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Policy distortions and aggregate productivity with heterogeneous establishments ☆

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ABSTRACT

We formulate a version of the growth model in which production is carried out by heterogeneous establishments and calibrate it to US data. In the context of this model we argue that differences in the allocation of resources across establishments that differ in productivity may be an important factor in accounting for cross-country differences in output per capita. In particular, we show that policies which create heterogeneity in the prices faced by individual producers can lead to sizeable decreases in output and measured total factor productivity (TFP) in the range of 30 to 50 percent. We show that these effects can result from policies that do not rely on aggregate capital accumulation or aggregate relative price differences. More generally, the model can be used to generate differences in capital accumulation, relative prices, and measured TFP.

1. Introduction

A large literature has emerged that attempts to use versions of the neoclassical growth model to understand cross-country differences in per capita incomes. A common assumption in much of this literature is a constant returns to scale aggregate production function that abstracts from heterogeneity in production units. Perhaps not surprisingly, therefore, much of this literature has been concerned with understanding the role of aggregate accumulation and how aggregate accumulation is affected by differences in (aggregate) relative prices.

Many important insights have emerged from this work. The thesis of this paper, however, is that the allocation of aggregate resources across uses may also be important in understanding cross-country differences in per capita incomes. That is, it is not only the level of factor accumulation that matters, but also how these factors are allocated across heterogeneous production units. And as a result, it is not only aggregate relative prices that matter but also the relative prices faced by different producers. Policies that leave aggregate relative prices unchanged but distort the prices faced by different producers will influence how resources are allocated across productive units and can potentially have substantial effects. Indeed there is substantial evidence of the importance of capital and labor allocation across establishments as a determinant of aggregate productivity. For instance, Baily et al. (1992) document that about half of overall productivity growth in US manufacturing in the 1980s can be attributed to factor reallocation from low productivity to high productivity establishments.[1]

We consider a version of the neoclassical growth model that incorporates heterogeneous production units as in Hopenhayn (1992) and Hopenhayn and Rogerson (1993). In the steady state of this model there is a non-degenerate distribution

☆ The views expressed herein are those of the author(s) and do not necessarily reflect the views of the National Bureau of Economic Research.

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[1] This aspect of the growth process is also emphasized by Harberger (1998).

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of establishment-level productivity and the distribution of resources across these establishments is a key element of the equilibrium resource allocation. In a calibrated version of the model we then study a class of distortions that lead to no changes in aggregate prices and no changes in aggregate factor accumulation. These distortions are to the prices faced by individual producers. Whereas in the competitive equilibrium without distortions all producers face the same prices, we examine policy distortions whose direct effect is to create heterogeneity in the prices faced by individual producers. Because of this feature we refer to these distortions as *idiosyncratic distortions* to emphasize the fact that the distortion is (potentially) different for each producer. These idiosyncratic distortions lead to a reallocation of resources across establishments. Although the policies we consider do not rely on changes in aggregate capital accumulation and in aggregate relative prices, we nonetheless find substantial effects of these policies on aggregate output and measured TFP. In our benchmark model we find that the reallocation of resources implied by such policies can lead to decreases in output and TFP in the range of 30 to 50 percent, even though the underlying range of available technologies across establishments is the same in all policy configurations.

The policies that we consider are simple and abstract. In particular, we analyze policies that levy establishment-level taxes or subsidies to output or the use of capital or labor. In reality, the list of policies that generate idiosyncratic distortions is both long and varied.[2] For instance, non-competitive banking systems may offer favorable interest rates on loans to select producers based on non-economic factors, leading to a misallocation of credit across establishments. Recent work by Peek and Rosengren (2005) argues that such misallocation is highly prevalent in Japan. Banerjee and Munshi (2004) and Banerjee and Duflo (2005) present evidence that financial market imperfections lead to misallocation of credit across producers.[3] Greenwood et al. (2007) develop a model where the level of financial development affects the allocation of resources across productive uses. Governments may offer special tax deals and lucrative contracts to specific producers, all financed by taxes on other production activities. Public enterprises, which are usually associated with low productivity, may receive large subsidies from the government for their operation. Various product and labor market regulations may lead to distortions in the allocation of resources across establishments. Corruption may also lead to idiosyncratic distortions. The imposition and enforcement of trade restrictions may also lead to distortions, and a substantial part of these may effectively be idiosyncratic. Each of these specific examples is of interest, and ultimately it is important to understand the quantitative significance of specific policies, regulations or institutions.

Closely related to our paper are studies that emphasize the misallocation of resources across productive uses in aggregate productivity. Bartelsmann et al. (2006) study the effects of idiosyncratic distortions in the context of a model similar to ours using cross-country data on firms. Hsieh and Klenow (2007b) study the impact of misallocation across establishments in explaining productivity in manufacturing in China and India. Alfaro et al. (2007) study income differences caused by the allocation of resources across heterogeneous firms using data for 80 countries.

There is a growing literature studying the role of particular distortions on TFP and output. For instance, Parente and Prescott (1999) have studied the role of monopoly-type arrangements in determining the use of inefficient technologies. Herrendorf and Texeira (2003) extend Parente and Prescott's model to allow for capital accumulation. If monopoly type arrangements are more prevalent in the investment sector, then these arrangements can lead to relative price and capital accumulation effects. Schmitz (2001) studies a similar channel, namely that low TFP in the investment sector leads to low capital accumulation, but in his model low TFP stems from a government policy supporting inefficient public enterprises. Low productivity in the investment sector seems to be at the core of low real investment rates in poor countries as argued by Hsieh and Klenow (2007a). Lagos (2006) studies the effects of labor market institutions on aggregate TFP. Bergoeing et al. (2002) argue that bankruptcy laws are at the core of the fast recovery of Chile relative to Mexico in the wake of the debt crises in the early 1980s (see also Bergoeing et al., 2004). Trade barriers and reforms are studied in the context of a general equilibrium model similar to ours in Chu (2002) (see also Melitz, 2003). Other studies focusing on particular distortions that induce misallocation include Caselli and Gennaioli (2005) emphasizing a missing market for corporate control, Burstein and Monge (2007) on barriers to foreign direct investment, and Buera and Shin (2007) on the role of financial frictions. However, we think it is valuable to begin with a generic representation of these types of policies in order to assess the overall quantitative significance of the potential effects as a complement to the studies that focus on specific channels.

