Regulation, Taxation, and Economic Development

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Regulation, Taxation, and Economic Development

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Abstract

In this paper we construct a model with increasing returns stemming from product variety to explore the different effects of regulations and taxes on economic development, real activity, and growth. Regulations raise fixed and variable costs, while taxes primarily increase variable costs. This is important because fixed costs determine the extent of specialization, which in our model plays an important role in human capital accumulation and development. Given the choice, taxation is preferred to regulation, because of regulation's negative effects on the growth of human capital. Empirical tests using panel data across countries provide support for the theory. (JEL Codes: O41, O33, O14, E24, E23)

1 Introduction

Regulation and taxation are used by governments to influence behavior, raise revenue, and carry out the administrative processes necessary for governing. To some extent, regulation and taxation are substitutes. Clean water, better gasoline mileage, redistribution of income, and other social goals can be accomplished by either regulation or taxation. One aim of this paper is to support the idea that, if a choice exists, taxation is the better option. The reason is that regulation is likely to have more negative consequences for development by reducing specialization and the accumulation of human capital.

We construct a model of growth with increasing returns to scale based on variety in production and monopolistic competition to analyze the effect of regulations and taxes on the level of output per capita and its rate of growth. The key difference between regulation and taxation is their fixed-cost character. Regulations have a potentially very large fixed-cost component, in addition to a variable-cost component. Taxes, on the other hand, are...
essentially variable costs. They depend, generally, on how much the firm produces or how much income it earns. Regulations, on the other hand, usually impose at least some costs that do not depend on the scale or success of the operation. For example, the cost of financial compliance, costs associated with medical standards of care, expenses for complying with environmental standards, health and safety costs, licensing fees, and many more impose annual costs on businesses that are at least partly independent of the amount produced.

The cost of tax compliance is counted as part of the regulatory burden, not taxation, both theoretically and in the data we use. It can, for example, be very simple to administer high tax rates imposed at low income levels: there is no connection between our index of taxation and the cost of complying with such tax rates. Complex and confusing tax collection processes, moreover, are possible at any level of taxation and are in the nature of fixed costs, or regulations. Our regulation index data explicitly includes the cost of tax compliance.

To investigate the effect of fixed costs, it is useful to use a model with increasing returns to scale. Our model has two stages of production. In the first stage, intermediate inputs are produced by monopolistically competitive firms using skilled labor. In the second stage, these inputs are combined with additional skilled labor to produce the consumable good. Increases in either regulation or taxation reduce the demand for every intermediate input, and therefore reduce the productivity of labor so real wages and output fall. On the other hand, only regulations reduce the growth rate of output per capita. The reason for the difference is that fixed costs, in the form of regulations, reduce the degree of specialization in the economy. This has two effects: it directly reduces output due to increasing returns in production (as in Romer, 1987) and it indirectly reduces the return to human capital, which depends on the complexity of the economy (as in Lucas, 2009a, 2015). Taxes do not have this effect in our model. Perhaps this is one reason that we, along with many past studies, do not find a significant association between tax rates and growth. We do find strong associations between regulations on both the level of per capita output and its growth rate. It follows, then, that if a country has a choice between regulating and taxing to achieve a policy outcome, it might be better to tax than to regulate.

The second part of the paper tests the predictions of the model using a panel data set going back to 1970 (for some countries). To measure regulation and taxation, we rely primarily on the data from the Economic Freedom of the World database constructed by the Fraser Institute. It constructs a regulation score and tax score, both of which go from 0 to 10, where 10 is the least restrictive regulatory and tax environment. For real GDP per capita, we use the Penn World Table v. 10.01 (depending on the context, we use either the series $RGDP^E$ or $RGDP^{NA}$, divided by the population).

We can summarize our results as follows, using Figure 1 for reference. This figure shows the nature of the relationship between the natural logarithm of per capita real output ($\ln y$) and the regulation score in Panel (a) and the tax score in Panel (b). The straight lines are the simple, pooled OLS regression lines, and the colors identify different countries. Low
regulation (a high regulation score) has a strong, positive association with $\ln y$ in Panel (a). This association persists with fixed effects and instrumental variables. The same is true for the relationship between the growth rate of per capita real output ($\Delta \ln y$) and the regulation score (not shown). These results fit the model’s predictions well. On the other hand, in Panel (b) the association between $\ln y$ and the tax score is barely perceptible, when it should be positive. When we use panel methods, however, we find a positive relationship, but it is weak: low tax rates and high tax brackets (a high tax score) are associated with a higher $\ln y$, but this relationship is not nearly as strong or as robust as that between the regulation score and $\ln y$. On the other hand, as predicted by the model, the tax score appears to have no discernible relationship to the growth rate of real per capita output.

