towards income inequality, misallocation of production factors across production units, and limits to private entrepreneurial initiatives. The first and the last ones follow almost by definition, while the second one is a manifestation of the distortions to management practices and production goals from the central planning authorities[10]. The joint consideration of these features, which are essential in accounting for the differences in the size distribution of firms between acceleration and post-communist economies that we documented in an earlier section, requires that we complement the misallocation frictions with a second distortion that discourages inequality and distorts entry. We show below that a parsimonious mechanism to achieve this is by feeding a profile of progressive taxes to the profits of the firms net of innovation costs.

Formally, let $\tau_t(z)$ and $\tau_t^{\pi}(z)$ denote the revenue and profit tax rates corresponding to a firm with productivity z in period t. Then, the revenue and profit tax schedules

[10]See Roland (2000), chapter 1, for a detailed explanation of the organization of production and exchange by the central administration, and for a description of how these production plans interfered with managerial incentives to operate firms efficiently.

are related to physical productivity in the following fashion:

$$[1-\tau_t(z)] = \left(\frac{z}{z_{I,t}}\right)^{-\upsilon_t(1-\alpha-\theta)} \tag{4.2}$$

$$[1-\tau_t^{\pi}(z)] = \tau_t^{\pi}(0)\, z^{-\xi_t(1-\alpha-\theta)} \tag{4.3}$$

The slope parameter in the misallocation schedule υ_t controls the degree of linear relationship between the logarithm of the marginal revenue product of the firm $(TFPR)$ and the logarithm of physical productivity $(TFPQ)$. As explained in greater detail in the calibration section, we appeal to Chilean and Chinese estimates for the regression coefficient between these variables to discipline its parameterization. The productivity index $z_{I,t}^{(1-\alpha-\theta)}$ separates firms into those that get a revenue subsidy from those that get a revenue tax. It is easy to show that flat revenue taxes have a neutral effect on aggregate productivity, so its introduction is innocuous for labor, capital, innovation, and occupational allocations. However, z_I is useful since it gives us a degree of freedom to neutralize secondary effects of distortions on the investment to output ratio in the model.

In terms of the profit tax schedule, the key elements are the parameter determining its degree of progressivity ξ_t and the flat component $\tau_t^{\pi}(0)$. It can be shown that unlike a flat revenue tax, a flat profit tax has a direct effect on occupational choices, innovation, and, thereby, the average size of a firm. We appeal to data on the latter for former communist countries to determine its value in the quantitative analysis.

We now turn to incorporating the profit and revenue taxes into the optimization problems of the agents. Consider first the value of an entrepreneur with productivity z and associated revenue and profit taxes $\tau_t(z)$ and $\tau_t^{\pi}(z)$. This is given by the following expression:

$$v_t^E(z) = max_{p_t}\left\{\begin{array}{c} [1-\tau_t^{\pi}(z)]\,\pi_t(z,\tau_t(z);w_t,r_t) - w_t\chi_t(p,z) \\ +\left(\frac{1}{1+r_t}\right)\left[p_t v_{t+1}\left(ze^{\Delta}\right) + (1-p_t)\, v_{t+1}\left(ze^{-\Delta}\right)\right] \end{array}\right\} \tag{4.4}$$

Profit taxes have a direct effect on the firm's incentives to innovate but have no implication for the entrepreneur's choice of labor and capital demands. Revenue taxes, on the other hand, do interfere with factor demand and profitability, as reflected in the firm's static profit maximization problem:

$$\pi_t\left(z,\tau_t\left(z\right);w,r\right)=\max{}_{l_t(z),k_t(z)}\left\{\left(1-\tau_t\left(z\right)\right)z^{(1-\alpha-\theta)}k_t^{\alpha}l_t^{\theta}-w_tl-\left(r_t+\delta\right)k\right\}$$

$$l_t\left(z\right)=\left(\frac{\alpha}{r_t+\delta}\right)^{\frac{\alpha}{1-\alpha-\theta}}\left(\frac{\theta}{w_t}\right)^{\frac{1-\alpha}{1-\alpha-\theta}}z\left[1-\tau_t\left(z\right)\right]^{\frac{1}{1-\alpha-\theta}}$$

$$k_t\left(z\right)=\left(\frac{\alpha}{r_t+\delta}\right)^{\frac{1-\theta}{1-\alpha-\theta}}\left(\frac{\theta}{w_t}\right)^{\frac{\theta}{1-\alpha-\theta}}z\left[1-\tau_t\left(z\right)\right]^{\frac{1}{1-\alpha-\theta}}$$

$$\pi_t\left(z,\tau_t\left(z\right);w,r\right)=\left(\frac{\alpha}{r_t+\delta}\right)^{\frac{\alpha}{1-\alpha-\theta}}\left(\frac{\theta}{w_t}\right)^{\frac{\theta}{1-\alpha-\theta}}\left(1-\alpha-\theta\right)z\left[1-\tau_t\left(z\right)\right]^{\frac{1}{1-\alpha-\theta}}$$

A feature of the value of entrepreneurship worth highlighting is that profit taxes affect the operating profits of the entrepreneur gross of the expenditure on innovation. In the context of the theory, this assumption is necessary in order to ensure that the profit tax indeed distorts the innovation decision of the entrepreneur. To the extent that the profit taxes are intended to capture the distortions to managers' incentives to invest in technology under a communist regime, it is necessary that these taxes have a non-neutral effect over the rate of return to innovation relative to the marginal cost of innovation expenses. It is to accomplish this goal that we set the tax to affect operating profits gross of innovation expenses.

We conclude the section by presenting the definitions of aggregate output and productivity in the version of the economy with distortions:

$$Y_t=\frac{\left[\int z\left(1-\tau\left(z\right)\right)^{\frac{\alpha+\theta}{1-\alpha-\theta}}o_t\left(z\right)dM_t\left(z\right)\right]}{\left[\int z\left(1-\tau\left(z\right)\right)^{\frac{1}{1-\alpha-\theta}}o_t\left(z\right)dM_t\left(z\right)\right]^{\alpha+\theta}}\left(K_t^s\right)^{\alpha}\left(L_{p,t}^s\right)^{\theta}\tag{4.5}$$

and

$$TFP=\frac{\left[\int z\left(1-\tau\left(z\right)\right)^{\frac{\alpha+\theta}{1-\alpha-\theta}}o_t\left(z\right)dM_t\left(z\right)\right]}{\left[\int z\left(1-\tau\left(z\right)\right)^{\frac{1}{1-\alpha-\theta}}o_t\left(z\right)dM_t\left(z\right)\right]^{\alpha+\theta}}\left(L_{p,t}^s\right)^{\theta}\tag{4.6}$$

The misallocation effect of revenue taxes is manifested in the aggregation of individual productivities, which now reflects the inefficiency in the distribution of capital and labor across producers. The dynamic effects of revenue and profit taxes, which operate through distortions to innovation, are captured in the distribution of firms across productivity levels $M_t\left(z\right)$.

5 Quantitative Exploration

In this section we start with the quantitative exploration of our theory. Our first set of results pertain to the long run properties of the model economy and its ability to replicate macro and firm level features of countries before growth accelerations and while under communism. Some of these features, such as the relative average firm size, will be replicated as part of the calibration strategy while others, such as the life-cycle dynamics of firms, will be used as tests of the internal mechanics of the model. In the case of the communist allocation, we offer a decomposition of the results isolating the contribution from each of the two types of distortions at play.

Then we turn to the main focus of the paper, the analysis of transitions. We model accelerations triggered by a reform that smoothly dismantles allocative distortions. We appeal to time series data for the evolution of misallocation around the reform years in Chile to discipline the path of reforms. For post-communist transitions, we assume that communist features (i.e. the profit taxes) are withdrawn once and for all, while we assume, as with Chile, a smooth reversal of misallocation taxes disciplined by time series summary statistics of misallocation in China.

5.1 Calibration

Parameters related to technology, shocks, and preferences will be calibrated to match features of the US, a relatively undistorted economy, while distortions will be disciplined by Chilean and Chinese firm-level data.

5.1.1 Parameters Common Across Economies

There are 7 parameters that remain invariant across the types of economies that we consider: the coefficient of relative risk aversion σ, the labor and capital shares in production α and θ, the subjective discount factor β, the scale and the convexity parameters in the innovation cost function μ and ϕ, and the capital depreciation rate δ. In addition, we must specify and parameterize the distribution of entrepreneurial ability types among workers.

For the coefficient of relative risk aversion, we set $\sigma = 1.5$, which is standard in the macroeconomics literature. We set $\beta = 1/(1 + 0.04)$, to target a 4% yearly interest rate, and set the annual capital depreciation rate at $\delta = 0.06$. In terms of factor shares in the production technologies, given a value of the span of control $1-\alpha-\theta$, we calibrate

$\alpha/(\alpha+\theta) = 1/3$, so that 1/3 of the income going to non-entrepreneurial factors is paid to to capital.