Our study is also related to the paper by Guner et al. (2008). These authors consider policies that directly target the size of the establishment such as a tax on establishments with more than x number of employees. When a general configuration of these policies are restricted to achieve a given reduction in average establishment size, the authors find a substantial reduction in aggregate output per worker. There are three important differences with our analysis that are worth highlighting. First, we consider a broader and more abstract set of policies with the objective of capturing the wide array of policies that effectively cause idiosyncratic distortions to establishment-level decisions across countries.[4] Second, size-dependent policies differ from the general configuration of policies we study in a substantive way. Whereas in our framework taxed

[2] Many policies or institutions can create heterogeneity in the costs or benefits of individual producers and affect the allocation of resources across producers. Our approach is to model the reallocation effects of these factors via taxes and subsidies. In the context of our model, the aggregate effects on output and productivity hinge on the reallocation of factors across establishments with different productivity and not on whether the reallocation is caused by actual taxes and subsidies.

[3] See also Galindo et al. (2007) for an empirical study of the effect of financial liberalization on the allocation of investment in developing countries.

[4] Clearly, the trade-off of broader policies is that there is less scope for direct empirical measurement. Nevertheless, recent empirical studies have devised general strategies to back-out distortionary policies from cross-country data, see for instance Hsieh and Klenow (2007b).

establishments become small and subsidized establishments become large, size-dependent policies mainly distort the size of establishments around and above the threshold size where the policy kicks in. This distinction is crucial for many policies in poor countries. For instance, consider the case of government enterprises which are prevalent in the developing world. Public enterprises are large, unproductive, and often supported by government budgets. This situation is captured in our framework as a subsidy to a low productivity establishment that in equilibrium becomes large. Or consider the case of misallocation of credit where some producers are favored with special non-market conditions. Again, this institution is well captured by a subsidy to the rental rate of capital for some producers. But the direct result of this policy is that the favored establishments demand more capital and become larger than in the absence of the distortion. Third, whereas in our framework the distribution of establishments across productivity levels is the same for all economies we study, less productive (small) establishments are opened up in Guner et al. causing a reduction in establishment size. While differences in average establishment size may be of practical importance across countries, we argue that these differences can be understood from a broader range of policies. For instance, in a simple extension of our model where potential entrants invest in the likelihood of draws with higher productivity, policy distortions can lead to a shift in the distribution of establishments towards low productivity levels, ensuring a reduction in average establishment size—but in this case the reduction in average size is neither linked to size-dependent policies nor to reductions in the aggregate capital stock.

Our model is implicitly a model of measured TFP. In addition to offering a theory to help account for differences in TFP, it can also potentially help shed light on observations about capital accumulation, relative prices, and TFP. For instance, in versions of the standard growth model, exogenous differences in TFP lead to lower capital accumulation. However, in the data there are several countries with high capital accumulation and low TFP. Our model offers a simple rationalization of this situation. If a country subsidizes the capital accumulation of low productivity units, then capital accumulation will increase but measured TFP will decline.

More generally, our model connects the literatures on capital accumulation and TFP. The literature on the role of capital accumulation emphasizes the impact of aggregate policy distortions on the return to capital investments, capital accumulation, and output, but TFP levels are exogenous and constant across countries.[5] Models of TFP, such as Parente and Prescott (2000), abstract from capital accumulation. How much of the cross country per capita income differences is accounted for by capital accumulation and other factors such as TFP is a subject of great controversy.[6] Our theory of establishment heterogeneity offers a link of these approaches to understanding per capita income differences across countries since idiosyncratic policy distortions can potentially lead to both capital accumulation and measured TFP differences.

The paper is organized as follows. In the next section we describe the model in detail, and in Section 3 we show how to construct the steady-state equilibrium of the model. In Section 4 we calibrate a benchmark undistorted economy to data for the United States and in Section 5 we analyze the quantitative effects of idiosyncratic distortions in our calibrated model. Section 6 discusses the results by expanding on the set of experiments we consider. We conclude in Section 7.

2. Economic environment

We consider a standard version of the neoclassical growth model augmented along the lines of Veracierto (2001) to allow for establishment level heterogeneity as studied by Hopenhayn (1992) and Hopenhayn and Rogerson (1993). Establishments have access to a decreasing returns to scale technology, pay a one-time fixed cost of entry, and a fixed cost of operation every period. Plants may die stochastically at an exogenous rate and hence, in steady state, there is ongoing entry and exit. We abstract from establishment-level productivity dynamics by assuming that the productivity level of the establishment remains constant over time. We study the competitive equilibrium of this model in which establishments take the wage rate and the rental rate of capital as given and make zero expected profits. We then analyze policy distortions that affect output or factor prices faced by individual establishments, the allocation of factors across establishments, and therefore, aggregate measured TFP. In what follows we describe the environment in more detail.

2.1. Base model

There is an infinitely-lived representative household with preferences over streams of consumption goods at each date described by the utility function,

$$\sum_{t=0}^{\infty} \beta^t u(C_t),$$

where C_t is consumption at date t and $0 < \beta < 1$ is the discount factor. The household is endowed with one unit of productive time each period and $K_0 > 0$ units of the capital stock at date 0.

Next we describe the technology. The unit of production is the establishment. Each establishment is described by a production function $f(s, k, n)$ that combines capital services k and labor services n to produce output. The function f is

[5] See for instance the work of Mankiw et al. (1992) and Chari et al. (1996).

[6] See for example, Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), Prescott (1998), and Mankiw (1995).

assumed to exhibit decreasing returns to scale in capital and labor jointly, and to satisfy the usual Inada conditions.[7] The parameter s varies across establishments and will capture the fact that technology varies across establishments. Since our goal is to focus on the cross-sectional heterogeneity of establishments we abstract from time-series variation in s and hence assume that the value of s is constant over time for a given establishment. In our quantitative work we assume

$$f(s,k,n) = sk^{\alpha}n^{\gamma}, \quad \alpha, \gamma \in (0,1), \quad 0 < \gamma + \alpha < 1.$$

Note that in adopting such a specification we are implicitly assuming that the only difference across establishments is the level of TFP. In particular, this functional form implies that capital to labor ratios are the same across establishments in an equilibrium with no distortions. This assumption allows us to focus attention on the allocation of resources across units which differ along a single dimension, namely the level of TFP.

We also assume that there is a fixed cost of operation equal to c_f, measured in units of output. If the establishment wants to remain in existence then it must pay the fixed cost. The net output produced by a establishment that remains in existence is therefore given by $f(s,k,n) - c_f$. If an establishment does not pay the fixed cost in any period then it ceases to exist.