We are aware that regulation and taxation are subject to reverse causality that may make them endogenous to some extent. We address this issue and make the case that our results tend to underestimate the true, structural effect of regulation. To provide more support, we use an instrumental variable to deal with simultaneity, even though the use of instrumental variables will also lead to bias if the strict assumptions do not hold. The instrumental variable results support our conjecture that the bias from OLS underestimates the true effect of regulations.

Our theoretical model does not consider any positive benefit for either regulation or taxation. Some level of both are certainly necessary for the functioning of government and the maintenance of public order. It is not difficult to imagine, however, that many of the benefits do not show up as increases in real output or the speed of development. For example, environmental regulations are very important to maintain and enhance quality of life, but place burdens on job creation and productivity. Taxation is often redistributionist, which can be a huge benefit to low-income workers and those who cannot work, but probably reduces output in both the short run and the long run. Most of the work discussed next takes the view, either explicitly or implicitly, that regulation and taxation on balance reduce economic activity.

We should also note that our empirical approach does not restrict the coefficients in any way, so if either more restrictive regulations or higher taxes raised output or its change, it would show up in our regression results. As we shall see, this is not the case.

An early treatment of regulation was by Stigler (1971), who showed that industry often had the ability to use regulation for its own benefit. Later empirical work seemed to confirm that regulations are often not in the public interest, but rather serve to reward business or politicians. In their work, Djankov et al. (2002) showed that the data was more consistent with what they called the “public choice” view of regulation than the “public interest” view. That is, that businesses were able to use the regulatory structure to reduce competition and increase market share and profit. Dawson and Seater (2013) use the number of pages in the US Code of Federal Regulations to construct a measure of the extent and complexity of regulation in the United States since 1949. Trebbi and Zhang (2023) use O*NET and OEWS/BLS data
Figure 1: Taxation Regulation and the Log of $y$
to measure the labor cost of complying with regulations at the establishment level. They find evidence in support of the idea that regulations impose fixed costs that rise with establishment size. Recent theoretical and empirical contributions by Nicoletti et al. (2003), Bento (2020), and Coffey et al. (2020) show that regulations can have non-trivial negative effects on output.

Taxation has also been examined for effects on economic activity. Probably more so than regulation, taxation is subject to simultaneous causality: changes in income certainly lead to changes in tax revenue, but also might lead to changes in top marginal tax rates and tax brackets – which our tax score measures. Thus, much of the empirical literature is concerned with identifying exogenous shocks to tax policy to see the subsequent effect on per capita output and growth. In a recent paper, Nguyen et al. (2021) use data from the United Kingdom to show that income tax reductions (unlike consumption tax reductions) have strong positive effects on output and growth. See also Zidar (2019), Mertens and Montiel Olea (2018), Barro and Redlick (2011), and Romer and Romer (2010); all of which show a negative impact of taxes on economic activity. Jaimovich and Rebelo (2017) propose a model, based on a distribution of ability among entrepreneurs, in which increases in taxes have little impact on growth when initial taxes are low, but very pronounced negative effects when taxes are already at a high level. They suggest that the effects of raising taxes when they are in this zone are so harsh that no developed countries ever raise taxes so high — so the data does not show a strong negative correlation between growth and taxes. We also find little to no effect from taxes on growth, but for different reasons.

There is also a recent literature that focuses on the effect of taxation and regulation on innovation. Aghion et al. (2021) use a Schumpeterian model to show that a “regulatory tax” that applies only to firms that employ more than 50 workers discourages innovation most strongly for firms just below the threshold. Stantcheva (2021) shows that taxes affect innovation negatively, so that optimal tax rates that account for innovation are lower than those that do not. Akcigit and Stantcheva (2020) provides an overview of this literature, with an emphasis on the margins upon which innovators respond to taxation. This literature, like ours, ignores the possible benefits of regulation and taxation. It does not, however, model regulation as having a fixed-cost component.

The paper is organized as follows. In Section 2 we set out the production technology and in Section 3 we describe how human capital is accumulated. Then, in Section 4 we solve the static production equilibrium for the firms. In Section 5 we solve for the households’ saving and consumption over time and calculate the closed-form solution for the growth rate. We look at the model’s predictions of regulatory and tax policy for both level effects and growth effects in Section 6. There, we provide some examples to show that regulation, unlike taxation, typically has a large fixed-cost component. We also calibrate the model to the US economy to illustrate that regulation has more severe effects on the path of output compared to taxation. Then, we use our model in Section 7 to set up an empirical framework and present our results. Section 8 concludes the paper.
2 Production Technology

There is one fundamental input, labor enhanced by human capital, that is used to produce both a final good $Y$ and several intermediate input goods $x_i$. The final good is produced by competitive firms while the inputs are produced by $M$ distinct monopolistic competitors. The household’s decision at each instant is to chose how much to work $e_w$ and how much to study $e_l$ to accumulate more human capital. Work is further subdivided into work in the final-goods sector $e_y$ and work in the intermediate-goods firms $e_x$. Individuals are endowed with one unit of effort per time period so the time constraint is:

$$1 = e_w + e_l = e_y + e_x + e_l$$

(1)

The production technology is given by:

$$Y = (e_y \bar{h}N)^{1-\alpha} \int_{0}^{M} (x(i))^\alpha di$$

(2)

where $0 < \alpha < 1$. The amount used of each intermediate input $i$ is $x(i)$. The inputs are combined into the final good with the help of effective labor, $e_y \bar{h}N$, where $N$ is the number of workers, $\bar{h}$ is average human capital per worker\(^1\), and, as noted above, $e_y$ is the effort devoted to tasks in the competitive final-goods sector. The limit in the integral $M$ stands for the range of different intermediate goods that are used.