The span of control $\alpha+\theta$ is calibrated jointly with the parameters of the innovation cost function, μ and ϕ, and the innovation step Δ, to match the concentration of earnings in the top 1% of the population, the employment share in the top 10% of the firm size distribution, the average employment ratio between firms aged 21-25 to 1 year old, and the log dispersion of the distribution of employment growth rates for large firms. Finally, we assume that the distribution of entrepreneurial abilities is Pareto, with a productivity lower bound equal to one and a tail parameter η that we calibrate to match the ratio between the average employment of entrants relative to the average employment of incumbents. This strategy leads to the following parameter values:

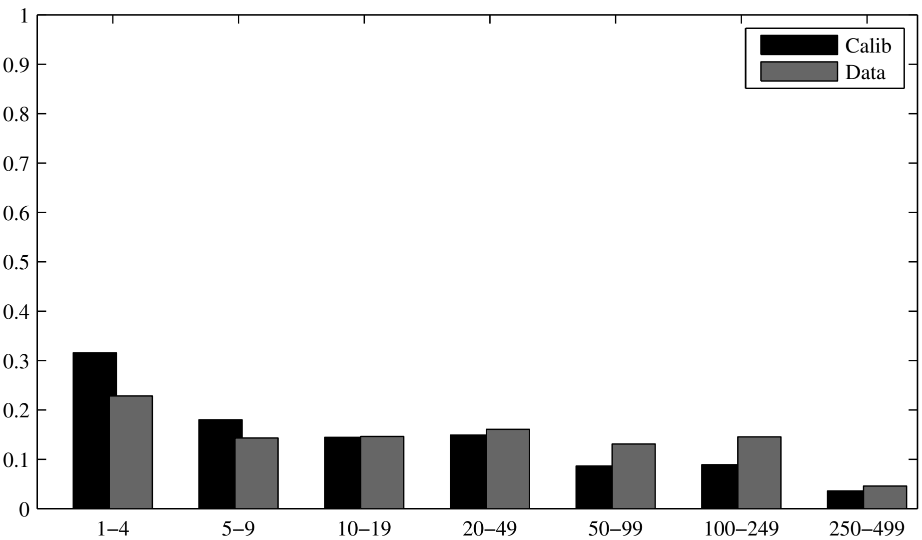
Table 1: Calibration of Common Parameters across Economies

	US data	Model	Parameter
Top 1 % Earnings Share	18.5%	18.5%	$\alpha+\theta = 0.71$
Top 10% Employment Share	0.76	0.77	$\mu = 4.8e-05$
Employment Age 21-25 relative to Age 1	3.95	3.83	$\phi = 10$
Std Dev. Employment Growth rate	0.25	0.25	$\Delta = 0.25$
Empl. Ratio Entrants to Incumbents	18.9%	18.9%	$\eta = 4.46$

Note: Top 1% earnings share for the US is taken from Kuhn and Rios-Rull (2015) We report the average of the top 1% earnings share between 2007 and 2013. The top 10% employment share, the average employment ratio between 21-25 and 1 year old firms, and the average employment ratio between entrants and incumbents were computed from Business Dynamics Statistics database for the year 2007. Numbers are for the manufacturing sector. Standard deviation of employment growth rates for large firms are reported in Atkeson and Burstein (2010).

Besides calibrating the shape parameter η to match moments of the size distribution of entrants in the data, we can further explore the goodness of fit of the Pareto assumption by comparing the entire employment size distribution of entrants with the data. We plot the employment-weighted distribution of entrants in figure 5.1.

Figure 5.1: Employment Weighted Size Distribution of Entrants: Model and Data



Note: The data corresponds to the employment-weighted distribution of firm sizes from the Business Dynamics Statistics database for the manufacturing sector in 2007. The unit of analysis are firms, and entrants are identified as firms with age equal to zero. Data points for firms with employment greater than 499 are undisclosed in the database.

The figure shows that while the Pareto distribution tracks closely the empirical distribution of entrants, it slightly under-predicts the shares towards the right tail of the distribution. There are two features of the equilibrium that are affected by the properties of the size distribution of entrants: the dynamics of employment over the life-cycle and the speed of convergence along transitional dynamics. Since large firms innovate more intensively, a smaller share at the top decreases the speed of employment growth over the life-cycle conditional on survival, and delays the speed of convergence. We experimented with a Log-Normal distribution, and found that aggregate and micro-level implications are largely unaffected once parameter values are re-calibrated to satisfy the empirical targets, specially the ones referring to the average size of entrants relative to incumbents and the employment ratio between 21-25 and 1 year old firms.

A feature of the calibration that is worth exploring further is the parameterization of the innovation cost function. Those parameters were calibrated to target the share of employment at the top of the US firm size distribution and, due to data availability, a particular data point in the life-cycle employment dynamics of a cohort of entrants. Hsieh and Klenow (2014), however, offer a description of the entire employment age profile for the US manufacturing sector against which we can further validate the life-cycle implications of the model.[11] Although we explore the model's implications for the evolution of employment size over the life-cycle in more depth once we get to the quantitative analysis, we can look ahead to figure 5.4 and evaluate the implications of the calibration along this dimension. Focusing on the line corresponding to the frictionless economy, we see that the model does a reasonable job at reproducing the life-cycle dynamics of firms in the data[12].

5.1.2 Parameterizing Distortions

We now turn to the discussion of our calibration strategy for the parameter values governing the distribution of distortions. Both the pre-acceleration equilibrium and the communist allocation are affected by factor misallocation and distortions to the selection of agents into entrepreneurial activity, so we need two targets for the relationship between revenue distortions and productivity in the model and for the flat component of the profit tax schedule. Furthermore, our representation of the communist regime requires that we identify a target for the degree of progressivity in the taxation of entrepreneurial earnings. Lastly, we must identify a strategy to discipline the speed of reversal of the distortions, which is the definition of reform that triggers a transition path in the model.

In terms of the initial level and the path of reversal of misallocation frictions, we appeal to time series data for the regression coefficient between the logarithm of TFPR, which captures distortions, and the logarithm of TFPQ, which stands for the physical productivity of the firms. Despite the lack of publicly accessible datasets that allow for these calculations, we were able to assemble a time series of these objects for two countries in the acceleration and post-commust groups: Chile and China. The quantification of the flat component of the profit tax, on the other hand, is disciplined to match the ratio between the average firm size of manufacturing firms in Chile and China with respect to USA respectively.

Regarding Chile, the data to calibrate revenue distortions comes from Chen and

[11]Our empirical reference comes from Hsieh and Klenow (2014), figure 1.

[12]Luttmer (2010) discusses the life-cycle properties of models with stochastic properties calibrated to match features of the firm size distribution, and argues that these models tend to predict implausibly slow life-cycle dynamics. One feature of our theory that allows us to circumvent this shortcoming is that we work with a theory of entry based on occupational choice, which generates a distribution of entrants arriving to entrepreneurship from an entire distribution. This contributes to the life-cycle growth of the entering cohort by exhibiting more selection over time, and by having firms already at the top of the size distribution and hence innovating at higher pace.

Irarrazabal (2014), who study the evolution of allocative efficiency between 1980 and 1996. The authors report the regression coefficient between the logarithm of TFPR and the logarithm of TFPQ across firms for each year between 1980 and 1996, appealing to Chile's manufacturing census covering all firms with 10 or more employees. We take the value of this coefficient in 1980 as the parameter value for the schedule of distortions that characterizes the initial steady state representing Chile in the model. This year preceeds the 1982 debt crisis and the start of the growth acceleration which is dated to be in 1985.

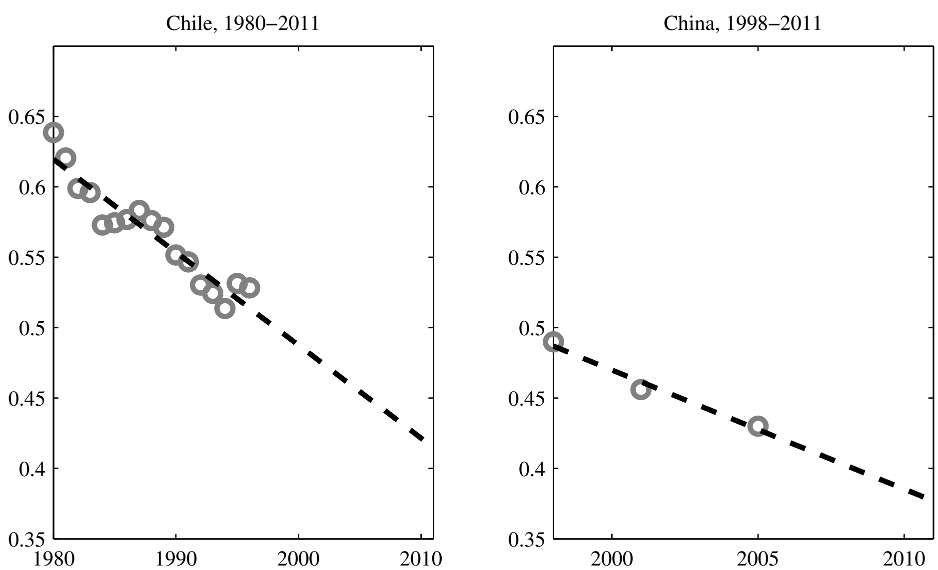
Our strategy to calibrate the flat component of profit taxes is to require that the calibrated initial condition is consistent with the observed differences in average firm size between Chile at the onset of the reforms and the reference frictionless economy, the USA. Since the Chilean data is a census of manufacturing firms with employment greater than or equal to 10 workers, we construct the USA manufacturing counterpart conditioning also on this size cutoff. This leaves us with a relative average firm size of 0.44, resulting from an average of 52 workers in Chile in 1980 and 118 workers in the USA in 2007. The required value of the flat profit tax to achieve this ratio in the model is $\tau^{\pi}_{1980}(0) = 0.941$. We keep the value of this tax fixed throughout the reform years in Chile in order to focus, in a transparent fashion, on the effect of allocative distortions. As we explain below, the steeper increase in the observed dynamics of average size in Chile relative to what can be accounted for by the model from dismantling revenue distortions is suggestive of a worsening, rather than an improvement, of the entry conditions in the Chile during the liberalization years.

