Policy Distortions and Aggregate Productivity with Heterogeneous Plants[†]

Diego Restuccia

University of Toronto

Richard Rogerson

Arizona State University

July 2003

Abstract

We formulate a version of the growth model in which production is carried out by heterogeneous plants and calibrate it to US data. In the context of this model we argue that differences in the allocation of resources across heterogeneous plants may be a significant 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 TFP, on the order of 30%. We show that these effects can result from policies that do not rely on aggregate capital accumulation or aggregate relative price differences. More generally though, the model can be used to generate differences in capital accumulation, relative prices, and measured TFP.

Keywords: Plant heterogeneity, productivity, policy distortions.

JEL Classification: O1.

[†]Very preliminary and incomplete. *E-mail:* diego.restuccia@utoronto.ca, Richard.Rogerson@asu.edu.

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 significant in understanding cross-country differences in per capita incomes. That is, it is not only the level of factor accumulation that matters but 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 plants as determinant of aggregate productivity. For example, Baily, Hulten, and Campbell (1992) document that about half of overall productivity growth in U.S. manufacturing in the 80's can be attributed to factor reallocation from low productivity to high productivity plants. This aspect of the growth process is also emphasized by Harberger (1998).

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 of plant-level productivities and the distribution of resources across these plants is a key element of the equilibrium resource allocation. In a reasonably 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 plants. 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 of almost 30%, even though the underlying range of available technologies is the same.

The policies that we consider are simple and abstract. In particular, we analyze policies that levy plant-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. For example, 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 Rosengreen (2003) argues that such misallocation is highly prevalent in Japan. 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.

Indeed, there is a growing literature studying the role of particular distortions on TFP and output. For example, 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 Klenow and Hsieh (2003). Lagos (2001) 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 80's. Trade barriers and reforms are studied in the context of a general equilibrium model similar to ours in Chu (2002). 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 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 example, 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.[1] 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 total factor productivity is a subject of great controversy.[2] Our theory of plant hetero-

[1]See for instance the work of Mankiw, Romer, and Weil (1992) and Chari, Kehoe, and McGrattan (1996).
[2]See for example, Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), Prescott (1999), and Mankiw (1995).

geneity offers a link of these two 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 our benchmark economy to data for the U.S. and in Section 5 we analyze the quantitative effects of idiosyncratic distortions in our calibrated model. Section 6 concludes.

2 Economic Environment

We consider a standard version of the neoclassical growth model augmented along the lines of Veracierto (2001) to allow for plant level heterogeneity as studied by Hopenahyn (1992) and Hopenhayn and Rogerson (1993). Plants have access to a decreasing returns to scale technology and pay a fixed cost of entry c_e. Plants die stochastically and hence in steady state there is ongoing entry and exit. Differently than the authors mentioned above we abstract from plant-level productivity dynamics by assuming that the productivity level of the plant remains constant over time. We study the competitive equilibrium of this model in which plants take the wage rate and the rental rate of capital as given and make zero expected profits. We then analyze distortions which leave aggregate relative prices constant but influence the output price or factor prices faced by individual firms. 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. Households are 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 plant. Each plant is described by a production function $f(s,k,n)$ that combines capital (k) and labor (n) services to produce output. The function f is assumed to exhibit decreasing returns to scale in capital and labor jointly, and to satisfy the usual Inada conditions. The parameter s varies across plants and will capture the fact that technology varies across plants. Since our goal is to focus on the cross-sectional heterogeneity of plants we abstract from time series variation in s and hence assume that the value of s is constant over time for a given plant. In our quantitative work we assume

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

Note that in adopting such a specification we are implicitly assuming that the only difference across plants is the level of TFP. In particular, this functional form implies that capital to labor ratios are the same across plants in an equilibrium with no distortions. While this is at odds with the data we make this assumption in order to focus attention on the allocation of resources across units which differ along a single dimension–their 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 plant wants to remain in existence then it must pay the fixed output cost. The net output produced by a plant that remains in existence is therefore given by $f(s,k,n) - c_f$. If a plant does not pay the fixed cost in any period then it ceases to exist.