Although establishment-level TFP is assumed to be constant over time for a given establishment, we assume that all establishments face a probability of death. Specifically, we assume that in any given period after production takes place, each establishment faces a constant probability of death equal to λ. It would be easy to allow this value to depend on the establishment-level productivity parameter s, but we will assume it to be constant across types in the analysis carried out below.[8] Exogenous exit realizations are *i.i.d.* across establishments and across time.

New establishments can also be created, though it is costly. Specifically, in each period a new establishment can be created by paying a cost of c_e measured in terms of output. After paying this cost a realization of the establishment level productivity parameter s is drawn from a distribution. In what follows, we assume a discrete set of possible values for productivity, i.e., $s \in \{s_1, \dots, s_{n_s}\}$ and these values are drawn from a *pdf* $h(s)$, where $h(s_i)$ is the probability of drawing productivity level s_i. Draws from this distribution are *i.i.d.* across entrants. We assume that there is an unlimited mass of potential entrants. Let E_t denote the mass of entry in period t.

Feasibility in this model requires:

$$C_t + X_t + c_e E_t \leqslant Y_t - M_t c_f,$$

where C_t is aggregate consumption, X_t is aggregate investment, E_t is aggregate entry, Y_t is aggregate output, and M_t is the mass of producing firms. As is standard, the aggregate law of motion for capital is given by:

$$K_{t+1} = (1-\delta)K_t + X_t.$$

2.2. Policy distortions

Our focus is on policies that create idiosyncratic distortions to establishment-level decisions and hence cause a reallocation of resources across establishments. As mentioned in the introduction, many different types of policies may generate such effects. While it is of interest to understand each such policy individually, the approach we take here is to analyze a generic family of distortions of this type. Specifically, we assume that each establishment faces its own output tax or subsidy. In what follows we will simply refer to this distortion as the output tax, with the understanding that tax rates less than zero are possible and reflect subsidies. We will use τ to generically refer to the establishment-level tax rate. To simplify our analysis we assume that τ can take on three values: a positive value reflecting that the establishment is being taxed, a negative value reflecting that the establishment is being subsidized, and zero reflecting no distortion for the establishment. At the time of entry, the establishment-level tax rate is not known, but its value is revealed once the establishment draws its value of productivity s and before production takes place. Generically, we denote different specifications of policy by $\mathcal{P}(s,\tau)$ representing the probability that a establishment with productivity s faces policy τ. We allow in $\mathcal{P}$ for the possibility that the value of the establishment-level tax rate may be correlated with the draw of the establishment-level productivity parameter, although this is not imposed in all our specifications. We also assume that the value of this tax rate remains fixed for the duration of the time for which the establishment is in operation.

From the perspective of an entering establishment, it faces draws of s and τ, and what matters to them is the joint distribution over these pairs. For a given *pdf* h over the idiosyncratic draws of s, different specifications of policy will induce different joint distributions over pairs of (s,τ). We will represent this joint *pdf* by $g(s,\tau)$. (Alternatively, $g(s,\tau) = h(s) \times \mathcal{P}(s,\tau)$.)

A given distribution of establishment-level tax and subsidies need not lead to a balanced budget for the government. We assume that budget balance is achieved on a per-period basis by either lump-sum taxation or redistribution to the

[7] Our model is a single-good model in which a non-degenerate distribution of establishment sizes is sustained by decreasing returns at the establishment level. An alternative framework is to assume differentiated products and constant returns at the establishment level. In this alternative framework, the non-degenerate distribution of establishment sizes is sustained by curvature in preferences. Conceptually these frameworks are very similar. See Hsieh and Klenow (2007b) and Alfaro et al. (2007) for empirical applications of the differentiated-products framework.

[8] As will be seen later, for our purposes what matters is the invariant distribution of establishments across types, and whatever changes we introduce via λ would be undone by changes to the draws of s by new entrants.

representative consumer. We denote the lump-sum tax by T_t. Because our model does not have a labor/leisure decision, lump-sum taxes have no effect on the model's equilibrium.

3. Equilibrium

We focus exclusively on the steady-state competitive equilibrium of the model. In a steady-state equilibrium the rental prices for labor and capital services will be constant, and we denote them by w and r respectively. The aggregate capital stock will be constant and there will also be a stationary distribution of establishments across types. Before defining a steady-state equilibrium formally it is useful to first consider the decision problems of the agents in the model and to develop some notation. This discussion will also motivate an algorithm that can be used to recursively solve for the steady-state equilibrium. As we will see, the consumer problem will determine the steady-state rental rate of capital. Given the rental rate of capital, the zero profit condition for entry of establishments will determine the steady-state wage rate. Labor is supplied inelastically, and so in equilibrium total labor demand must equal unity. We show that this condition determines the amount of entry. We now go through the details.

3.1. Consumer's problem

The consumer seeks to maximize lifetime utility subject to a budget constraint:

$$\sum_{t=0}^{\infty} p_t\big(C_t + K_{t+1} - (1-\delta)K_t\big) = \sum_{t=0}^{\infty} p_t(r_t K_t + w_t N_t + \Pi_t - T_t),$$

where p_t is the time zero price of period t consumption, w_t and r_t are the period t rental prices of labor and capital measured relative to period t output, Π_t is the total profit from the operations of all establishments, and T_t is the lump-sum taxes levied by the government. N_t is total labor services supplied to the market, which will always be equal to one since the individual does not value leisure.