In terms of the dynamics of the distortion parameter along the reform path, we use the observed improvement in the degree of misallocation in the Chilean economy to discipline a path of reversal of allocative frictions in the model. From the Penn World Tables version 8.1, which is our data source for the cross country analysis of accelerations and post-communist dynamics, we can gather aggregate data up until the year 2011. Since we only have actual data about the evolution of the regression coefficient for the years between 1980 and 1996, we fit a linear trend to this data and come up with a forecast for the regression coefficients for the remaining years between 1996 and 2011. In this way, we are interpreting Chile's trend dynamics between 1980 and 2011 as resulting from a linear process of dismantlement of distortion that makes the economy transition from an initial steady state with the distortions observed in 1980 to a steady state exhibiting the degree of distortions implied by our forecast for 2011.

We proceed in similar fashion in disciplining the initial, terminal, and transitional levels of distortions in China. Our data source in this case is Hsieh and Klenow (2007), who report regression coefficients between the objects of interest for the years 1998, 2001, and 2005. As we did with Chile, we use these three data points to construct a forecast of evolution of the coefficient for the remaining years between 1998 and 2005 and moving forward to 2011. Like before, the interpretation that we are giving to China's trend dynamics between 1998 and 2011 is that of a transitional path resulting from a linear process of dismantlement of allocative distortions and profit taxes (in this case, yet to be specified) to a stationary allocation featuring the degree of misallocation we forecast for 2011, and a schedule of profit taxes that we specify below.

We present the dynamics of misallocation frictions for Chile and China, $\left\{\nu_t^{Chile}, \nu_t^{China}\right\}$, in figure 5.2. The left panel illustrates the dynamics of the elasticity between the logarithm of TFPR and the logarithm of TFPQ between 1980 and 1996 (dots) together with our fitted estimate for the extended period until 2011 (solid line). The right panel illustrates the same objects for China, between 1998 and 2011.

Figure 5.2: Misallocation Frictions Chile 1980-2011 and China 1998-2011



Note: The plots reproduce the evolution of the coefficient of regression between $log\,(TFPR_i)$ and $log(TFPQ_i)$ for repeated cross sections in Chile and China. Data points come from Chen and Irarrazabal (2014) and Hsieh and Klenow (2007) for the case of Chile and China respectively. The dashed line results from fitting a linear trend to the data points.

A last feature regarding the parameterization of the path of allocative distortions refers to the scaling parameter $Z_{I,t}$. We have a clear disciplining target for its value in the initial and terminal steady states, since we are introducing this degree of freedom to neutralize any effect of distortions on the capital to output ratio in the long run. However, we have no clear target for its parametrization along the transition. Absent a clear best practice, we proceed as with the parameterization of the slope parameter. That is, we fit a linear trend between the initial and terminal values and use it to predict values for every period in between.

It remains to specify a strategy to pin down parameters governing the profile of profit taxes in the communist allocation. As argued above, we appeal to this instrument to introduce communist features into the model. To capture the egalitarian natures of these regimes, we set the slope parameter in the profit tax schedule to $\xi_t = 0.9$.

Both this parameterization and the calibration of misallocation frictions create a strong depressing force over the average firm size in the economy. This prediction is opposition to the fact documented earlier that firms are relatively larger on average in communist regimes. Thus, to remedy this feature, we appeal to the scale parameter $\tau_t^{\pi}(0)$ in the profit tax function. This parameter governs the scale of the profit taxation scheme, and is primarily intended to capture distortions to entry into entrepreneurship. Even though $\tau_t^{\pi}(0)$ also contributes to discouraging innovation, this effect is dominated by the progressivity of the profit and revenue taxes. The major contribution of $\tau_t^{\pi}(0)$ is to discourage entry and to increase the average firm size. We calibrate this parameter to target the ratio between the average size of firms in China in 1996 with respect to the US, which we find to be equal to 3.01. This gives a parameter value of $\tau_0^{\pi}(0) = 0.9$.

Having specified a strategy to characterize a communist stationary allocation, we move on to describing the behavior of the economy during the liberalization. We model post-communist transitions as a process of transformation in which countries completely and permanently liberalize communist elements in the environment and ignite a transition with distorted but steadily improving product and factor markets. In terms of the evolution of parameters of distortions in the model, we are assuming that $\xi_t = 0$ and $\tau_t^{\pi}(0) = 0$ for all t after liberalization, while ν_t^{China} evolves according to the right panel in figure 5.2.

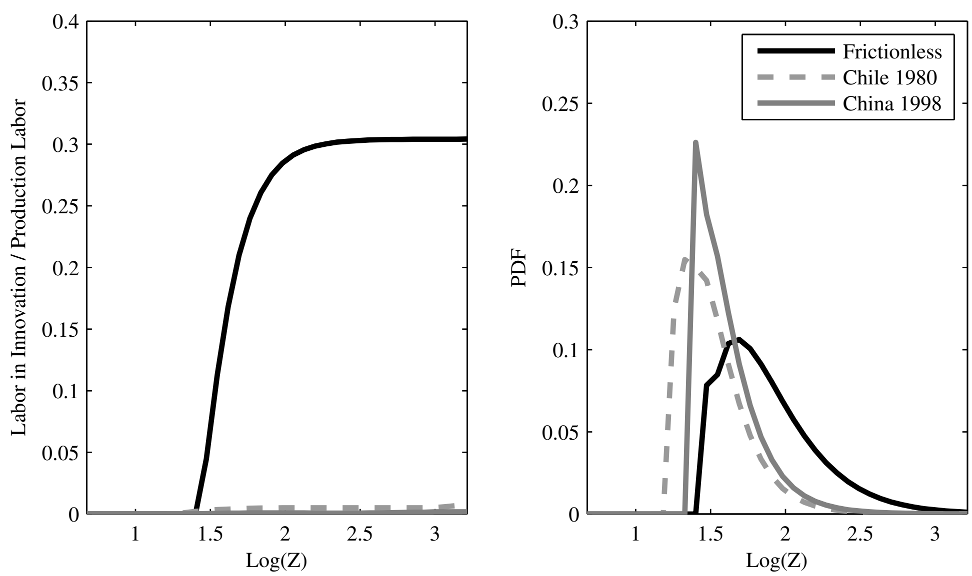
5.2 Long Run Analysis

We start with the exploration of the long run implications of distortions in the model. Firstly, we explore micro-implications, such as changes in innovation expenditures, the productivity distribution of firms, and the dynamics of employment over the firms' life-cycle. Then, we move on to exploring macroeconomic outcomes, emphasizing the effects on GDP, TFP, entrepreneurship rates, and average firm size.

5.2.1 Micro-Implications

The following figure illustrates the implications of the theory with respect to the profile of innovation intensities as a function of firm productivity and the resulting equilibrium distribution of firms. The left panel shows the ratio of employment in innovation activities relative to the labor demanded in production for three stationary equilibria of the model: the frictionless, the distorted one calibrated to Chile in 1980, and the distorted one calibrated to China in 1998. The right panel plots the corresponding productivity distributions.

Figure 5.3: Innovation Profiles and the Productivity Distribution of Firms



One salient feature of the profile of innovation intensities is that, in accordance with Gibralt's law, the share of labor devoted to innovation in large firms is independent of productivity, and hence size, in the frictionless economy. This is not surprising, since it is precisely the goal we sought to achieve by scaling the innovation cost function by the firm's productivity. The independence between firm growth and firm size does not hold for entrepreneurial abilities that are close to the exit cutoff, a region in which innovation intensities are lower and increasing in a firm's productivity. For entrepreneurs that are close to the cutoff, the rate of return to innovation is challenged by the value of selecting into the labor force, which gives the agent the opportunity to work for a period and get a new entrepreneurial ability from the entrant's distribution in the following period.