Although plant level TFP is assumed to be constant over time for a given plant, we assume that all plants face a probability of death. Specifically, we assume that in any given period after production takes place, each plant faces a constant probability of death equal to λ. It would be easy to allow this value to depend on the plant-level productivity parameter s, but we will assume it to be constant across types in the analysis carried out below.[3]

[3] As will be seen later, for our purposes what matters is the invariant distribution of plants across types,

Exogenous exit realizations are *iid* across plants and across time.

New plants can also be created, though it is costly. Specifically, in each period a new plant can be created by paying a cost of c_e measured in terms of output. After paying this cost a realization of the plant level productivity parameter s is drawn from the distribution with *cdf* $H(s)$. Draws from this distribution are *iid* across entrants. Let E_t denote the mass of entry in period t. We assume that there is an unlimited mass of potential entrants.

Feasibility in this model requires:

$$C_t + X_t + c_e E_t \leq Y_t - M c_f,$$

where C_t is aggregate consumption, X_t is aggregate investment, E_t is aggregate entry, Y_t is aggregate output, and M 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 plant-level decisions and hence cause a reallocation of resources across plants. 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 plant 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. At the time of entry, the plant-level tax rate is not known, but its value is revealed once the plant draws its value of s and before production takes place. We allow for the possibility that the value of the plant-level tax rate may be correlated with the draw of the plant-level productivity parameter, although this is not imposed in all our specifications. We also assume that the

and whatever changes we introduce via λ would be undone by changes to the draws of s by new entrants.

value of this tax rate remains fixed for the duration of the time for which the plant is in operation. We will use τ to generically refer to the plant-level tax rate.

From the perspective of an entering plant, they face draws of s and τ, and what matters to them is the joint distribution over these pairs. For a given *cdf* 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 *cdf* by $G(s, \tau)$.

A given distribution of plant-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 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 plants 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 plants 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:

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

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 plants, 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 Plant's Problem

The profit maximization problem of a plant is effectively static since there is no link between decisions made in different periods. In particular, conditional upon remaining in operation a plant 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 plant's value of s does not change over time. Consider a plant 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:

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

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

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

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

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

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

where R is the (steady-state) real interest rate.

3.3 Entering Plant's Problem

Potential entering plants 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:

$$W_e = \int_{(s,\tau)} \max_{e\in\{0,1\}} \left[\pi(s,\tau), 0\right] dG(s,\tau) - c_e,$$

where the max inside the integral reflects the fact that the potential entrant will optimally decide whether to engage in production after observing their realized draw of (s,τ). We let $\bar{e}(s,\tau)$ denote the optimal entry decision with the convention that $\bar{e}=1$ implies the potential entering plant produces and hence remains in operation.

In an equilibrium with entry, W_e must be equal to zero, since otherwise additional plants would enter. The condition $W_e = 0$ is thus referred to as the free-entry condition. Note, however, that the function $\pi(s,\tau)$ is completely determined by the values of 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 Plants

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

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

where the first term represents the mass of plants this period that remain productive and the second term represents the mass of entering plants that produce. 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:

$$\hat{\mu}(s, \tau) = \frac{\bar{e}(s, \tau)}{\lambda} dG(s, \tau).$$

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 $\bar{e}(s, \tau)$, and also the associated invariant distribution $\hat{\mu}$. Aggregate labor demand is then given by

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

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:

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

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 plants $\mu(s,\tau)$, a mass of entry E, value functions $W(s,\tau)$, $\pi(s,\tau)$, W_e, policy functions $\bar{e}(s,\tau)$, $\bar{k}(s,\tau)$, $\bar{n}(s,\tau)$ for individual plants, and aggregate levels of output (Y), 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 plant's problems and $\bar{k}$, $\bar{n}$, $\bar{e}$ are optimal policy functions,

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

(iv) (Market clearing)

$$\begin{aligned} 1 &= \int_{s,\tau} \bar{n}(s,\tau) d\mu(s,\tau), \\ K &= \int_{s,\tau} \bar{k}(s,\tau) d\mu(s,\tau), \\ C + \delta K + c_e E &= \int_{s,\tau} (f(s,\bar{k},\bar{n}) - c_f) d\mu(s,\tau), \end{aligned}$$

(v) (Government budget balance)