A standard argument using the first order conditions for this problem allows us to conclude that if there is a solution with r_t and C_t constant it must be that:

$$r = \frac{1}{\beta} - (1-\delta),$$

where r is the constant value of r_t. For future reference, the corresponding real interest rate, denoted by R, is given by

$$R = r - \delta = \frac{1}{\beta} - 1.$$

3.2. Incumbent establishment's problem

The decision problem of an establishment to hire capital and labor services is static since there is no link between decisions made in different periods, that is, conditional upon remaining in operation an establishment should simply hire labor and capital so as to maximize current period profits. And the decision of whether to remain in operation is equivalent to asking whether current period profits are non-negative since the establishment's value of s does not change over time. Consider a establishment with productivity level s and tax rate τ that faces (steady-state) input prices of r and w. Conditional upon producing, the maximum one period profit function $\pi(s,\tau)$ satisfies:

$$\pi(s,\tau) = \max_{n,k\geqslant 0}\big\{(1-\tau)sk^{\alpha}n^{\gamma} - wn - rk - c_f\big\}.$$

Conditional upon remaining in operation, optimal factor demands of this establishment are thus given by:

$$\bar{k}(s,\tau) = \left(\frac{\alpha}{r}\right)^{\frac{1-\gamma}{1-\gamma-\alpha}}\left(\frac{\gamma}{w}\right)^{\frac{\gamma}{1-\alpha-\gamma}}\big(s(1-\tau)\big)^{\frac{1}{1-\alpha-\gamma}},$$

$$\bar{n}(s,\tau) = \left(\frac{(1-\tau)s\gamma}{w}\right)^{\frac{1}{1-\gamma}} k^{\frac{\alpha}{1-\gamma}}.$$

Because both the establishment-level productivity and tax rate are constant over time, the discounted present value of an incumbent establishment is given by,

$$W(s,\tau) = \frac{\pi(s,\tau)}{1-\rho},$$

where $\rho = \frac{1-\lambda}{1+R}$ is the discount rate for the establishment, R is the (steady-state) real interest rate, and λ is the exogenous exit rate.

3.3. Entering establishment's problem

Potential entering establishments make their entry decision knowing that they face a distribution over potential draws for the pair (s,τ). Letting W_e represent the present discounted value of a potential entrant, this value is given by:

$$W_e = \sum_{(s,\tau)} \max_{\bar{x}\in\{0,1\}} \left\{\bar{x}(s,\tau)W(s,\tau)g(s,\tau) - c_e\right\},$$

where the max inside the summation reflects the fact that the potential entrant will optimally decide whether to engage in production after observing their realized draw of (s,τ). We denote by $\bar{x}(s,\tau)$ the optimal entry decision with the convention that $\bar{x}=1$ means that the establishment enters and remains in operation.

In an equilibrium with entry, W_e must be equal to zero since otherwise additional establishments would enter. The condition $W_e = 0$ is thus referred to as the free-entry condition. Note, however, that the function $W(s,\tau)$ is completely determined by the values of endogenous variables w and r. Moreover, it is straightforward to see that this function is strictly decreasing in w and r. Since we have already argued that in steady state the value of r is determined by β and δ, it follows that there is at most one value of w for which $W_e = 0$. Hence, if there is an equilibrium with production then the free-entry condition will determine the wage rate.

3.4. Invariant distribution of establishments

Let $\mu(s,\tau)$ denote the distribution of producing establishments this period over establishment-level characteristics (s,τ). If the mass of entrants is E and the decision rule for production of entering establishments is given by $\bar{x}(s,\tau)$ then next period's distribution of producers over (s,τ) pairs, denoted μ', satisfies:

$$\mu'(s,\tau) = (1-\lambda)\mu(s,\tau) + \bar{x}(s,\tau)g(s,\tau)E,$$

for all s and τ, where the first term represents the mass of incumbent establishments that survive this period and the second term represents the mass of entering establishments that remain in operation. In steady state the distribution μ will be constant over time, so we are interested in a fixed point of this mapping, or equivalently, an invariant distribution defined by this mapping. As long as death rates are bounded away from 0 this mapping will have a unique invariant distribution associated with it, and moreover, the invariant distribution will be linear in the mass of entry E. Letting $\hat{\mu}$ represent the invariant distribution associated with $E=1$, it is easy to show that

$$\hat{\mu}(s,\tau) = \frac{\bar{x}(s,\tau)}{\lambda} g(s,\tau), \quad \forall s,\tau.$$

3.5. Labor market clearing

In the steady state, wage and capital rental rates determine the functions $\bar{k}(s,\tau)$, $\bar{n}(s,\tau)$, and $\bar{x}(s,\tau)$, and also the associated invariant distribution $\hat{\mu}$. Aggregate labor demand is then given by

$$N(r,w) = E\sum_{(s,\tau)} \bar{n}(s,\tau)\hat{\mu}(s,\tau).$$

Given values for w and r as determined as above, this equation can be used to determine the steady-state equilibrium level of entry. Recalling that labor supply is inelastic and equal to one, it follows that E satisfies:

$$E = \frac{1}{\sum_{(s,\tau)} \bar{n}(s,\tau)\hat{\mu}(s,\tau)}.$$

3.6. Definition of equilibrium

We are now ready to formally define a steady-state competitive equilibrium for the economy.

A *steady-state competitive equilibrium* with entry is a wage rate w, a rental rate r, a lump-sum tax T, an aggregate distribution of establishments $\mu(s,\tau)$, a mass of entry E, value functions $W(s,\tau)$, $\pi(s,\tau)$, W_e, policy functions $\bar{x}(s,\tau)$, $\bar{k}(s,\tau)$, $\bar{n}(s,\tau)$ for individual establishments, and aggregate levels of consumption (C) and capital (K) such that:

(i) (Consumer optimization) $r = 1/\beta - (1-\delta)$,

(ii) (Plant optimization) Given prices (w,r), the functions π, W, and W_e solve incumbent and entering establishment's problems and $\bar{k}$, $\bar{n}$, $\bar{x}$ are optimal policy functions,

(iii) (Free-entry) $W_e = 0$,

(iv) (Market clearing)

$$1 = \sum_{(s,\tau)} \bar{n}(s,\tau)\mu(s,\tau),$$

$$K = \sum_{(s,\tau)} \bar{k}(s,\tau)\mu(s,\tau),$$

$$C + \delta K + c_e E = \sum_{(s,\tau)} \big(f(s,\bar{k},\bar{n}) - c_f\big)\mu(s,\tau),$$

(v) (Government budget balance)

$$T + \sum_{(s,\tau)} \tau f(s,\bar{k},\bar{n})\mu(s,\tau) = 0,$$

(vi) (μ is an invariant distribution)

$$\mu(s,\tau) = E\frac{\bar{x}(s,\tau)}{\lambda} g(s,\tau), \quad \forall s,\tau.$$

4. Calibration

In this section we calibrate the model to data for the United States. In our calibration we treat the United States as an economy with no distortions. Several of the model's parameters are those of the growth model and we follow standard procedures for choosing those values. Relative to the growth model what is new are the parameters that determine the distribution of establishments in equilibrium.