Innovation patterns and occupational choices are notably different depending on the type of distortions affecting the economy. With misallocation frictions only, calibrated to Chile in 1980, the structure of subsidization and taxation is such that it encourages entrepreneurship among the lowest productivity types in the population. This can be seen by the set of productivities for which innovation intensity was equal to zero in the frictionless economy but has a positive value in the distorted one.

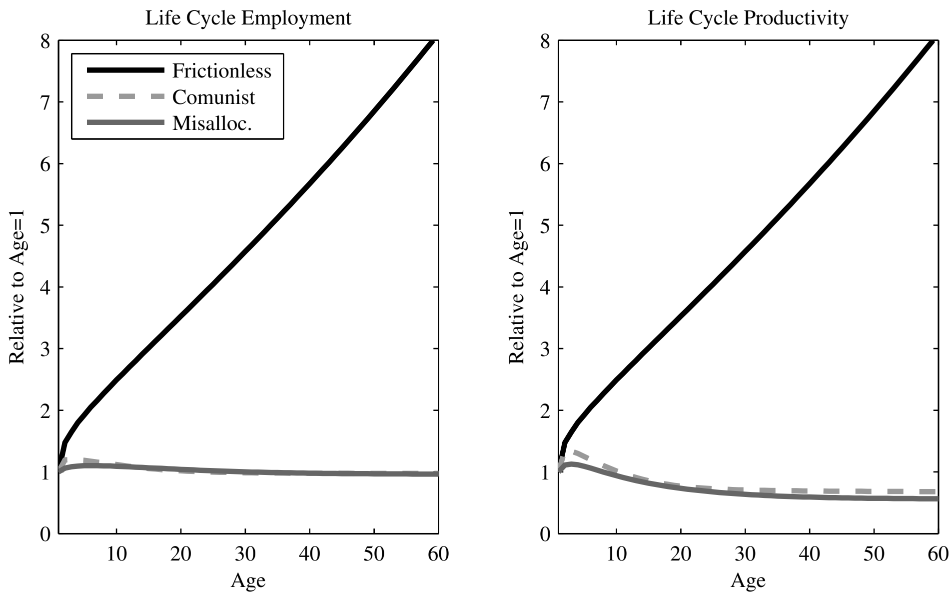
Innovation decisions are also heavily distorted in both economies. The increasing nature of revenue and profit taxes hinders the rate of return to innovation relative to the marginal cost, so innovation intensities decline in all levels of productivity. Furthermore, through a general equilibium effect, the flat component of the profit tax schedule also magnifies the disincentives to innovate. This effect arises because, given prices, profit taxes have no effect over the demands for labor and capital across firms, yet profit taxes discourage entrepreneurship and increases the supply

Innovation decisions are also heavily distorted. Because the revenue tax rates are increasing in productivity, the rate of return to innovation expenditures is hindered relative to the marginal cost, which remains unaffected by the idiosyncratic distortion. The result is that innovation declines in all ability levels except those that are new to entrepreneurial activity. In China, the disincentives to innovate are magnified by the combination of misallocation frictions with progressive profit taxes, bringing the innovation intensities almost all the way to zero for every type of firm in the economy.

The distortionary effect of distortions on innovation and occupational choices manifests in the distribution of firms across productivity levels (right panel). In Chile in 1980, there are a larger fraction of firms in the lower end of the entrepreneurial ability spectrum and the whole distribution is shifted to the left relative to the frictionless case. In China in 1998, the flat component of the profit tax profile counteracts this force so we do not obtain a magnification of the left tail. Combined with virtually no innovation across firms, the distribution is concentrated closer to the exit cutoff.

A second dimension along which we can evaluate the micro-implications of the model is with respect to the life-cycle dynamics of employment and productivity. This is an interesting dimension since there are concrete empirical references in the literature against which to compare the predictions of the theory. Hsieh and Klenow (2014), for example, document a notable flatness in the behavior of employment and physical productivity across firms of different ages in Mexico and India relative to the US. A similar conclusion, albeit less dramatic, is reached by Ayyagari et.al. (2013) for a larger sample of developing and low income countries. We plot the model counterparts of these objects in figure 5.4.

Figure 5.4: Life Cycle of Employment and Productivity



The left panel of the figure illustrates employment over the life-cycle, while the right panel illustrates productivity. The frictionless economy shows that the calibration of the innovation cost parameters and the choice of a Pareto distribution of entrants delivers a reasonable match between the life-cycle evolution of employment in the model and in the data. In Hsieh and Klenow (2014), a typical 20 year old US firm is more than twice as large as the group of firms between the ages of 1 and 5, and is almost 5 times larger by the age of 39. A similar growth is experienced by a typical cohort of entrants in the frictionless model. The distortions underlying the model's equilibrium for Chile 1980 and China 1998, on the other hand, generate a substantially flatter pattern of employment and productivity growth over the life cycle, which is consistent with the findings from Hsieh and Klenow (2014) and Ayyagari et.al (2013).

In summary, we have characterized the micro-implications of allocative distortions and profit taxes in our theory and we have described how they map into observable empirical counterparts. The next goal is to assess the aggregate implications of these firm level responses.

5.2.2 Aggregate Implications

Having characterized the implications of distortions for firm-level decisions we now focus on the ability of the economies with distortions to account for the income and productivity gaps that were observed in acceleration and communist economies relative to the US prior to the reforms.

To do so, we compute the ratio between the variables of interest in the calibrated economies of Chile in 1980 and China in 1998 relative to their values in the frictionless allocation. Since there are the two distortions at play, we complement the analysis turning off the profit taxes and considering misallocation frictions only. The goal is to understand the interaction between the two.

Table 2: Steady State Analysis: Chile 1980 and China 1998 vs Frictionless

	Pre-Acceleration (Chile 1980)		Communist (China 1998)		
	Benchmark	Misallocation Only	Benchmark	Misallocation Only	Misallocation & Flat Profit Taxes
GDP	0.46	0.63	0.4	0.7	0.54
TFP	0.56	0.71	0.5	0.76	0.62
TFP dynamic	0.68	0.79	0.59	0.8	0.71
Entrepreneurs (difference)	-0.001	0.22	-0.014	0.19	0.008
Av. Size	0.44 ($L \geq 10$)	0.14	3.10	0.11	0.97
Wage	0.36	0.69	0.30	0.78	0.42

The combination of the calibrated distortions for Chile in 1980 are capable of generating a TFP contraction of 44% and a decline in output of 54%. The average firm size, conditional on firms being larger than or equal to ten workers, declines to a value of 0.44 which is the magnitude with targeted when calibrating the flat profit tax distortion. A comparison between the first two columns allows us to appreciate the importance of the profit distortion in helping achieve the desired reduction in the average firm size conditional on ten workers or more. With misallocation frictions only, the average firm in Chile would have been only 14% of the size of the corresponding firm in the US, while TFP would have contracted by 30%. The number of entrepreneurs shows that the key mechanism through which the profit tax helps to preserve the average firm size is by limiting the increase in entrepreneurship that is induced by the structure of subsidization and taxation inherent in the distribution of revenue distortions.

The combination of allocative distortions and progressive profit taxes in China, used to capture incentives in a communist regime, magnifies the decline in output and productivity, reaching almost 60% for the former and 50% for the latter. The two distortions reinforce each other in discouraging innovation, which results in a stronger decline in productivity and output. Furthermore, as anticipated in the calibration, the flat component of the profit tax profile reverses the depressing forces of the misallocation frictions over the average size, generating an increase in the average size of 3.3 times the size in the undistorted allocation, which is the factor of increase we targeted in the calibration.

The third column shows that had misallocation frictions been the only distortion in the communist regime, the reduction in output and productivity would have been less than half of what they were in the benchmark. This suggests that the barriers to entrepreneurship and apprehension to income inequality represented in the profit tax schedule are a fundamental ingredient of communist regimes that help understand the sources of their development and technological gaps. Furthermore, the last two columns already hint at a non-trivial behavior of the firm size distribution along the transitional path. On one hand, the removal of profit taxes pushes the average firm size downwards, while the reversal of misallocation generates the opposite effect. Which of these forces prevails in the model's dynamics will be important for its ability to replicate the dynamics of the average firm size in post-communist transitions.

The steady state analysis gives us an idea of the type of adjustment that would have to take place along a full transition path to development. The economies have to close significant development gaps, especially for communist regimes, and are expected to exhibit substantial reorganizations at the micro-level, in light of the differences in innovation, entrepreneurship rates, and the firm size distribution.

5.3 Development Dynamics

Here we turn to the main goal of the paper, to investigate the macro and firm-level features of development dynamics. As explained in the calibration section, we interpret transitional growth as a consequence of a set of reforms, which in the case of Chile entails a protracted process of dismantlement of misallocation frictions, and in the case of China entails a similar process of removal of allocative distortions combined with a sudden removal of the communist features embedded in the profit tax schedule. The calibrated paths of distortions in the two economies are the ones shown in figure 5.2.