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

(vi) (μ is an invariant distribution)

$$\mu(s, \tau) = E \frac{\bar{e}(s, \tau)}{\lambda} dG(s, \tau).$$

4 Calibration

In this section we calibrate the model to US data. In our calibration we treat the US 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 plants 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%, implying a value for β of .96. The extent of decreasing returns in the plant level production parameter is potentially an important parameter. It is not clear to us how to pin this down from the data. For our benchmark model we assume a 10% profit share $(1 - \alpha - \gamma)$ and split the remaining share 1/3 to capital and 2/3 to labor, implying $\alpha = .3$ and $\gamma = .6$. We will later discuss the implications of a higher profit share. We choose δ so that the investment to output ratio is equal to .20. This implies $\delta = .08$. The implied capital to output ratio is 2.47.

We assume that there are three levels of plant productivity: $s \in \{s_1, s_2, s_3\}$. We set the parameter $c_f = 0$, in our benchmark model, which implies that all plants that receive draws of s will produce output and remain in operation (as long as s is positive). The value of c_e is normalized to one. Effectively, any changes to this parameter can be undone by scaling the distribution of the individual TFP values. Using the demand functions for capital and labor of a given plant with productivity parameter s the relative demand for labor between any two plants is given by:

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

With $\alpha = 0.3$ and $\gamma = 0.6$, $1/(1 - \alpha - \gamma) = 10$. We use the following decomposition of plant size from the Census of Manufactures: 46% of plants have 5 to 19 employees (weighted average employment size of 10.7), 53% of plants have 20 to 999 employees (weighted average employment size of 118), and 1% of plants have more than 1000 employees. We assume an average employment size of 5000 for this group. Therefore the employment ratio between these plant types relative to the smallest group is 1.0, 11.0, and 467.3. Using the above formula we obtain $s_2/s_1 = 1.27$, and $s_3/s_1 = 1.85$. We also set $s_1 = 1$ as a normalization. The distribution H is chosen so as to match the invariant distribution of plant size across these employment categories. Because we have assumed $c_f = 0$ and that λ is independent of s, the ratios of plant types in the invariant distribution are exactly the same as in the distribution H, making this determination very simple. Given that H only puts mass on three points we simply specify H as (H_1, H_2, H_3) where H_i is the probability that an entering plant draws productivity parameter s_i.

Note that there is a close connection between the elasticity of the plant-level factor demand functions with respect to taxes and the elasticity of these functions with respect to plant-level TFP. Given our calibration procedure it follows that there is a close connection between the implied range of TFP values and the elasticity of plant 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 plant productivity types and set this value to 10%. This generates an annual job destruction ratio of 10% which is roughly what Davis, Haltiwanger, and Schuh (1996) report for US manufacturing. Tybout (2000) reports annual exit rates for plants in developing countries that are consistent with this value as well. A summary of parameter values and targets is provided 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.

As already noted, we assume no distortions in the benchmark economy. When we consider

Table 1: Benchmark Calibration to U.S. Data

Parameter	Value	Target
α	.3	Capital income share
γ	.6	Labor income share
β	.96	Real rate of return
δ	.08	Investment to output ratio
c_e	1.0	Normalization
c_f	0.0	Benchmark case
λ	.1	Annual exit rate
(s_1, s_2, s_3)	(1.00,1.27,1.85)	Relative plant sizes
(H_1, H_2, H_3)	(.46,.53,.01)	Plant size distribution

distortions in the next section we will consider distortions that place all of their mass on two values of τ which we denote by τ_s and τ_t. The interpretation is that $\tau_s < 0$ and reflects a subsidy that is offered to some plants, and $\tau_t > 0$ and reflects a tax that is levied on some plants.

It is of interest to look at some of the properties of the steady-state distributions. Table 2 displays the values for some statistics of interest.

Table 2: Distribution Statistics of B.E.

	Plant Type s		
	s_1	s_2	s_3
Share of plants	.46	.53	.01
Share of output	.04	.53	.43
Share of labor	.04	.53	.43
Share of capital	.04	.53	.43
Average $\bar{n}$	.57	6.28	267.96

There are two main points to note here. First, although almost half of the plants are in the lowest TFP category, they account for only 4% of total output. 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 that capital and labor shares are equalized, which implies that the distribution of labor and capital across plant types is the same as the distribution of output across plant sizes.