We let a period in the model correspond to one year in the data. We target a real rate of return of 4 percent, implying a value for β of 0.96. The extent of decreasing returns in the establishment-level production function is an important parameter in our analysis. Direct estimates of establishment-level production functions and different calibration procedures point to a value for $\alpha + \gamma = 0.85$.[9] The split between α and γ is done according to the income share of capital and labor, so we assign 1/3 to capital and 2/3 to labor, implying $\alpha = 0.283$ and $\gamma = 0.567$. We choose the depreciation rate of capital δ so that the investment to output ratio is equal to 20 percent. This choice implies $\delta = 0.08$. The implied capital to output ratio is 2.3, close to the estimated capital to output ratio in the US economy.

Another important component of the calibration is the range of values for establishment-level productivity. Because we study policies that produce a reallocation of resources across establishment types relative to the benchmark economy with no distortions, the range of establishment-level productivity will determine the impact of factor allocation in aggregate productivity. In the benchmark economy there is a simple mapping between establishment-level productivity and employment. As a result, the range of employment across establishments puts discipline on the range of establishment-level productivity. In our model for the benchmark economy, the relative demand for labor between any two establishments i and j is given by:

$$\frac{n_i}{n_j} = \left(\frac{s_i}{s_j}\right)^{\frac{1}{(1-\gamma-\alpha)}}.$$

According to data from the US Census Bureau, the number of employees at the establishment level ranges from 1 to 10,000.[10] With our assumptions about α and β and normalizing the lowest level of establishment productivity to 1, the above mapping implies a range of establishment-level productivity from 1 to 3.98.

We set the parameter $c_f = 0$ in our benchmark calibration, which implies that all establishments that receive draws of s will produce output and remain in operation (since $s > 0$ for all establishments). Since we focus on the steady-state implications of the model, endogenous entry and exit will affect the aggregate implications of distortions as long as they affect the invariant distribution of establishments by productivity levels. We discuss the potential importance of this channel in the conclusion section. The value of c_e is normalized to one. Effectively, any changes to this parameter can be undone by scaling the values of establishment-level TFP.

The distribution h is chosen so that the invariant distribution of establishment size across employment levels matches the data. A key feature of the data is that a large number of establishments have a small number of employees so they account for a small share of total employment, whereas a small number of establishments have a large number of employees so they account for a disproportionately large share of total employment. For instance, according to the US Census Bureau for 1997, establishments with less than 10 workers are 73 percent of all the establishments but account for only 14.6 percent of the employment, while establishments with 100 or more workers represent only 2.6 percent of the establishments but 45 percent of the employment. We approximate the distribution h on a grid with 100 points. We consider a log-spaced grid so we have more points at lower levels of productivity than at higher levels of productivity. Because we have assumed that $c_f = 0$ and that λ is independent of s, the ratios of establishment types in the invariant distribution μ are exactly the same as in the distribution h. From the data, we only observe the number of establishments for a set of employment ranges. We assume that establishments are uniformly distributed in each range so that the cumulative distribution function is a linear interpolation across the points for which we have data. In Fig. 1 we document our approximated cumulative distribution

[9] See for instance Pavcnik (2002), Atkeson et al. (1996), Veracierto (2001), Atkeson and Kehoe (2005), among others.

[10] Actually, there are a small number of establishments with 10,000 or more employees in the data. We set the upper limit conservatively to 10,000.

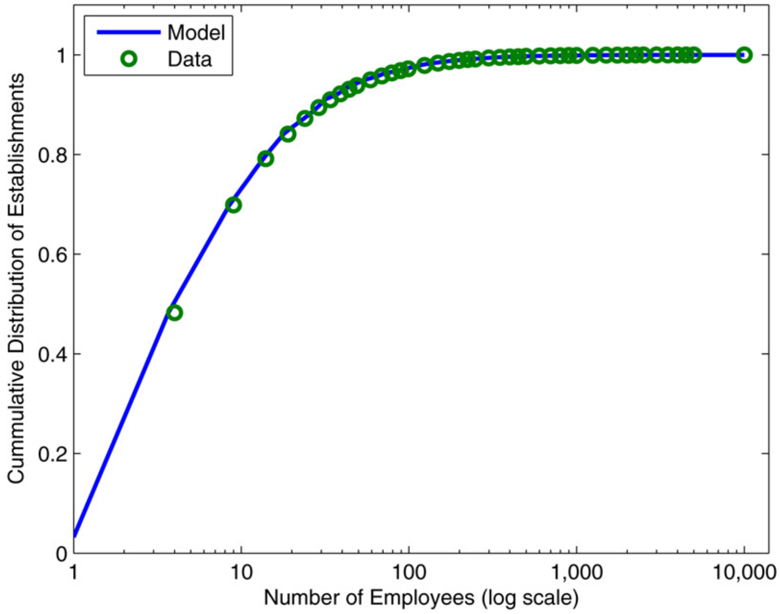

Fig. 1. Distribution of establishments by employment—model vs. data.

Table 1
Benchmark calibration to US data

Parameter	Value	Target
α	0.283	Capital income share
γ	0.567	Labor income share
β	0.96	Real rate of return
δ	0.08	Investment to output ratio
c_e	1.0	Normalization
c_f	0.0	Benchmark case
λ	0.1	Annual exit rate
s range	$[1, 3.98]$	Relative establishment sizes
$h(s)$	see Fig. 1	Size distribution of establishments

H and the cumulative distribution across establishment sizes in the data. The distribution h (and therefore the invariant distribution μ) matches well the size distribution of establishments in the US data.[11]

Note that there is a close connection between the elasticity of the establishment-level factor demand functions with respect to taxes and the elasticity of these functions with respect to TFP at the establishment level. Given our calibration procedure it follows that there is a close connection between the implied range of TFP values and the elasticity of establishment-level factor demands with regard to taxes and subsidies. In particular, if the range of s values is large then these elasticities are small. We will return to this point later on in the paper when we discuss our results.

As noted earlier, we assume a constant exit rate λ across all establishment types and set this value to 10 percent. This generates an annual job destruction ratio of 10 percent which is roughly what Davis et al. (1996) report for the US manufacturing sector. Tybout (2000) reports annual exit rates for establishments in developing countries that are roughly consistent with this value as well. We summarize parameter values and targets in Table 1.

Note that because we focus only on the steady state, there is no need to specify the utility function in order to solve for the equilibrium allocation. If we wanted to evaluate the welfare costs of distortions then we would need to specify the utility function, but since we will focus on quantifying the effects of various policies on TFP this will not be necessary.