Even though the table in the previous section gave us an idea of the detrimental power of allocative distortions and progressive profit taxes, the development gaps were measured relative to the frictionless allocation. In the transition exercises below, however, the economies do not attain the frictionless level of development. This is because in our benchmark experiments we assumed that the progress of reversion of misallocation stalls and remains stagnant at the level forecasted for the latest year in our sample of aggregate data, namely 2011. In order to get a sense of the long run changes in productivity, entrepreneurship, and average firm size that our calibrated reforms are able to achieve, we report the steady state ratios between the terminal and the initial values of each variable in the table below.

Table 3: Development Dynamics: Terminal vs Initial Allocations

	Chile 2011 relative to 1980	China 2011 relative to 1998
GDP	1.07	1.94
TFP	1.06	1.66
# of Entrepr. (diff.)	-0.006	0.16
Av. Size	1.31	0.045
Wage	1.08	2.69

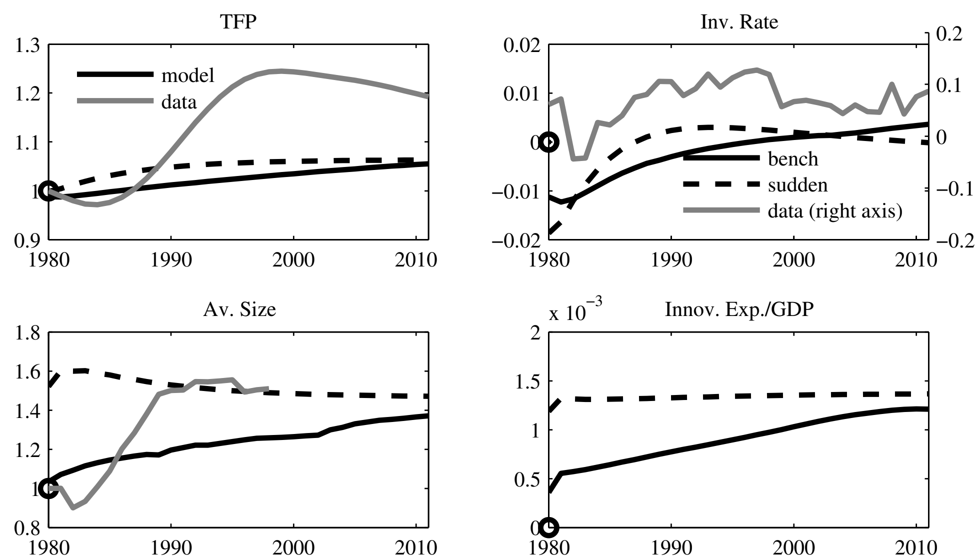
Note: Chile 2011 relative to 1980 refers to ratios of the corresponding variables in a stationary equilibrium with regression coefficients between TFPR and TFPQ equal to $\nu_{1980}^{Chile} = 0.6$ and profit tax $\tau_{1980}^{\pi}(0) = 0.941$, relative to a stationary equilibrium with $\nu_{2011}^{Chile} = 0.415$ and the same value of the profit tax in 2011, $\tau_{2011}^{\pi}(0) = 0.941$. China 2011 vs 1998 refers to ratios between stationary equilibriums with $\left\{\tau_{1998}^{\pi}(0) = 0.84, \xi_{1998} = 0.9, \nu_{1998}^{China} = 0.5\right\}$ and $\left\{\tau_{2011}^{\pi}(0) = 0, \xi_{2011} = 0, \nu_{2011}^{China} = 0.3\right\}$ respectively.

For our calibrated path of distortions, Chile experiences a transition that increases TFP by 6% in the long run. Recall that we are preserving the profit tax component of the distorted initial steady state, so all the gains accrue from reverting misallocation and fostering innovation. The increase in productivity combined with a contraction in the number of entrepreneurs translates into a 31% increase in the size of an average plant. In China, removing communist forces and withdrawing distortions induces a productivity increase of 72%. At the micro level, the depressing effect of abolishing communist features outweighs the enhancing effect exerted by the improvement in allocative efficiency over the average size.

5.3.1 Acceleration Episode: Chile 1980-2011

We now turn to the analysis of transitions. Consider first the acceleration episode of Chile between 1980 and 2011, presented in figure 5.5. The figure depicts three lines, a light gray one corresonding to the data, a solid black one corresponding to the calibrated dismantlement of distortions (solid black), and a dashed black one illustrating a counterfactual experiment in which the distortions are reduced abruptly and unexpeactedly from the 1980 to the 2011 level, instead of doing so smoothly as in the calibrated one. In the case of the investment rate, the units of the data are measured on the right axis. TFP and the average size are reported as a ratio with respect to the initial steady state, while the investment and the innovation expenditure rates are expressed as absolute differences from the initial steady state level.

Figure 5.5: Transition Dynamics Acceleration Episode: Chile 1980-2011



Note: The data for TFP corresponds to the trend component of HP filtered (smoothing parameter of 100) Chilean data between 1980 and 2011. The investment rates is the raw data for the period. The average size data is the same as in section 3. TFP and the average size are expressed as ratios with respect to 1980 values, where, in the case of the model, 1980 stands for the calibration of the economy to the distortions in that year. The investment rate and the ratio of innovation expenditure over GDP are expressed as absolute differences.

The figure shows that the calibrated reform is able to capture the qualitative features of the dynamics of TFP, investment, and average firm size in the data. Aggregate productivity increases protractedly, as a result of the reallocation gains that accrue in each period due to the improvement in allocative efficiency and due to the returns to investments in innovation which, as shown in the lower right panel also increase steadily over time.

A measure of the protractedness of the transition is captured in the half-life of the transition paths for TFP and GDP. These stand at 20 and 24 years respectively for the benchmark reform and 6 and 10 years under an immediate reduction of distortions to their 2011 level. As a point of comparison, the half-life of the transition dynamics for GDP in the one sector neoclassical growth model after permanent increase in exogenous TFP and for an identically calibrated physical capital share is equal to 6. Compared with the half-life of the sudden reform, it follows that the endogenous response in both technology and physical capital accumulation in our model almost doubles the length of the half-life relative to one with exogenous TFP. The sluggish nature of the dismantlement of distortions in the benchmark reform significantly reinforces the magnification.

The investment rate is, by construction, starting and finishing at the same level between the two steady states. However, along the transition, it declines in the onset of the reform and increases smoothly until it reverses back to the steady state, a reversal that materializes beyond 2011. Physical capital investment declines in response to the economy's allocation of resources towards the financing of innovation expenses. As innovation pays off and productivity starts to increase, the rate of return to capital goes up and so does the rate of tangible capital investment in the economy. The sudden reform precipitates the changes, but preserves the qualitative conclusions. Perhaps the most salient feature of the latter case is the faster firm-level adjustment, which manifest in a substantially faster increase in the average firm size and jump in innovative activity. Both features are symptomatic of a stronger selection ocurring at the onset of the reform, drawing a larger fraction of unproductive and unprofitable firms out of business. The protractedness of the transition, albeit persistent, gets somewhat mitigated by the abrupt nature of the reform, reducing the half-life for TFP and GDP to 6 and 10 years.

Evaluating the model quantitatively in this period is difficulted by the large cyclical swings exhibited by the Chilean economy in the early eighties, which get partly absorbed by the HP trend. Of course, there is no force in the model that can allow us to track this cyclicality. However, we can conclude that the reforms in the model can account for only half of the total gains in productivity at the end of the period, and that it can replicate the hump-shaped dynamics of investment in the data although, again, at magnitudes that fall short from the empirical counterparts[13].

The model also captures the adjustments in the size distribution of firms, as manifested by the dynamics of the average firm size. Although less abruptly than in the data, the average size of firms increases by 30% between 1980 and 2011. In the last period with available firm-level data, the average firm size had increased by 50% in Chile. As argued in the context of steady state analysis, the increase in the average firm size depends, on the one hand, to the progressive dismantlement of distortions, which eliminates subsidies at the bottom of the productivity distribution and discourages low-productivity entrepreneurship, and on the other hand on the increase in innovation investment by productive firms, which concentrates employment and production into fewer and more productive entrepreneurs.

Although we have taken Chile as the reference country for the evaluation of the model, we can also compare the theory with respect to the more general patterns that come out from the broader sample of acceleration episodes. In this sense, the model captures the monotone upwards trajectory of TFP, the hump-shaped behavior of investment rates, and the increasing dynamics of the average firm size that are typical of these episodes.