5 Quantitative Analysis of Distortions

In this section we study the quantitative impact of distortions to plant-level decision making. We report four main sets of results. Although our primary interest is in idiosyncratic distortions, we begin with an analysis of a common aggregate distortion. Specifically, we analyze the consequences of an aggregate tax on capital services. This is of interest not only since it serves as a useful benchmark but also because the effects of this type of distortion are quantitatively different in a model with heterogeneous production units such as the one that we study than they are in a standard growth model. Although in our calibrated exercise the quantitative differences are not that large it is at least worth noting. Next we move on to consider idiosyncratic distortions. The first results we report correspond to calculations performed using the steady state of the undistorted economy that the calibration was based on. In particular, we ask in the context of that situation what the consequences would be for output (and hence TFP) if resources were to be reallocated away from the most productive plants toward the least productive plants, holding the total amount of resources fixed. This experiment does not correspond to any particular policy experiment but we report the results for it because it seems interesting as a measure of the importance of the cross-sectional resource allocation in an economy with heterogeneous production units.

The next set of results assess the impact of idiosyncratic distortions when these distortions are uncorrelated with plant-level productivity s. And the final set of results assess the impact of idiosyncratic distortions when these distortions are negatively correlated with plant level productivity, meaning that plants with low values of s are subsidized and plants with high 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 plants will also have aggregate effects on capital accumulation. For example, a policy that subsidizes low productivity plants will cause a greater share of resources to be allocated to low productivity plants, as will a policy that taxes high productivity plants. 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 Aggregate Distortions

In this subsection we report how the steady state is affected by a tax on the use of capital services. For purposes of illustration we assess the consequences of a tax rate of 50% levied on all output. This tax rate results in a relative steady state output level of .63 between the distorted and undistorted economies. Note that in the growth model with a capital share equal to one half of the labor share (i.e., capital share equal to one third) this tax would generate a relative steady state level of output given by $.5^{.5} = .70$. The output effect is roughly 10% larger in our model than it is in the standard growth model. The reason for the difference is that in the present model there are decreasing returns to scale and when capital is taxed there is also decreased entry of plants. This means that there is an increase in the number of workers per plant which decreases productivity. In fact, the drop in measured TFP in the model as a result of the tax on income is roughly 10% and hence accounts for all the predicted output difference between our model with plant heterogeneity and the standard growth model.

5.2 Effects of Reallocation in the Steady State

In this section we carry out the following calculation. Consider the steady state equilibrium for the calibrated economy. This economy has no distortions and hence the steady state equilibrium is efficient. In this steady state equilibrium there is heterogeneity of productive units in equilibrium; plants with all three levels of TFP are in operation. In equilibrium, capital to labor ratios are the same across all plant types, but higher productivity plants are allocated more inputs. In particular, as noted earlier, the distribution of plants across s_1, s_2, and s_3 is given by the vector $(.46, .53, .01)$ but the distribution of output across the three plant types is given by the vector $(.04, .53, .43)$.

We now ask the following hypothetical question. Taking as given the aggregate resources (capital, labor, number of plants) from the steady state equilibrium, how large would the output effects be if we were to reallocate resources across existing plants? In particular, we assume that all resources are divided equally among all of the low productivity plants in the steady state equilibrium. Because the amount of aggregate capital accumulated and the number of plants in existence reflect decisions that were optimal under the original allocation, this reallocation does not correspond to an equilibrium. However, despite this we think it is informative as a measure of the size of effects that are implicit in the model. Moreover, because we will look at policy packages which imply no change in the aggregate capital stock, it will turn out that this experiment is not so far from some of the experiments we look at later.

When we carry out this exercise we find that output drops by 29%. There are a couple of points of interest to note about this answer. First, the answer is not exactly given by taking the appropriate change in the output-weighted averages of plant-level TFP's. In the original equilibrium this weighted average is 1.51 and if we reallocate all resources to the low productivity plants then the level drops to 1.00 (a fall of 33%). But the drop in output associated with the reallocation is smaller than this number. This calculation would only be of interest if plants had CRS technologies. But, in this model, if plants have CRS technologies and different TFP's then only the plants with the highest TFP's will produce in equilibrium. In the steady state with decreasing returns to scale at the plant level, marginal products are equalized across plants. With our production function, this also implies that average products are equalized across plants. So, in the equilibrium, a low TFP plant is operating at a scale such that its efficiency is the same as that of the high TFP plants. It follows that at the margin, a slight reallocation of resources across plants has no aggregate impact. In particular, for a marginal reallocation the difference in TFP's does not reflect the output loss.