The intermediate goods $x_i$ are distinct inputs, each produced by a unique monopolistically competitive firm using effective labor. The cost function for producing the quantity $x$ of any input good, in units of effective labor, is the same for all intermediates and is given by:

$$V(x) = v_0 + v_1 x$$

(3)

where $v_0$ and $v_1$ are constants. The amount of labor effort $e_x$ in (1) is related to $V(x)$ in a manner specified below.

Aggregate consumption is $C = Y$. There is no difference between the population and the workforce, so per capita consumption and output are given by: $c = \frac{C}{N} = \frac{Y}{N} = y$.

3 Learning Technology

To accumulate human capital, the representative individual spends time learning $e_l$. A key feature of the model is that the degree of specialization in the economy $M$ raises the produc-

\(^1\text{It is important to distinguish between an agent’s own human capital — which she accumulates to increase her real wage — and the economy-wide average human capital } \bar{h}, \text{ which the individual does not regard as something over which she has any influence. Eventually, we equate the two, but not before we derive the conditions for intertemporal equilibrium.} \)
tivity of $e_l$ (see Goodfriend and McDermott, 1995, 1998, 2021). In particular, we model the learning technology as follows:

$$\dot{h} = L^\gamma h^{1-\gamma} e_l - \eta h$$ \hspace{1cm} (4)

where $0 < \gamma < 1$ and $\eta$ is the population growth rate. Population growth $\eta$ enters (4) because of our assumption that parents must spend time to educate the newly born. The \textit{specialization spillover} $L$ is defined to be:

$$L \equiv \frac{M}{\bar{e}_w N}$$ \hspace{1cm} (5)

so that specialization enters proportionally, but we divide $M$ by $\bar{e}_w N$ to account for a negative effect of congestion on the learning externality.$^2$ In (4) the effect of own human capital $h$ and the spillover through $M$ are sufficient to generate steady growth, as we show below.

The fact that specialization $M$ raises learning productivity is a key component of the model. As we shall see, it provides the link from fixed cost of producing intermediate goods $v_0$ to the growth in human capital, and to the growth in $y$.

There is a long tradition of incorporating human capital spillovers into models of economic development, although usually in the production of output, not human capital itself. A notable example is Robert Lucas (1988). In that same paper, however, Lucas conjectures that the quantity and variety of human capital, especially in large cities, spills over to help others generate new, individual knowledge (Section 6). The larger the city, the greater the specialization of activity at all levels, and the larger the spillover to new knowledge formation. He credits Jane Jacobs (1969, 1984) for the key idea that such spillovers raise creativity within and between occupations. In later work, using a framework developed by Kortum (1997), he expanded on the idea that people learn from each other, largely via externalities from random encounters (Lucas 2009b, 2015), perhaps facilitated by trade (Alvarez et al. 2013). We can think of specialization – a measure of goods variety – as a stand-in for the scale of exchange within a country. In his model of population and very long-run development, Michael Kremer linked population size to the generation of knowledge by arguing that ideas arrive randomly through people (Kremer, 1993). Learning-by-doing across different industries is another way of relating specialization to the growth of individual human capital (Arrow 1962). Ehrlich and Kim (2007) construct a model in which human capital spillovers to new knowledge generation account for some key facts of structural change and the demographic transition.

Our spillover $L$ can be thought of as a reduced-form way of accounting for the effect that complexity and variety of modern economies have on the generation of new knowledge.

$^2$Desmet et al. (2018) incorporate negative congestion externalities into their utility function.
4 Production Equilibrium

Final firms operate in a purely competitive market, so factor prices are equal to marginal products. In this section, we solve for the equilibrium values of quantities and prices, taking as given overall effort $e_w$ and the stocks $h$ and $N$.