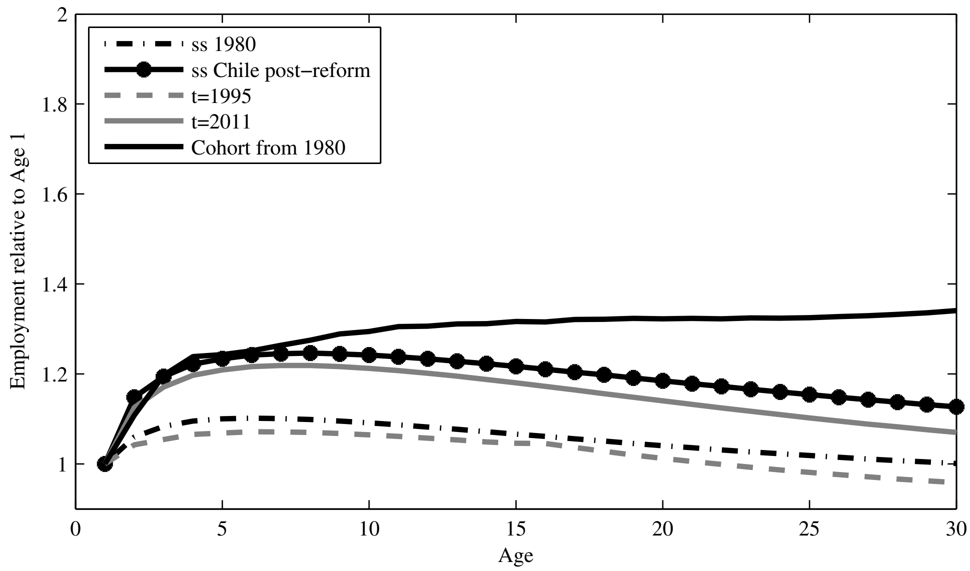
5.3.2 Life-Cycle of Firms during Acceleration Episodes

A robust conclusion from our analysis so far is the protracted nature of development episodes that are triggered by the dismantlement of distortions. This implication arised from the model both at the aggregate level, in terms of GDP and TFP dynamics, and at the micro level in terms of the evolution of average firm size. In this section we explore another dimension in which the economy is adjusting to the reforms: the life-cycle dynamics of firms. Because of data limitations, most current empirical investigations of the cross-country differences in the life-cycle of firms has been carried out inferring the life-cycle from the cross-sectional distributions of employment across ages. Since this distribution is changing over time, the model will have predictions about the speed at which the life-cycle adjusts during the acceleration. We show below that, like other features of the model, the adjustment along this dimension is also very protracted.

[13]Recall that we calibrated distortions so that they were neutral with respect to capital to output ratios. Thus, part of the divergence between theory and data in terms of the dynamics of investment could stem from our abstraction from investment wedges. Consideration of adjustment costs to the investment in physical capital could also contribute to improve the behavior of the investment rate in the model, particularly in the first years post-reform. However, these would delay the dynamics of TFP even further by crowding out intantigle capital accumulation.

To see this, consider figure 5.6, where we reproduce life-cycle employment profiles from the model's cross sectional age-size relationship at various points of the transition path for Chile between 1980 and 2011. In particular, we show the life cycles for the initial steady state, Chile 1980, for the post-reform steady state, and for the years 1995 and 2011. To make use of it later, we also constructed a proper life-cycle for the cohort of entrepreneurs that entered the economy in the first year of the reform[14].

Figure 5.6: Life Cycle of Firms during Acceleration Episodes: Chile 1980-2011



The sluggishness of the adjustment can be appreciated in that by 1995, 15 years into the transition, the cross-section based life-cycle of employment is virtually the same than what it was prior to the reform. By 2011, the life-cycle is still below the steady state level, even though by 2011 the degree of allocative distortions has already achieved its terminal level.

In the cross section, the shape of the life-cycle is determined by a combination of age and cohort effects. On the one hand, newly created firms are innovating at a pace consistent with the more friendly economic environment and are, therefore, making the life-cycle look steeper. On the other hand, older cohorts comprise low productivity, formerly subsidized, entrepreneurs whose protection is being withdrawn by the reform and who are consequently cutting down on innovation and headed towards exit. Since

[14]It is a proper life-cycle in the sense that we kept track of the time series evolution of employment for a given cohort, conditional on survival.

these low productivity firms have accumulated investments in productivity, the productivity process implies that it takes time for the profitability of these establishments to go below the indifference level for exit, even if innovation expenses were very low. Hence, they contribute to making the life-cycle look flatter.

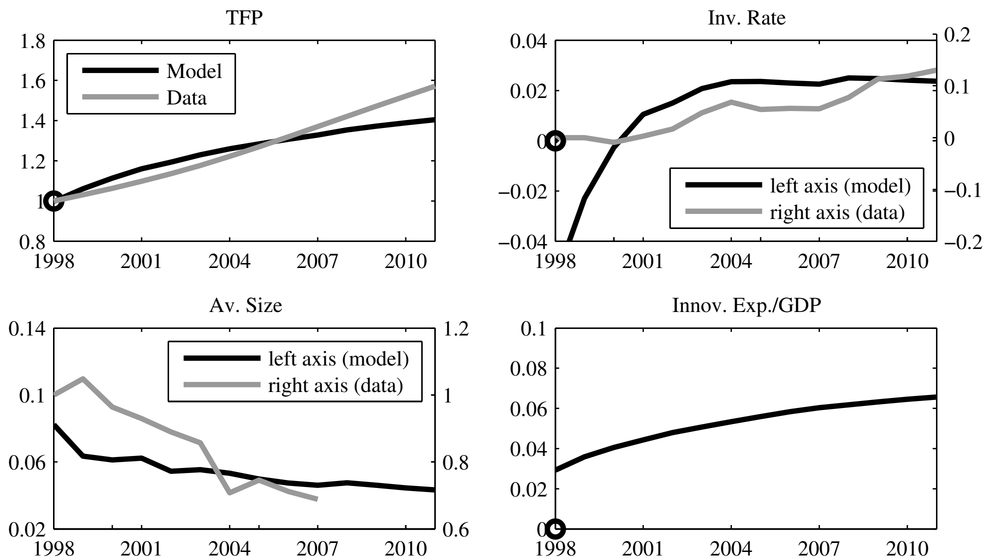
The interaction between age and cohort effects in the cross-sectional distribution of employment across ages raises a word of caution about using stationary models to infer underlying distortions, specially when studying economies undergoing fast growth episodes or large reforms. Suppose one were to observe the cross-sectional distribution of employment over age for Chile in 1995, and wanted to infer the life-cycle of firms from this data. Furthermore, suppose one wanted to learn about the degree of allocative distortions in Chile in that year, appealing to a stationary model of firm dynamics and calibrating distortions so that they deliver the same age-size relationships as in the data. Since the life cycle of firms in the cross section of the model for 1995 is slightly below that in 1980, the researcher would back out distortions that are slightly *more* severe than those in 1980. This would be inaccurate, since we know that in 1995 distortions were significantly below the 1980 level.

The figure also shows that for economies undergoing an acceleration, the life-cycle of firms calculated based on keeping track of the evolution of a cohort of entrants over time depicts a different picture than the life-cycle that is constructed based on cross-sectional employment size-age relationships. In particular, by being free from the bias from older cohorts, the proper life-cycle is steeper than the one based on the cross-section.

5.3.3 Post-Communist Transition: China 1998-2011

We now present the results for our representation of China's transition between 1998 and 2011. The results are illustrated in figure 5.7, where the solid black line corresponds to the model, and the light gray line corresponds to the data. Investment rates and the average firm size are measured on the right axis.

Figure 5.7: Post-Communist Transition Dynamics: China 1998-2011



Note: The data for TFP corresponds to the trend component of HP filtered (smoothing parameter of 100) Chinese data between 1998 and 2011. The investment rates is the raw data for the period. The average size data is the same as in section 3. TFP and the average size are expressed as ratios with respect to 1998 values, where, in the case of the model, 1998 stands for the calibration of the economy to the distortions in that year. The investment rate and the ratio of innovation expenditure over GDP are expressed as absolute differences.

The model is also able to replicate the similarity between acceleration episodes and post-communist transitions from an aggregate point of view, at the same time that it accounts for the differential behavior of firms at the micro level. This can be noted in that, contrary to Chile, the average firm size declines for a number of periods along the transitions, while TFP and investment rate display the same increasing pattern. Of course, the two experiments differ in the magnitudes, which is not surprising in light of the different development gaps to be bridged by the reforms that we propose for each country.

The protractedness of the adjustment in TFP is also a feature of the model's response to a more sudden reform, like the one implied by our implementation of a communist liberalization. In this case the half-life of the transition for TFP and GDP are 10 and 14 years respectively. Notice that there are sudden and protracted components in the post-communist liberalization, that explain the faster convergence of productivity and output in China relative to the benchmark reform in Chile. The sudden component stems from the immediate elimination of two essential features of the communist regime, namely the progressivity and the flat component of the profit tax schedule. The protracted stems from the smooth rate of progress in the reversal of misallocation in China. Since the former force accounted for the largest share of the initial TFP gap, the fact that is is suddenly reversed speeds up the transition. Still, the half-life is more than twice then one in the reference one sectorl neoclassica growth model.