The importance of this logic becomes even clearer if we were to consider the reverse reallocation. If we reallocate from low TFP plants to high TFP plants we would also see a decrease in output, even though higher TFP plants are being allocated more resources. This point is important because it explains why the reallocation effect cannot simply be reported directly from knowing the plant level TFP factors.

5.3 Uncorrelated Idiosyncratic Distortions

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

We examine four different levels of this type of policy. We consider taxes of 10%, 20%, 30%, and 40%. 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 5% to 7%.

It is interesting to note the apparent asymmetry of the size of the tax and subsidy rate. The reason for this asymmetry is that factor input demands from plants are very responsive to net factor costs in our calibration: a one percent increase in after tax returns leads to a ten percent increase in capital, holding factor prices constant. Hence, small differences in percent changes for equal size taxes and subsidies are greatly magnified, leading to the apparent asymmetry.

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. The third row reports the level of entry relative to the distortion free case. Since the total mass of plants 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 plants 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 plants that are receiving a subsidy, the variable S/Y is the total subsidies paid out to plants 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.

Table 3: Effects of Idiosyncratic Distortions - Uncorrelated Case

	τ_t			
	.10	.20	.30	.40
Relative Y	.98	.95	.94	.93
Relative TFP	.98	.95	.94	.93
Relative E	1.00	1.00	1.00	1.00
Y_s/Y	.79	.93	.98	1.00
S/Y	.04	.06	.07	.07
τ_s	.051	.066	.070	.072

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 plant productivity types remain constant across all of these experiments: the output shares of s_1, s_2, and s_3 plants are .04, .53, and .43 respectively. The source of the TFP differences is that subsidized plants become larger and taxed plants become smaller, so that whereas in the undistorted economy all plants with the same value of s are of the same size, in these economies there is a non-degenerate distribution of plant size within a plant level TFP class. With decreasing returns, this entails an efficiency loss. There is also potentially a change in the number of plants, 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 plant. 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 significant 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 7%. Note that it takes a relatively small tax rate to generate the bulk of this effect. Even with a 10% tax rate the output share of subsidized firms is equal to 79%, and the maximum effect is virtually

Table 4: Effects of Idiosyncratic Distortions - Correlated Case

	τ_t			
	.10	.20	.30	.40
Relative Y	.88	.79	.74	.73
Relative TFP	.88	.79	.74	.73
Relative E	1.00	1.00	1.00	1.00
Y_s/Y	.57	.84	.95	.99
S/Y	.18	.30	.35	.37
τ_s	.318	.359	.370	.372

attained with a tax rate of 30% . Although the maximum drop in TFP is relatively small, it is also interesting to note how few resources are required to finance this distortion. In particular, the total revenues needed to finance this maximum drop in TFP of 7% is only 7% 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 not clear what the correct metric is to compare these distortions to aggregate distortions, but as one comparison, we ask what an aggregate proportional tax rate of 7% (i.e., a tax on the output of all plants) would do in this model. The answer is that output would fall by 5%. So, by this metric, although the maximum effect is relatively small, the size of the effect is similar to that generated by aggregate distortions.

5.4 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 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 plants with low TFP receive a subsidy and plants with high TFP are taxed. In particular, we assume that plants with $s = s_1$ receive a subsidy while those with $s = s_2$ or $s = s_3$ are taxed. Table 4 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 plants. A key difference is that in this case the distortion is not to the size distribution of plants of a given productivity, but rather to the distribution of resources across plants 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 27%, 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 27%, subsidies totalling 37% 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. Again, as a comparison we can ask what magnitude of effects would be generated by an aggregate output tax of 37%, and the answer is that this tax would reduce output by 27%. So, once again the message is that by this metric the effects due to idiosyncratic distortions seem to be comparable to those generated by aggregate distortions.