Final firms demand the input $x$ from each of $M$ distinct monopolistically competitive firms. The price $p$ that they pay reflects the marginal product of each $x$ in the production of the final good given by (2). This yields:

$$p = \alpha \left( \frac{e_y hN}{x} \right)^{1-\alpha}$$

(6)

The intermediate firms, though different, enter final production symmetrically, so the inverse demand curves (6) are the same for each input. The wage of a unit of effective labor $e_y hN$ is likewise equal to its marginal product. From the symmetry of intermediate firms and (2) this yields:

$$w_b = \frac{\partial Y}{\partial (e_y hN)} = (1 - \alpha) \left( \frac{e_y hN}{x} \right)^{-\alpha} M$$

(7)

We call $w_b$ the base wage; it rises with $M$ because labor is combined with all of the different inputs into the final good. The actual wage of a worker $w_s$ is the product of the base wage $w_b$ and that worker’s human capital, $h$: $w_s = w_b h$.

Intermediate firms exploit the demand (6) and produce the quantity $x$ to maximize their profit

$$\pi = px - w_b V(x)$$

(8)

taking the base wage $w_b$ as given. It is well known that profit maximization requires setting the price as a mark-up over marginal cost $v_1 w_b$:

$$p = \left( \frac{1}{\alpha} \right) v_1 w_b$$

(9)

where the gross mark-up is $1/\alpha$.

At all times, the following constraint must hold:

$$e_x hN = MV(x)$$

(10)

This says that the supply of effective labor to the intermediate firms $e_x hN$ must equal the economy-wide demand for those inputs by all intermediate firms $MV(x)$.

We assume that entrepreneurs can costlessly enter and hire labor to produce a new intermediate good. We use Figure 2 to illustrate the nature of the equilibrium that results

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3To derive the markup, put (3) and (6) into the profit expression (8), then take the derivative with respect to $x$, and set to zero.
from this assumption. The EQ curve shows the amount of input $x$ that each intermediate firm would produce to maximize profit, as a function of the range of intermediate firms $M$, given the amount of work in efficiency units, $e_w \hat{h} N$. The ZP locus shows the set of $(M, x)$ points such that the representative intermediate firm makes zero profit. Profit is positive for all points in the shaded area below the ZP locus. The ZP curve crosses the EQ curve from above and they only cross once. The two equations are derived in Appendix B.

If $M$ is small, output $x$ as determined by EQ is relatively high and intermediate-good firm profits are positive. This creates an incentive for entrepreneurs to enter and produce a new, distinct intermediate good. If entry is costless, and there are no legal barriers, then entry will take place and lead to an increase in $M$ and a fall in profit to zero. The zero-profit equilibrium number of firms is $M^*$ in Figure 2.

In the symmetric, zero-profit equilibrium each input is produced in the same quantity:\footnote{To derive (11), substitute the cost function (3) and the mark-up (6) into the profit equation (8), set to zero and solve for $x$.}

\[ x^* = \frac{\alpha e_0}{(1 - \alpha) v_1} \tag{11} \]

Labor effort, in this equilibrium, is allocated proportionally between the two stages of production:\footnote{To see this, substitute the base wage (7) and the input price (6) in the markup equation (9). Then use the constraint (10) and the work relationship $e_w = e_x + e_y$ in the result.}

\[ e_x = \alpha e_w \tag{12} \]
\[ e_y = (1 - \alpha) e_w \tag{13} \]
(11), and (12) to see that in the zero-profit equilibrium $M$ is:

$$M^* = \left(\frac{\alpha (1 - \alpha)}{v_0}\right) e_w \bar{h}N$$  \hspace{1cm} (14)

It is important in what follows that specialization — the number of intermediate goods $M^*$ — is inversely related to fixed cost $v_0$ but not to variable cost $v_1$. It is convenient to think of the degree of specialization $M^*$ as depending on two parts, the fixed-cost component $(\alpha (1 - \alpha) / v_0)$ and the scale component $(e_w \bar{h}N)$.

The equilibrium base wage can be found by taking (7) and substituting the equilibrium values for $x^*$, $e_y$, and $M^*$ found in this section:

$$w_b = B (e_w \bar{h}N)^{1-\alpha}$$  \hspace{1cm} (15)

where:

$$B \equiv x^* \alpha \left(\frac{(1 - \alpha)}{v_0}\right) (1 - \alpha)^{-\alpha} = \frac{\alpha^{1+\alpha} (1 - \alpha)^{2(1-\alpha)}}{v_0^{1-\alpha} v_1^\alpha}$$  \hspace{1cm} (16)

The object $B$ represents the effects on the real wage in (7) that are independent of scale $e_w \bar{h}N$. That is, $B$ shows the effect on the real wage from the quantity of intermediates used $x^*$ and the fixed-cost portion of specialization $M^*$, which is $(\alpha (1 - \alpha) / v_0)$. The other term, $(1 - \alpha)^{-\alpha}$ represents the relation of $e_y$ to $e_w$, insofar as it affects the wage. Below, we separate out the effects of policy change on the effects coming through $B$ and those coming through the scale variable $(e_w \bar{h}N)^{1-\alpha}$.