Even though aggregate productivity increases substantially in the model, gaining 40% in 2011 relative to 1998, the model can only account for about half of the actual TFP gain experienced by China between 1998 and 2011. Recall that the only source of technological progress in the model stem from resource reallocation gains and expansions in innovation investments from the withdrawal of the stylized distortions that we modelled. The data suggests other forces are having a significant role as well.

As in the case of acceleration episodes, investment in physical capital declines upon reform, and does so more abruptly in light of the larger productivity gaps that need to be closed by investing in technology. The flip-side of the deeper contraction in investment is the greater increase in the innovation expenditure rate, which is twice as large as in the acceleration episode upon reform, and almost three times as large by 2011. Relative to the data, however, the extent of decrease and increase in the investment rate in the model is one order of magnitude smaller.[15]

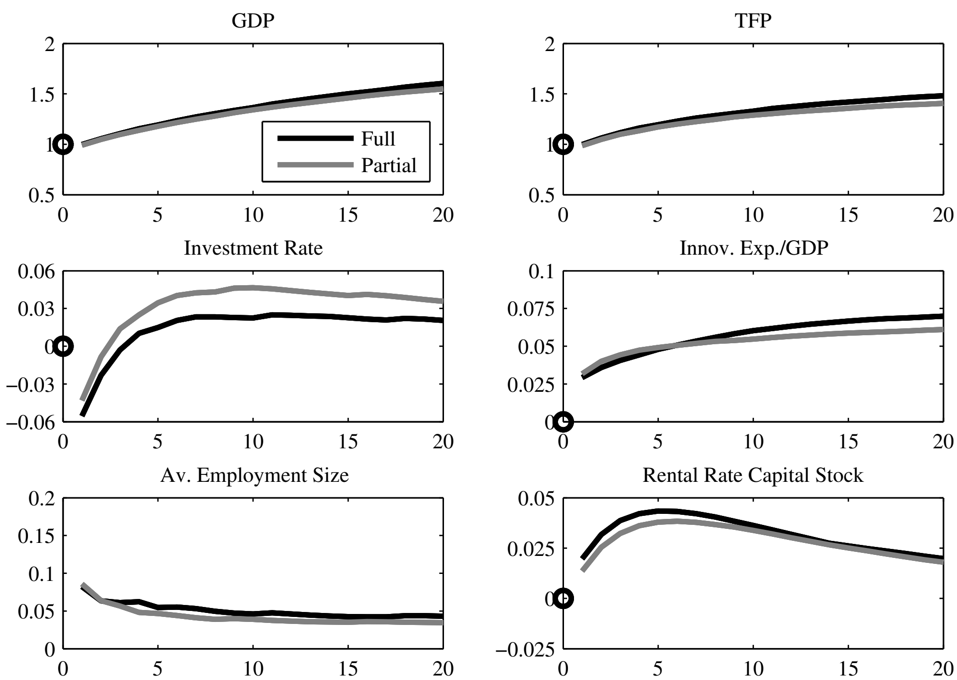
The dynamics of average firm size warrant a closer inspection. The steady state analysis already anticipates that the calibrated reform for China generates a contraction in average firm size. However, the figure shows that these opposing forces manifest at different stages of the transition, generating a non-monotone path of convergence. Upon reform, misallocation is dismantled smoothly, while profit taxes are eliminated abruptly. This creates a severe decline in entrepreneurship which more than compensates for the incipient expansion in productivity, reducing the average firm size to just about 14% of the initial steady state value. Thereafter, the exit from entrepreneurship and the decline in average size persists for a few periods, until the expansionary effect from undoing misallocation starts to prevail. The average size flattens out and eventually increases gradually towards the new steady state value. The increasing part does not materialize until later than 2011 so, in a sense, it constitutes a forecast from the model about what we should expect to happen with the dynamics of the average firm size in China in the near future.

[15] The remarks in footnote 13 apply to the Chinese case as well.

Lastly, notice that the degree of contraction in the average firm size in the model exceeds largely the one observed in China. In the context of the theory, an important factor underlying the results is the abruptness with which we withdraw the communist features in the model, which had happened at a similar pace in many of the post-communist countries but certainly not in China.

We conclude the analysis of post-communist transitions by performing an experiment that allows us to disentangle the relative contribution of each ingredient of a post-communist reform in shaping development dynamic. To achieve this, we compute a counterfactual reform in which only the communist features, embedded in the profit taxes, are dismantled, while resource misallocation persists at the same level as in the initial allocation. We overlay the results form this experiment, which we label partial, with those of the benchmark, which we label full in figure 5.8 below.[16]

Figure 5.8: Decomposition of Post-Communist Transitions: Full Reform vs Removing Profit Taxes Only



[16]To be clear about the meaning of "full", it does not refer to fully removing all type of distortions, as in a frictionless economy, but rather to contemplating both of the reforming forces that we are allowing to happen in the model, namely the protracted reversion of misallocation and the abrupt withdrawal of profit distortions.

It follows from the figure that the fundamental force driving the dynamics of China during the liberalization years is the withdrawal of the profit distortions. Removing this friction allows China to reap almost all of the productivity gains from the more comprehensive reform. The figure also reinforces the intuition that the contribution of improvements in allocative efficiency for average firm size manifest later in the transition process, pushing average size upwards. As shown in the lower-left panel of the figure, average size is below the benchmark level throughout the partial transition. Lastly, the bottom right figure shows that even though the productivity gains from the partial reform are, by 2011, very similar to the complete reform, they require a slower investment in innovation to achieve them.

5.3.4 Forecasting China's Development Dynamics

The main application of our theory so far has been to shed light onto the mechanisms that underlie the dynamics of development in growth accelerations. In this section we perform a different application of the model, namely to forecast the behavior of the economies beyond the periods of analysis that end in 2011. What should we expect the dynamics of development to be like in the model in the years beyond 2011? How different would these dynamics be depending on the extent to which reforms continue to be deepened?

We answer these questions for the economy of China which, even after several years of economic transformation and liberalization is, by 2011 significantly behind the income levels of the developed world. Specifically, we use the the theory to forecast the evolution of the Chinese economy under two alternative time path of idiosyncratic distortions. First, we project the time path of TFP in China under the assumption that allocative distortions do not decline after 2011. This exercise, which we label *partial reform,* boils down to reporting the dynamics variables of interest in the benchmark transition for several years after 2011. Secondly, we contrast this path with the evolution of an economy where allocative distortions continue to decline at the same pace as in our sample until they are fully dismantled. We label this experiment *complete reform.*[17]

[17] *For the two cases we assume that the entire path of allocative distortions is announced in 1998. Therefore, the dynamics of equilibrium variables are different between the partial and complete reform cases both before and after 2011. This is because entrepreneurs anticipate the dynamics of allocative distortions in the post 2011 period, and this affects their innovation decision.*

Figure 5.9: Forecasting China: Partial vs Complete Reform

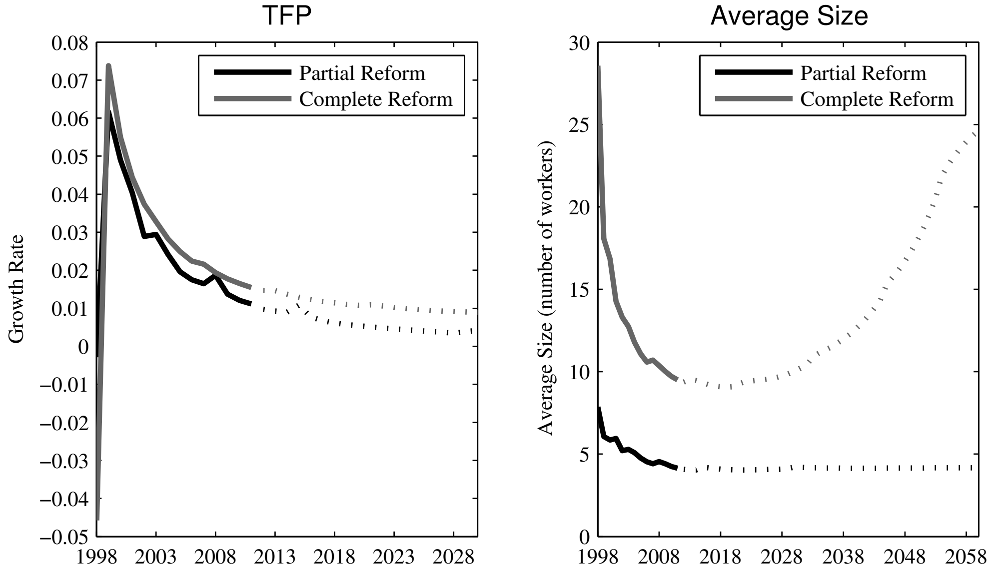


Figure 5.9 plots representative macro and firm-level variables for each of the forecasts. The left panel illustrates the growth rate of TFP while the right panel shows average firm size in terms of employment. The black line shows the predictions of the theory for the case of partial reform. The dotted portion of the line represents the forecast of the model for the years beyond 2011, which is the period in which distortions stabilize under the partial reform. The grey line contains the same information for the case in which the dismantlement of distortions continues until the undistorted allocation.