5.5 Discussion

The above exercises assumed that the reallocation of resources was achieved through taxes and subsidies that were applied to plant-level output. We can also repeat the exercises assuming that either labor or capital input serves as the base. In Table 5 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 plants 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 are significantly smaller than those 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 latter case capital to labor

Table 5: Idiosyncratic Distortions to Capital Rental Rates

	Uncorrelated		Correlated	
	$\tau_t = .50$	$\tau_t = 1.00$	$\tau_t = .50$	$\tau_t = 1.00$
Relative Y	.97	.95	.89	.82
Relative TFP	.97	.95	.89	.82
Relative E	.97	.95	.89	.82
Y_s/Y	.82	.91	.43	.62
K_s/K	.89	.96	.66	.84
S/Y	.03	.03	.09	.12
τ_s	.10	.09	.42	.40

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 decreases in both cases 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.

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 plants and also leave the aggregate capital stock unchanged by using only taxes and subsidies to plant-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 simply report the results for a case in which we set $\tau_t = \tau_s = .5$. This will necessarily result in a lower level of capital in the steady state, thus making the results not strictly comparable to those reported earlier. In view of this we direct our attention primarily to the effects on TFP rather than the effects on output. Results are reported in Table 6.

Table 6: Idiosyncratic Distortions to Wage Rates

	Uncorrelated	Correlated
Relative Y	.89	.60
Relative TFP	.92	.70
Relative K	.89	.60
Relative E	.89	.60
Y_s/Y	1.00	.97
N_s/N	1.00	.99
S/Y	.60	.58
τ_s	.50	.50

The effect on TFP is somewhat larger here than in the case where taxes and subsidies are levied on output. In the uncorrelated case the drop is 8% and in the correlated case the drop is 30%, whereas with output as the base we obtained TFP decreases of 7% and 27%. As with the case of capital as a base, these subsidies also distort the capital to labor ratio at the plant level, thereby suggesting the possibility of somewhat larger effects. Also note that the level of subsidies required are much larger in this case than in the other cases.

The final issue that we touch on here concerns the sensitivity of our results to changes in the underlying specification. In particular, because the TFP losses that we measure are due to moving resources across plants with different levels of TFP, one would presume that if we had larger dispersion in values of s across plants that the potential TFP effects would be much larger. In a mechanical sense this is certainly true. In this regard it is important to note that in our calibration the range of plant level TFP's is disciplined by the data on relative plant sizes. Hence, the range of TFP values cannot be set arbitrarily. One might conjecture that if we considered more classes of plant size in our calibration exercise that we would be able to obtain much larger differences in the values of s and hence also much larger decreases in TFP. The potential size of this effect, however, is not particularly large. For example, if we considered an extreme case in which plants with 1 employee were treated as the smallest unit, the lowest value of s would be roughly .8 instead of the current value of 1.

More generally, however, while larger differences in the range of s will make it possible to obtain larger decreases in TFP associated with reallocation, the larger range of s will only arise if it requires a larger range of s values to reproduce a given relative plant size. This requires that the elasticity of employment with respect to s be smaller. But, if this is true, then it will require much larger subsidies to reallocate resources in such an economy. Hence, although there may be a greater potential for reallocation to produce larger decreases in TFP, it will also take much larger distortions to generate those losses. It is because of this that we feel it is useful in our current analysis to relate the TFP losses with the associated volume of subsidies. For example, if we change the extent of decreasing returns in our plant level production function then we can obtain much larger ranges of s but we also get less reallocation for a given tax and subsidy plan.

We have explored this issue via sensitivity analysis. In the interest of space here we simply report one such case. Following the choices of Veracierto (2001) we set $\alpha = .19$ and $\gamma = .64$, implying a profit share of 17%, substantially larger than our benchmark value of 10%. This reduces the elasticity of labor to changes in plant level TFP from 10 to approximately 6. Using the same calibration procedure we obtain an s vector of $(1.0, 1.51, 2.89)$ instead of $(1.0, 1.27.1.85)$. We find that in the case of correlated idiosyncratic distortions applied to output that the maximum effect on TFP is roughly 40%, which is roughly an additional 10% higher than we found above. However, to achieve this effect requires a tax on high productivity plants of 50%, and a subsidy rate of 72%. Previously we obtained drops in TFP of roughly 27% from a tax rate of 40% and a subsidy rate of 37%. So, although larger differences can be generated, it is more costly to generate them as well.