Scale — whether through $\bar{h}$ or $N$ — has a positive effect on the base wage (15) after we endogenize $M$. New intermediate firms enter the market when effective labor rises and this increases the base wage since the productivity of labor is enhanced when any input increases in quantity or there are more inputs. The effect of $h$ on skilled wages $w_s = w_b h$ is even larger, since it raises productivity proportionally.

In this model there is only one input, labor enhanced by human capital. In the symmetric, zero-profit equilibrium, per capita output $y$ — which is the same as consumption $c$ — is equal to the earnings of the representative worker:

$$y = c = w_b h e_w = B (e_w h)^{2-\alpha} N^{1-\alpha} \hspace{1cm} (h = \bar{h})$$  \hspace{1cm} (17)

The term after the third equality uses (15) and (16) for $w_b$. Increasing returns to scale shows

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6A fixed cost $v_0 > 0$ is necessary for equilibrium. This principle can be illustrated with a simpler model in which output is produced according to $Y = Mx^\alpha$ and a unit of any intermediate good is produced with one unit of labor. The latter means that the cost constraint is $Mx = N$, where $N$ is labor. Without a fixed cost, given $N$, it is possible to increase $Y$ to infinity by continuously raising $M$ and reducing $x$ in the same proportion. In our model, (11) and (14) illustrate the principle. That is, if $v_0 \to 0$, then $M^*$ rises to infinity while $x^*$ goes to zero. See Romer (1987).

7The easiest to way to see this is to multiply (7) by $e_w$ and $h$, then compare it to (2) after dividing by $N$ and assuming symmetry to eliminate the integral in (2).
up clearly in (17): an increase in population $N$ raises wages — as specialization increases — and increases in human capital per worker $\bar{h}$ raise wages more than proportionally.

5 Dynamic Equilibrium

The infinitely-lived representative household maximizes:

$$
\int_{0}^{\infty} N(t) u(c(t)) e^{-\rho t} dt = \int_{0}^{\infty} u(\ln c(t)) e^{-(\rho-\eta)t} dt
$$

by choosing how much to work and learn at each moment. In (18), $u(c(t)) = \ln c(t)$ is instantaneous utility and $\rho$ is the subjective rate of discount. We choose logarithmic utility for tractability. Initial population $N(0)$ is normalized to 1; and population grows at the rate $\eta$.

The only asset in the economy is human capital, and the only form of saving is learning. Individuals spend time studying to accumulate $h$ to raise the skilled wage $w_s = w_b h$, taking $w_b$ to be given. In reality, $w_b$ rises with $h$, as we have seen, due to the scale effect that raises specialization $M$, but individuals are not aware of their own impact on the aggregate scale effect.

The allocation of effort between work $e_w$ and learning $e_l$ is determined by the instantaneous value of $h$ and the instantaneous value of the shadow utility price of human capital $\lambda$. In Appendix C we show how the first-order conditions for the dynamic optimization problem reduce to two differential equations in $h$ and $\lambda$. The learning technology, (4) and (5), controls the change in $h$ over time. The shadow utility price $\lambda$ must change instantaneously to equate the cost and benefit of accumulating $h$: $\dot{\lambda} = (\rho-\eta) \lambda - \frac{\partial H}{\partial h}$, where $H$ is the Hamiltonian equation for the optimization problem. Finally, the transversality condition:

$$
\lim_{t \to \infty} \lambda(t) h(t) e^{-(\rho-\eta)t} = \lim_{t \to \infty} z(t) e^{-(\rho-\eta)t} = 0
$$

assures that the utility value of the stock is zero by the end of time. In (19), we define $z \equiv \lambda h$. We work with the dynamic system in $h$ and $z \equiv \lambda h$, since $z$ is constant in balanced growth (see Appendix C).

The representative household considers the economy-wide averages $\bar{h}$ and $\bar{e}_w$ to be given, but these change as individual behavior evolves over time. To ensure a consistent equilibrium, we force the representative household’s choices to match economy-wide averages. That is, we only consider equilibria where $\bar{h} = h$ and $\bar{e}_w = e_w$.

To begin, note that the learning productivity externality $L$, expressed relative to $h$, is a constant in this model. Put (14) into (5) and divide both sides by $h$ to obtain:

$$
A \equiv \left( \frac{L}{\bar{h}} \right)^\gamma = \left[ \frac{\alpha (1 - \alpha) v_0}{v_0} \right]^\gamma
$$
In what follows, we refer to \( A \) as the “learning productivity”. It is important that \( A \) depends on the fixed cost \( v_0 \) of producing inputs. Above, we called \( \frac{\alpha(1-\alpha)}{v_0} \) the “fixed-cost component” of specialization \( M^* \) in equilibrium. We now see that this fixed-cost component – raised to the power \( \gamma \) — is all that matters for learning productivity.