It is of interest to look at some of the properties of the steady-state distributions in the benchmark economy. (See Table 2.) First, although more than 50% of the establishments have less than 5 workers, these establishments represent a small fraction of total employment (around 8 percent). Second, as commented earlier, because of the exponential functional form for the production function and the assumption that the exponents are independent of TFP, we see in Table 2 that

[11] We are grateful to Esteban Rossi-Hansberg for providing us specially tabulated data from the US Census Bureau, Statistics of US Businesses for 2000. This data has 44 employment categories from 1 to 10,000 or more employees. See Rossi-Hansberg and Wright (2007) for a detailed documentation of this data.

Table 2
Distribution statistics of benchmark economy

	Establishment size (number of employees)		
	< 5	5 to 49	$\geqslant 50$
Share of establishments	0.56	0.39	0.05
Share of output	0.08	0.34	0.58
Share of labor	0.08	0.34	0.58
Share of capital	0.08	0.34	0.58
Average employment	2.4	15.5	183.0

output and labor shares are equalized, which implies that the distribution of labor and capital across establishment types is the same as the distribution of output across establishment sizes.

5. Quantitative analysis of distortions

In this section we study the quantitative impact of distortions to establishment-level decision making. We present two main sets of results. We first analyze the impact of idiosyncratic distortions when these distortions are uncorrelated with establishment-level productivity s. Second, we analyze the impact of idiosyncratic distortions when these distortions are negatively (positively) correlated with establishment-level productivity, meaning that establishments with low (high) values of s are subsidized and establishments with high (low) levels of s are taxed.

The primary goal of these exercises is to assess the potential impact of reallocation on TFP and the cost of generating a given amount of reallocation. In general, policies that reallocate resources across establishments will also have aggregate effects on capital accumulation. For example, a policy that subsidizes low productivity establishments will cause a greater share of resources to be allocated to low productivity establishments, as will a policy that taxes high productivity establishments. But, whereas the subsidy will also cause capital accumulation to increase, the tax will cause capital accumulation to decrease. Because the effect of taxes on accumulation is relatively well-studied, in each case that we analyze we consider packages of idiosyncratic distortions such that there is no effect on aggregate capital accumulation. In this sense we focus on the TFP effects associated with reallocation and abstract from the capital accumulation effects.

5.1. Uncorrelated idiosyncratic distortions

In this section we introduce idiosyncratic taxes and subsidies as discussed earlier. Here we assume that the distortions are uncorrelated with establishment-level productivity. In particular, we assume that half of the establishments are taxed and half of the establishments are subsidized. Such a configuration of distortions will cause resources to shift from the taxed establishments to the subsidized establishments. However, this will not entail a direct reallocation across productivity classes since there is no correlation between establishment-level TFPs and taxes.

We examine four different levels of this type of policy. We consider taxes of 10, 20, 30, and 40 percent. As described earlier, in each case we set the size of the subsidy so that the net effect on steady-state capital accumulation is zero. This implies subsidies in the range of 6 to 11 percent.

It is interesting to note the apparent asymmetry of the size of the tax and subsidy rate. The reason for this asymmetry is related to decreasing returns in production at the establishment level. Not only are factor input demands from establishments very responsive to net factor costs in our calibration, but also the response is stronger for subsidized plants than for taxed plants. This follows from the shape of the demand function for capital with respect to taxes or subsidies.[12] In the calibrated economy, a one percent increase in after-tax price of output leads to a 6.7 percent increase in capital, holding factor prices constant. Hence, small differences in percent changes of taxes and subsidies are greatly magnified.

Table 3 summarizes the effects of the distortions on several variables of interest. The first row reports the level of output relative to the distortion-free economy. Because aggregate inputs of labor and capital are the same in all cases, this is also the level of aggregate TFP relative to the distortion-free economy. For completeness this is also reported in the second row.[13] The third row reports the level of entry relative to the distortion-free case. Since the total mass of establishments operating is proportional to the mass of entry and the constant of proportionality is the same across all economies, this row also tells us the total mass of establishments in operation relative to the distortion-free economy. The final three rows report statistics related to the distortions. The variable Y_s/Y represents the output share of establishments that are receiving a subsidy, the variable S/Y is the total subsidies paid out to establishments receiving subsidies as a fraction of output, and the variable τ_s is the size of the subsidy required to generate a steady-state capital stock equal to that in the distortion-free economy.

[12] The demand function for capital at the establishment is decreasing in τ (being zero at $\tau = 1$) and convex to the origin. As a result, when half the establishments are taxed randomly, for any given tax rate, a smaller subsidy rate is required to achieve the same aggregate capital stock as in the benchmark economy.

[13] We compute aggregate TFP as the ratio of output to composite input, where composite input is a Cobb–Douglas of aggregate capital and labor using their respective shares in national income.

Table 3
Effects of idiosyncratic distortions—uncorrelated case

Variable	τ_t			
	0.1	0.2	0.3	0.4
Relative Y	0.98	0.96	0.93	0.92
Relative TFP	0.98	0.96	0.93	0.92
Relative E	1.00	1.00	1.00	1.00
Y_s/Y	0.72	0.85	0.93	0.97
S/Y	0.05	0.08	0.09	0.10
τ_s	0.06	0.09	0.10	0.11

Table 4
Relative TFP—uncorrelated distortions

Fraction of establishments taxed (%):	τ_t			
	0.1	0.2	0.3	0.4
90	0.92	0.84	0.78	0.74
80	0.95	0.89	0.84	0.81
60	0.98	0.94	0.91	0.89
50	0.98	0.96	0.93	0.92
40	0.99	0.97	0.95	0.94
20	1.00	0.99	0.98	0.97
10	1.00	0.99	0.99	0.99

We begin with the qualitative patterns. As expected, as the distortion increases so does the effect on output and TFP. Although not reported in the table, output shares across establishment productivity types remain constant across all of these experiments. The source of the TFP differences is that subsidized establishments become larger and taxed establishments become smaller, so that whereas in the undistorted economy all establishments with the same value of s are of the same size, in these economies there is a non-degenerate distribution of establishment size within an establishment level TFP class. With decreasing returns, this entails an efficiency loss. There is also potentially a change in the number of establishments, but as the third row of the table indicates, this effect is zero, so that there is no change in the average level of capital or labor per establishment. As the distortion increases, the share of output accounted for by subsidized firms increases, as do the subsidy rate and the total payment of subsidies relative to output.