Having said this 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 plants choose to produce output. In this case, subsidies that are negatively correlated with plant 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 productivities below those being used 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 plants to operate that would not operate at all in a market free of distortions, so this margin may be of practical importance. 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).

6 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. Based on one metric, we find that the effect of these distortions is roughly similar to the effects associated with distortions to aggregate relative prices. Given the pervasiveness of policies and regulations that induce reallocations of resources across productive units, it seems to us that this channel may be significant in accounting for some of the cross-country patterns in output, capital accumulation and TFP.

References

[1] Baily, M., C. Hulten, and D. Campbell, 1992, "Productivity Dynamics in Manufacturing Plants," *Brooking Papers on Economic Activity: Microeconomics* 187-267.

[2] Bergoeing, R., P. Kehoe, T. Kehoe, and R. Soto, 2002, "A Decade Lost and Found: Mexico and Chile in the 80's," *Review of Economic Dyanamics* 5(1): 166-205.

[3] Chari, V., P. Kehoe, and E. McGrattan, 1996, "The Poverty of Nations: A Quantitative Exploration." Staff Report 204. Federal Reserve Bank of Minneapolis.

[4] Chu, T., 2002, "Exit Barriers and Productivity Stagnation," manuscript, University of Hawaii.

[5] Davis, S., J. Haltiwanger, and S. Schuh, 1996, *Job Creation and Destruction,* The MIT Press: Cambridge, Massachusetts.

[6] Harberger, A., 1998, "A Vision of the Growth Process," *American Economic Review,* 88(March): 1-32.

[7] Hall, R. and C. Jones, 1999, "Why Do Some Countries Produce so Much More Output per Worker Than Others? *Quarterly Journal of Economics*: 83-116.

[8] Herrendorf, B. and A. Texeira, 2003, "Monopoly Rights Reduce Income Big Time when there is Capital Accumulation," manuscript, Universidad Carlos III de Madrid.

[9] Hopenhayn, H., 1992, "Entry, Exit, and Firm Dynamics in Long Run Equilibrium," *Econometrica* 60: 1127-50.

[10] Hopenhayn, H. and R. Rogerson, 1993, "Job Turnover and Policy Evaluation: A General Equilibrium Analysis," *Journal of Political Economy,* 101(5): 915-38.

[11] Klenow, P. and A. Rodriguez-Clare, 1997, "The Neoclassical Revival in Growth Economics: Has it Gone Too Far?," NBER Macroeconomics Annual. University of Chicago Press.

[12] Klenow and Hsieh, 2003, "Relative Prices and Relative Prosperity," manuscript, Princeton University.

[13] Lagos, R., 2001, "A Theory of TFP," manuscript, New York University.

[14] Mankiw, G., D. Romer, and D. Weil. 1992. "A Contribution to the Empirics of Economic Growth." *Quarterly Journal of Economics* 107(2): 407-38.

[15] Mankiw, G., 1995, "The Growth of Nations," *Brookings Papers on Economic Activity: Macroeconomics,* 1: 275-326.

[16] Parente, S. and E. C. Prescott, 1999, "Monopoly Rights: A Barrier to Riches," *American Economic Review,* 89: 1216-33.

[17] Parente, S. and E. C. Prescott. 2000. *Barriers to Riches.* MIT Press. Cambridge, Massachusetts.

[18] Peek, J. and E. Rosengren, 2003, "Unnatural Selection: Perverse Incentives and the Misallocation of Credit in Japan," NBER Working Paper 9643.

[19] Prescott, E. C. 1998. "Needed: A Theory of Total Factor Productivity." *International Economic Review* 39: 525-52.

[20] Schmitz, J., 2001, "Government Production of Investment Goods and Aggregate Labor Productivity," *Journal of Monetary Economics* 47: 163-87.

[21] Tybout, J., 2000, "Manufacturing Firms in Developing Countries: How Well Do They Do, and Why?" *Journal of Economic Literature,* 38(1): 11-44.

[22] Veracierto, M., 2001, "Employment Flows, Capital Mobility, and Policy Analysis," *International Economic Review* 42(3): 571-95.