In Appendix C, we show that equilibrium work effort \( e_w \) and learning \( e_l \) are given by:

\[
e_w = \frac{1}{zA} \quad (21)
\]
\[
e_l = 1 - \frac{1}{zA} \quad (22)
\]

This allows us to express the dynamic system with the following two equations:

\[
\dot{h} = h \left( A - \frac{1}{z} - \eta \right) \quad (23)
\]
\[
\dot{z} = z \left[ \rho - \eta + \gamma A \right] - [\gamma + 1] \quad (24)
\]

The representative household selects the initial value \( z(0) \), given the initial \( h(0) \), then must follow the \((h, z)\) system of first-order differential equations (23) and (24). The solution must satisfy transversality (19) to be optimal. The optimal \( z(0) \) is unique — and, in this case, it is such that balanced growth is achieved immediately. There are no transitional dynamics, so the equilibrium values of \( e_w \) and \( e_l \) are constant.

We first note that if \( z \) is constant, the transversality condition (19) will be satisfied. If we set (24) to zero and solve for \( z \), we get the following constant:

\[
z^* \equiv \frac{1 + \gamma}{\rho - \eta + \gamma A} \quad (25)
\]

It follows that the optimal policy is to set \( z(t) = z^* \) for all \( t \). Using (21) we find the constant work effort to be:

\[
e_w^* = \frac{\rho - \eta + \gamma A}{(1 + \gamma) A} = \frac{\rho - \eta}{(1 + \gamma) A} + \frac{\gamma}{1 + \gamma} \quad (26)
\]

Substituting \( z^* \) from (25) into (23) shows that the growth of per capita human capital \( h \) is constant at the rate:

\[
g_h = \frac{A - \rho - \gamma \eta}{1 + \gamma} \quad (27)
\]

From (17) we calculate the growth rate of per capita output to be:

\[
g_y = (1 - \alpha) \eta + (2 - \alpha) g_h \quad (28)
\]

where \( g_h \) is given in (27).

It should be emphasized that the construct \( A \) plays a critical role in the model. It determines the value of \( e_w \) through (26) and the growth rate through (27). The positions of both curves in Figure 2 depend on the value of \( e_w \) that is determined by \( A \). We focus on \( A \)
because it is directly influenced by regulatory policy through the fixed cost $v_0$.

6 Regulation and Taxation

6.1 Regulation and Taxation: Fixed vs Variable Cost

We distinguish regulation from taxation in that the former contains a greater element of fixed cost. We formalize this idea as follows. In the absence of regulation and taxation, the cost function for every intermediate-good firm is given by (3). With regulation and taxation, and recognizing that firms differ across industries $i$ and countries $j$, the cost function for producing $x$ units of the intermediate good is:

$$V_{ij}(x) = (1 + \beta^R_{ij} + \beta^T_{ij}) v_0 + (1 + \tau^R_{ij} + \tau^T_{ij}) v_1 x$$

where $\beta^R_{ij} > \beta^T_{ij} \geq 0$, and $\tau^R_{ij}, \tau^T_{ij} \geq 0$. There are several things to point out about this cost function. First, for tractability, we assume that the regulation and taxation policies raise costs proportionally for both fixed ($v_0$) and variable ($v_1$) costs. Second, we assume that the fixed-cost component of regulation $\beta^R_{ij}$ is strictly greater than zero and strictly greater than the fixed-cost component of taxation $\beta^T_{ij}$, which may be zero. Third, we assume that both regulation and taxation impose non-trivial variable costs, $\tau^R_{ij}$, and $\tau^T_{ij}$.

What is important for our argument is that regulations contain a fixed-cost element that is significantly greater than that of taxation. That is, that $\beta^R_{ij} > \beta^T_{ij} \geq 0$. Virtually all regulations have an important cost component that does not depend on volume of output. The fact that regulations also increase variable costs ($\tau^R_{ij} > 0$) only strengthens our argument that regulations are more harmful than taxation.

Examples of regulatory fixed costs include compliance costs for banks and other financial firms, tax compliance, the cost of environmental studies to secure construction permits, health and safety standards, homeland security requirements, and orders that limit numbers of customers during a pandemic. Regardless of the scale of operation, firms must employ a certain minimum number of employees to deal with compliance, or sub-contract various services to make sure they fill out the proper forms and comply with regulations for their industry. All universities must hire staff to oversee compliance with Title IX, for Equal Opportunity and other HR standards, and many more. Some of these costs do depend on scale — large universities have to hire more administrators than small colleges to verify compliance — but all institutions must have such an office, and probably more than one.

Trebbi and Zhang (2023) estimate the labor cost of regulations by establishment and firm by linking task descriptions to occupations and wages.⁹ Their RegIndex measures the

⁸As argued earlier, there is a conceptual distinction between the cost of complying with the tax code and the structure of the tax code in terms of the rates and the degree of progressivity. A tax code can be simple to administer (low regulation) but have a very high and steep schedule of taxes (high taxation) – or vice versa.