Next we turn to the quantitative magnitudes of these effects. Perhaps the most relevant result is that the overall magnitude of the effect on output and TFP is somewhat limited. As the table indicates, the maximum effect on TFP through this channel is around 8 percent. Note that it takes a relatively small tax rate to generate the bulk of this effect. Even with a 10 percent tax rate the output share of subsidized firms is equal to 80 percent, and the maximum effect is virtually attained with a tax rate of 30 percent. Although the maximum drop in TFP is relatively small, it is also interesting to note that few resources are required to finance this distortion. In particular, the total revenues needed to finance this maximum drop in TFP of 8 percent is only 10 percent of output. For the higher tax rates the values of S/Y and τ_s are virtually identical since the tax rate has decreased the tax base by so much that there is virtually no revenue generated.

It is of interest to note that the overall aggregate impact of idiosyncratic distortions depends on the fraction of establishments that are taxed and subsidized. In our previous experiment we assumed that 50 percent of the establishments were taxed and 50 percent subsidized. For the purpose of illustration, Table 4 reports the results on TFP relative to the undistorted economy for different configurations on the fraction of establishments that are taxed. If 90 percent of the establishments are taxed and 10 percent subsidized, the impact of a 40 percent tax would be a reduction in TFP of 26 percent (as compared to 8 percent when 50 percent of the establishments are taxed). When fewer establishments are subsidized, a larger subsidy rate is needed to keep the aggregate capital stock constant and, as a result, it produces a larger reallocation of factors and output across establishments. This reallocation makes establishments operate much farther away from their optimal size, ensuring the larger aggregate effects.

5.2. Correlated idiosyncratic distortions

The distortions considered in the last section were in some sense adding noise to the competitive market. Instead of all firms facing the same prices, each firm faces a different price, but there is nothing systematic about who faces what price. We found that unless the majority of establishments are taxed, the consequences of this were relatively minor. We now consider distortions which at least on the surface would seem to have the potential to do much more damage. In particular we consider the case where establishments with low TFP receive a subsidy and establishments with high TFP are taxed. In particular, we assume that 50 percent of the establishments receive a subsidy while the rest are taxed. In this case,

Table 5
Effects of idiosyncratic distortions—correlated case

Variable	τ_t			
	0.1	0.2	0.3	0.4
Relative Y	0.90	0.80	0.73	0.69
Relative TFP	0.90	0.80	0.73	0.69
Relative E	1.00	1.00	1.00	1.00
Y_s/Y	0.42	0.67	0.83	0.92
S/Y	0.17	0.32	0.43	0.49
τ_s	0.40	0.48	0.52	0.53

Table 6
Relative TFP—correlated distortions

Fraction of establishments taxed (%):	τ_t			
	0.1	0.2	0.3	0.4
90	0.81	0.66	0.56	0.51
80	0.84	0.70	0.62	0.57
60	0.88	0.77	0.69	0.65
50	0.90	0.80	0.73	0.69
40	0.92	0.82	0.76	0.72
20	0.95	0.89	0.84	0.81
10	0.97	0.92	0.88	0.86

the establishments with low productivity s receive a subsidy while those with high s are taxed.[14] Table 5 summarizes the results for this case.

Qualitatively the patterns are similar to those of the uncorrelated case: as distortions increase the drop in output and TFP increases and more resources are shifted toward subsidized establishments. A key difference is that in this case the distortion is not to the size distribution of establishments of a given productivity, but rather to the distribution of resources across establishments of varying productivity. This distortion is much more important quantitatively. As the table shows, the maximum effect on TFP and output in this case is 31 percent, almost four times the effect in the uncorrelated case. The table also shows that this distortion is somewhat more costly to finance. To achieve the TFP reduction of 31 percent, subsidies totaling 49 percent of output are required, and since there are virtually zero revenues raised from taxation, this is the amount of resources that the government must raise in lump-sum taxes.

While protecting and subsidizing low productivity establishments is pervasive in poor countries, large, presumably productive establishments also get subsidized in some countries. The view that often motivates these policies is that larger and more productive establishments need to take on a bigger role in the development process. In the context of our model, policies that subsidize high productivity establishments also have negative effects on output and TFP. These subsidies distort the optimal establishment size even though subsidies entail a reallocation towards more productive units. Overall the effect of these policies is a drop in measured TFP. For instance, in the context of our calibrated model, subsidizing the highest 10 percent of the establishments and taxing the rest at 40 percent would imply a drop in output and TFP of 5 percent.

As with the case of uncorrelated distortions, the quantitative impact of distortions on TFP depends on the number of establishments taxed. Table 6 reports the results on TFP for different configurations on the fraction of establishments taxed. For instance, if 90 percent of the establishments are taxed at 40 percent, the drop in TFP would be 49% (compared to 31 percent in the case where 50 percent of the establishments are taxed).

6. Discussion

6.1. Non-constant aggregate capital

We have focused on experiments where distortions to output prices at the establishment level affect the allocation of factors across establishments with different productivity. In all of these experiments, the amount of resources to be allocated across the different establishments was kept constant and in the context of our model, an implication of this was that the number of establishments and average establishment size was kept constant. In this section, we extend our results to cases where the capital stock changes.

We focus on the correlated case where 50 percent of establishments are taxed at the rate of 40 percent. The proceeds from this tax are rebated back to the consumer as a lump-sum transfer. Table 7 reports the results for different configurations on the fraction of establishments that are completely exempt from the output tax. This is equivalent to taxing a

[14] Establishments are ranked by productivity and since distortions do not affect the distribution of establishments by productivity, we use the cumulative distribution $H(s)$ to find the productivity level threshold $\hat{s}$ such that 50 percent of the establishments are at or below that level, i.e., $H(\hat{s}) = 0.5$. Then establishments with $s \leqslant \hat{s}$ are subsidized and the rest are taxed.