At the macro level, both reforms exhibit a smooth appropriation of the productivity gains from reforms. Even though there is a spike in growth at the onset of the transition, this is followed by a period of lower but sustained growth in aggregate productivity[18].

There are, however, two salient differences in the dynamics of TFP between the two reforms. First, the complete reform delivers an extra 0.5% growth in TFP over a period of about 30 years as a payoff for the continued reversal of distortions. Secondly, it produces a more pronounced contraction in measured TFP in the first year after its announcement. When informed about a process of liberalization that continues until all frictions are removed, entrepreneurs allocate larger shares of the labor force to

[18]Recall that since the model does not have an engine of balanced growth embedded in it, the positive growth rate that we show in the graph should be interpreted as "above trend" growth if attempted to be compared with the data.

innovative activity from the beginning. Since these efforts are intangible investments that go unmeasured in output, they act as a drag in TFP until they materialize into actual productivity enhancements.

The dynamics of average firm size also show some salient differences between cases. The first difference is evident upon reform, when the average size declines from its initial level of 166 workers to about 30 and 8 workers in the complete and partial reform respectively. The inital decline is almost entirely accounted for by increases in the rate of entrepreneurship that result from the abolishment of communist features in China's initial steady state. When reforms are complete, stronger competitive forces stemming from higher innovation from high productivity firms and the temporary nature of subsdies to low productivity firms discourage low ability types from selecting into entrepreneurship, and hence mitigates the fall in the average size.

The second difference refers to the dynamics of the average size beyond 2011. Once the initial impulse to firm entry created by the removal of communist distortions disipates, the discouragement to entrepreneurship inherent in the withdrawal of allocative distortions gains traction, giving rise to a reduction of the number of firms and an increase in average productivity among survivors due to enhanced innovation. The prediction of the theory is that if China were to continue with its liberalization at the same pace it has been doing so until 2011, we should expect a point of inflection in the dynamics of the average size that we reported from the data, and convergence to US levels of average employment.

6 Conclusion

In this paper we presented a quantitative model of economic transitions to aid in understanding the macro and micro patterns of development dynamics in post-war acceleration episodes and post-communist transitions.

Our model builds upon the most recent theories of firm-level innovation, with entry and exit and a stationary firm size distribution. We innovated upon these theories by interacting the built-in mechanisms of the model with two types of allocative distortions, misallocation wedges and progressive profit taxes, and characterizing transition dynamics. Furthermore, our analysis exploits the time-series dimension in existing empirical studies of misallocation in developing countries to come up with a novel strategy to discipline reforms. This allowed us to explore the quantitative behavior of the model in the context of a calibrated path of dismantlement of distortions.

Our findings suggest that our theory can account for the salient features of development dynamics in acceleration episodes and post-communist transitions. A property of our findings is that, despite dispensing from frictions to resource reallocation, the model can deliver a protracted path of growth in the rate of investment and in TFP in the economy. A key feature for the sustained growth in these variables is our theory of innovation, and the co-existence of heterogeneous incentives to invest in intangible capital along transition paths. There, the incentives to spur innovation from new and previously taxed entrepreneurs interact with a decline in innovation incentives from older cohorts of firms with relatively low productivity. As a result from this tension, it takes several years for TFP to attain its new steady state level.

Our work also provides results that feedback into the empirical literature. In particular, our analysis of the evolution of the life-cycle of firms and the cross-sectional distribution of employment across ages along the transition path can be of help in the growing literature trying to understand cross-country differences in the life-cycle of firms and their repercussions for cross-country differences in productivity. Our results suggest that inferences about life-cycle behavior drawn from cross-sectional characterizations of employment across ages may be misleading with respect to capturing the actual patterns of firm growth over the life-cycle, especially so in countries that are undergoing a growth acceleration.

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A Data Description

We first provide a list of the countries captured by the methodology of Haussman et.al (2005) as accelerations, and the full list of post-communist transitions.

Table 4: List of All Sustained Accelerations, Successful Post-Communist Transitions, and All Post-Communist Transition Countries

Sustained Growth Accelerations				Successful Post-Communist	All Post-Communist
Denmark	(1957)	Turkey	(1981)	Albania	Bulgaria
Nigeria	(1957)	UK	(1982)	China	Cambodia
Thailand	(1957)	Spain	(1983)	Lesotho	China
Egypt	(1958)	India	(1983)	Poland	Czech Rep.
Spain	(1958)	Korea	(1983)	Vietnam	Hungary
Ireland	(1958)	Mauritius	(1983)		Latvia
Japan	(1958)	Portugal	(1984)		Lithuania
Belgium	(1959)	Taiwan	(1985)		Poland
Greece	(1959)	Chile	(1985)		Romania
Portugal	(1959)	Ireland	(1987)		Slovenia
Taiwan	(1960)	Panama	(1988)		Ukraine
USA	(1960)	Singapore	(1988)		Vietnam
Canada	(1962)	Laos	(1988)		
Mexico	(1962)	Sri Lanka	(1990)		
Korea	(1963)	Vietnam	(1990)		
Costa Rica	(1964)	China	(1991)		
Thailand	(1964)	Dom. Rep.	(1991)		
Japan	(1965)	El Salvador	(1991)		
Panama	(1965)	Albania	(1993)		
Botswana	(1967)	Poland	(1993)		
Congo	(1967)	Sudan	(1993)		
Finland	(1967)	Trin. And Tob.	(1994)		
Indonesia	(1967)				
Malaysia	(1967)				
Singapore	(1967)				
Tunisia	(1967)				
Mauritius	(1970)				
Romania	(1970)				
Chile	(1974)				
China	(1976)				
Sri Lanka	(1976)				
Egypt	(1977)				
Laos	(1978)				

For these countries, we construct3.1 the average of TFP and investment rate dynamics relative to the acceleration year, or relative to the liberalization year in the case of a post-communist transition, which we date to be 1990. The underlying data comes from Penn World Tables version 8.1. TFP is taken directly from the variable $rtfpna$ in the dataset, while the investment rate is given by csh_i. The lines correspond to simple averages among countries within each group.

Average size dynamics for Singapore, Japan, and Korea 3.2 are constructed based on the data in Buera and Shin (2013) . The average firm size for Chile and Romania was constructed from the supplementarial material accompanying Bartelsman, Haltiwanger, and Scarpetta (2009) . For Hungary, the data comes from Varela (2015) .

In terms of computing average size dynamics for China, we have two data sources that we use for different purposes: the Census Yearbooks for 1995, 2004, and 2008; and the Annual Survey of Industrial Production conducted by the National Bureau of Statistics for the years 1998 through 2007. Since part our calibration of the Chinese economy in 1998 relies on matching the average size ratios with the US, we need to make sure that the dataset covers most firms in the economy in order to avoid biasing the calibration of the underlying distortion. Thus, for calibration purposes, we appeal to data from the Census Yearbooks as reported in Brandt, Van Biesebroeck, and Zhang (2014) . They report the total number of firms and the employment level from the Census Yearbooks of 1995, 2004, and 2008, allowing us to compute the average size in these years. The average size for 1995, our calibration target in the model, amounts to 166 workers. We plot this number along with the other two available data points in figure 3.2[19] of motivating facts.

We appeal to the alternative dataset, the NBSsurveys, to provide a longer and more continuous point of comparison for the model with respect to predictions about the evolution of average firm size during the reforms. The Annual Survey of Industrial Production conducted by the National Bureau of Statistics covers all non-state firms with 5 millon yuan in revenue or more. Even though we find this data useful for illustrating the evolution of the average firm size for a longer period of time (see figure 5.7), appealing to it for calibration purposes would have delivered a much higher value of the flat component of the profit tax distortion. That is because in the surveys, the average size of an industrial firm in China in 1998 was 341 workers, twice as large as the magnitude emerging from the Census. Matching this target would have required a stronger disincentive to entrepreneurship in the model.

When we contrast the model's predictions about transitions with data, we make

[19]The figure also shows a data point for 1993. We thank Gueorgui Kambourov for calculating this number for us. The source is the same as in Brandt et.al (2014), which did not report number of firms and employment data for the year 1993 in their work.

them comparable by making the following adjustments to the latter. First, for TFP, we extract the trend component of the time series of Chile and China applying the Hoddrick-Prescott filter, with a smoothing parameter $\lambda = 100$. Then, since we work with a model that features no growth in the stationary equilibrium, we extract a balanced growth path rate of improvement in aggregate productivity of 0.8% per year to the HP filtered trends. We estimate this growth rate to be 0.8%, which is the average post-war TFP growth rate in the USA implied by the PWT database 8.1.