⁹They do this by using the O*NET data on tasks and occupations and the BLS data on wages in the
fraction of total labor cost dedicated to complying with regulations for all jurisdictions in the US in 2014. Although they only measure labor cost, these can be as high as 3.33 percent of the wage bill (by their broad measure). Moreover, they find evidence of fixed costs of regulation, especially for large firms, which “can be inferred from the growing presence of regulatory compliance specialists as establishment size increases” (p. 22). Their measure leaves out many costs of regulation that are not directly related to in-house labor, especially capital costs, and contract services that are performed by others (legal and data, for example). Also, they exclude firms who do legal and compliance work as their main business, as well as universities.

Consider four examples. The American Hospital Association (see AHA (2017)) has estimated that in 2017, health systems, hospitals and other providers had to comply with 629 different regulations. About half applied to hospitals and half to post-acute care providers. The regulations were mainly in the form of federal rules issued by agencies like the Centers for Medicare & Medicaid Services (CMS), the Office of the Inspector General (OIG), the Office for Civil Rights (OCR), and the Office of the National Coordinator for Health Information Technology (ONC). An average-size hospital dedicated 59 employees to regulatory compliance (see AHA, 2017). No doubt, some of these costs increase with the number of patients, but even small medical facilities incur sizable compliance costs that are essentially fixed.

As a second example, consider the cost of complying with the regulations on financial institutions. Hogan and Burns (2019) estimate that the cost of compliance with Dodd-Frank regulations was about $64.5 billion per year in non-interest cost. This can be broken down into salary expense and non-salary expense (legal fees, consulting, data processing). The non-salary expenses tended to be higher, but salaries increased by about $15 billion per year. One independent management and compliance consulting firm\textsuperscript{10} says: “Regulations themselves are so complex, the first thing a bank should do is consult or hire someone who is an expert in compliance. Typically, a bank will have a Compliance Officer, and larger banks might even have a compliance team. This person or team should be knowledgeable about underwriting, appraisals, financial regulations, customary and reasonable fees, TRID, and more. There are so many rules related to delivering reports, how quickly they need to be done, and when evaluations (versus appraisals) should be completed.” Individual Registered Investment Advisors almost always hire compliance consultants, both for starting up and for ongoing work to maintain compliance. This runs typically from $10,000 to $25,000 for the start-up and $8,000 to $12,000 per year for ongoing work.\textsuperscript{11}

Third, trucking is subject to several regulations that are independent of the number of miles driven per day, or the number of workers in the establishment. In 2021, federal proposals

\textsuperscript{10}The following quote is from the website of MountainSeed, a firm specializing in regulatory compliance for small banks. There are hundreds of such firms.

\textsuperscript{11}This information came from the web page of the consultant Brad Wales. See https://transitiontoria.com/how-much-does-an-ria-compliance-consultant-cost/
were introduced to raise the cost of truck purchase by mandating speed governors, limiting hours of service by drivers, mandating ELD’s (electronic logging devices that make it harder for drivers to misrepresent their hours), and limiting emissions of CO₂. These regulations raise the fixed cost of any fleet size, but also raise the variable cost of moving goods. These and other rules are proposed and enforced by the Federal Motor Carrier Safety Administration (FMCSA) as well as state regulatory agencies (notably California).

Fourth, accreditation rules for universities involve substantial time for ongoing assessment and periodic report writing. These reports must be prepared, regardless of the size of the institution, although they surely involve more expense for larger universities.

In all cases, firms must hire (or sub-contract) people who spend time understanding existing regulations, keeping up with public comments on proposed rules and regulations, and even lobbying government at all levels to influence the creation of new rules and the interpretation of existing rules. They must also purchase new equipment to deal, most directly, with environmental regulations.

Occupational licensing fees, which are in the nature of taxes, would be considered regulations in our framework, since they are essentially fixed costs that serve to restrict entry. Licenses often have to be renewed periodically, if not annually.

We now consider taxation. Unlike regulation, the fixed-cost component of taxation is minimal: \( \beta^T_{ij} \approx 0 \). Most business taxes are levied on output, revenue, or profit, all of which depend on volume or success of operation. Property taxes appear to be fixed in nature, but in most localities they also depend on the firm’s income and expense. That is, typically property taxes are calculated as \( PT = \rho \ast AR \ast MV \), where \( MV \) is the market value of the property, \( AR \) is the assessment ratio (around, say, .25) and \( \rho \) is the tax rate (say, .10). The market value usually depends on a formula that takes into account the firm’s annual income and expenses, and capitalizes this net income at some standard rate of interest. In this sense, it is a local profit tax. Since \( MV \) is not calculated every year – and since \( AR \) can be changed arbitrarily – there is some element of fixed-cost to property taxes. Nevertheless, it seems to us that the fixed-cost nature of taxation is considerably smaller than that of regulation.