Table 7
Taxing all but some exempt establishments ($\tau_t = 0.40$)

Variable	Establishments exempt (%)				
	10	30	50	70	90
Relative Y	0.66	0.65	0.65	0.69	0.78
Relative TFP	0.85	0.80	0.78	0.79	0.85
Relative E	0.42	0.47	0.53	0.62	0.75
Relative w	0.42	0.47	0.53	0.62	0.75
Relative K	0.42	0.47	0.53	0.62	0.75
Y_s/Y	0.10	0.31	0.52	0.73	0.89

fraction of establishments leaving the remaining establishments undistorted. Compared to our previous analysis, these experiments imply a substantial drop in capital accumulation, ranging from 52 to 25 percent when 10 and 90 percent of the establishments are exempt from the tax. This effect on capital accumulation has an impact on general equilibrium prices and therefore the amount of entry in equilibrium. In all of these configurations, a decrease in the capital stock causes wages and entry to drop by the same magnitude relative to the benchmark economy. These effects cause output effects to be stronger but TFP effects to be weaker than in our previous analysis. For instance, when 50 percent of the establishments are taxed, the drop in TFP is 22 percent (compared to 31 percent in the case where the capital stock is kept constant) while the drop in output is 35 percent. The effect on capital accumulation causes output to drop more, but there is less reallocation to unproductive establishments leading to a lesser effect on relative TFP—output is 52 percent in exempt establishments vs. 92 percent in subsidized establishments in the previous analysis.

6.2. *Taxes on capital and labor*

The previous exercises assumed that the reallocation of resources was achieved through taxes and subsidies that were applied to establishment-level output. We can also conduct the exercises assuming that either labor or capital input serves as the base.

6.2.1. *Tax on capital*

In Table 8 we present the results when capital serves as the base for two different levels of the tax rate. As before, we assume a subsidy that leaves total capital accumulation unchanged. Although the basic message is similar, there are a few differences from the case in which output is taxed/subsidized that bear mentioning. First, there is a more substantial reallocation of capital than there is of output, and this difference is particularly pronounced in the correlated case. Second, there is now also an effect on the mass of establishments in operation, and this effect is of the same magnitude as the change in output and TFP. Third, the level of subsidies required to generate these changes is substantially smaller than that required in the case of output subsidies. Note that distortions levied through capital have an additional channel relative to distortions that work through output. In the case of output taxes, capital to labor ratios are unaffected by the distortions, but this is no longer true in the case of distortions that operate through factor prices. Finally, there is one result that seems somewhat perverse—namely that the subsidy rate required to maintain a constant aggregate capital stock does not increase in the correlated case as the tax rate increases. The reason for this is that an increase in the tax rate also causes wages to decrease and this decrease in wages also affects the demand for capital.

6.2.2. *Tax on labor*

It turns out that our exact exercise cannot be carried out for the case of taxes and subsidies applied to labor. In particular it is generally not possible to distort the labor allocation across establishments and also leave the aggregate capital stock unchanged by using only taxes and subsidies to establishment-level labor. The reason for this is that labor is fixed, and any misallocation of labor necessarily affects the marginal product of capital. If more labor could be hired then this would raise the marginal product of capital and lead to increased capital accumulation, but our current formulation does not allow for this channel. One possible way to accommodate this is by adding a subsidy to capital accumulation or a subsidy to output. This leads to an extra degree of freedom and thus makes it somewhat difficult to compare the results. Given this issue, for the case of taxes and subsidies levied on labor we report the results for a case in which distortions to wage rates are set to $\tau_t = -\tau_s = 0.5$ and half of the establishments are taxed and the other half are subsidized. Because this policy may not lead to the same level of capital in the steady state, we also report the same policy configuration for the case of distortions on output. Results are reported in Table 9. For the case of uncorrelated distortions, the effect on TFP is somewhat larger with taxes on labor than in the case where taxes are levied on output, whereas for the correlated case, the effect on TFP is comparable but the effect on output is larger with taxes on labor. In the uncorrelated case the drop in TFP is 11 percent and in the correlated case the drop is 33 percent, whereas with output as the base we obtain TFP decreases of 2 and 34 percent. As with the case of capital as a base, these subsidies also distort the capital to labor ratio at the establishment level, thereby suggesting the possibility of somewhat larger effects. Also note that the amount of reallocation—measured by the share of output of subsidized establishments—is somewhat larger for distortions on output than for distortions on labor.

Table 8
Idiosyncratic distortions to capital rental rates

	Uncorrelated		Correlated	
	$\tau_t = 0.50$	$\tau_t = 1.00$	$\tau_t = 0.50$	$\tau_t = 1.00$
Relative Y	0.97	0.95	0.89	0.82
Relative TFP	0.97	0.95	0.89	0.82
Relative E	0.97	0.95	0.89	0.82
Y_s/Y	0.74	0.83	0.33	0.46
S/Y	0.03	0.04	0.10	0.14
τ_s	0.14	0.15	0.51	0.51

Table 9
Idiosyncratic distortions—output vs. wages

	Uncorrelated		Correlated	
	Output	Wages	Output	Wages
Relative Y	1.14	0.84	0.65	0.58
Relative TFP	0.98	0.89	0.66	0.67
Relative K	1.70	0.84	0.96	0.58
Relative E	1.70	0.84	0.96	0.58
Relative w	1.70	1.67	0.96	1.00
Y_s/Y	1.00	0.98	0.97	0.79
S/Y	0.50	0.56	0.48	0.45

7. Conclusion

We have analyzed distortions that lead to reallocation of resources across heterogeneous production units. Our results indicate that the impact of these distortions on aggregate output and TFP can be quite large. Given the pervasiveness of policies, regulations, and institutions that induce reallocations of resources across productive units, it seems to us that this channel may be important in accounting for some of the cross-country patterns in output, capital accumulation and TFP.

It remains of interest to examine how our findings would be affected by assuming production functions with different features such as fixed costs, capacity constraints or fixed proportions. We also note that larger TFP differences would also result if we assumed that c_f were greater than zero and there was some selection in terms of which entering establishments choose to produce output. In this case, subsidies that are negatively correlated with establishment productivity may reduce the productivity-entry threshold thereby bringing less productive technologies into the market. We have avoided this channel since by placing a lot of mass on establishments with productivity below those being used in the distortion-free economy, it would seem to add an arbitrary element to the analysis. At the same time, it could be that policies in many countries do serve to allow establishments to operate that would not operate at all in a market free of distortions, so this margin may be of practical importance. In fact, government policies such as trade protection and corporate bankruptcy laws are usually studied in the context of models with this margin (see for example Tybout, 2000 and the references therein, and Bergoeing et al., 2002).

An important objective for future work is to devise ways of restricting the magnitude and types of policy distortions and to evaluate their aggregate consequences. A general procedure is already being implemented empirically by Hsieh and Klenow (2007b) on the characterization of the generic type of policies we emphasize in China and India. Also important would be to develop strategies to obtain better measures of specific distortions and to evaluate them.

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