Taxes, however, have a major effect on intermediate-good firms’ variable cost: \( \tau^T_{ij} > 0 \). Firms typically pay sales taxes and excise taxes on every unit sold. In addition, there are taxes on employment, which rise directly with the amount produced. The employer share of such federal taxes is about 7.5% of the payroll. Federal excise taxes on fuel and heavy trucks add another large item to firms’ cost, most of which is variable. Sales taxes in the US are collected mainly at the state level, where they run between 4% and 7% of the value of the product sold, but when local sales taxes are added, these can get close to 10% (see Cammenga, 2021).

In light of this, it seems most plausible to us that regulations impose significant fixed and variable costs (\( \beta^R_{ij} > 0, \tau^R_{ij} > 0 \)), whereas taxation only raises variable cost (\( \beta^T_{ij} \approx 0, \tau^T_{ij} > 0 \)). All we really need is that the fixed-cost element of taxation is considerably lower than that
of regulation: $\beta_{ij}^T < \beta_{ij}^R$.

We are interested in isolating the effects of these policies on both the level of output per capita and its growth rate. Since there are no transitional dynamics in the model, we can represent the path of output as $y(t) = y(0) e^{g_y t}$. We evaluate each policy in terms of what it will do to $y(0)$ and $g_y$ separately. We show that increases in $\tau_{ij}^k (k = (R, T))$ reduce $y(0)$ and leave $g_y$ unchanged. However, increases in $\beta_{ij}^R$ reduce $g_y$ unambiguously and may reduce $y(0)$ as well.

6.2 Increase in Variable Cost in the Model

Let $\tau_j = \tau_j^R + \tau_j^T$, where $\tau_j^k$ is the average variable-cost component of policy $k$ in country $j$. This represents the proportional increase in variable cost from both regulation and taxation in country $j$. Until the empirical section, we abstract from country differences and let $\tau$ be the total effect of policy on variable cost in the representative country. The effect is to raise variable cost to $(1 + \tau) v_1$.

This policy change does not change specialization $M$ or $A$ in (20), so $z^*$, $e_w$, and $e_l$ remain at their original magnitudes and the economy continues to grow at the same rate. Thus, our model is consistent with the predictions of recent theoretical literature on growth and taxation like Jaimovich and Rebelo (2017).

To see what happens to the level of $y(0)$, we use (17). Although $e_w$ does not change, $B$ falls according to (16); that is, with an elasticity equal to $-\alpha$. We noted earlier that $B$ is a reduced form for the influence on wages of changes in $x^*$ and the fixed-cost component of $M^*$. In this case, the source of the reduction in $B$ is the fall in $x^*$ to $x^* = \frac{\alpha v_0}{\alpha v_0 + (1-\alpha)(1+\tau)} v_1$, which we see from (11). The reduction in $x^*$ causes the productivity of labor (7) to fall — since neither overall effort $e_w$ or its allocation to tasks in (12) and (13) is changed — which reduces the real wage $w_b$ and per capita output $y$. In terms of Figure 2, the increase in $v_1$ shifts both curves down by the same amount and so reduces $x^*$ without changing $M^*$.\footnote{To see this, see (37) and (38) in Appendix B.} We note that $v_1 x^* = (1 + \tau) v_1 x^{*'} = \frac{\alpha v_0}{\alpha - \alpha}$ so that the constraint (10) continues to hold, without any change in the allocation of labor.

6.3 Increase in Fixed Cost in the Model

In this section we consider a policy that increases the fixed cost $(1 + \beta_j) v_0$, where $\beta_j = \beta_j^R + \beta_j^T$ and $\beta_j^k$ is the average fixed-cost component of policy $k$ in country $j$. Again, we abstract from different countries in this section, and let $\beta$ be the fixed-cost component of the representative country. In this case, there is a negative growth effect as well as a negative effect on the current level of output per capita.
The key change is to $A$. By (20), the productivity of learning time falls to:

$$A \equiv \left( \frac{\alpha (1 - \alpha)}{(1 + \beta) v_0} \right)^\gamma \tag{30}$$

This causes $e_w$ to rise by (26). Not only is each hour of learning less productive, but the rise in the steady-state $e_w$ means that the equilibrium $e_l$ falls. The reductions in $A$ and $e_l$ reduce the growth rates of $h$ and $y$, which show up in (27) and (28). There is, then, an unambiguous fall in $g_y$; it changes by the amount:

$$\frac{\partial g_y}{\partial \beta} = \left( \frac{2 - \alpha}{1 + \gamma} \right) \frac{\partial A}{\partial \beta} = -\gamma \left( \frac{2 - \alpha}{1 + \gamma} \right) \frac{A}{1 + \beta} \tag{31}$$

The higher the value of $\beta$, the greater the fall in growth.\(^{13}\)

Although it is not obvious from (17) — since $e_w$ increases — an increase in $\beta$ will also cause current real output per capita $y(0)$ to fall. We demonstrate this result numerically in Appendix D. To do so, we carry out a simple, back-of-the-envelope calibration of the model to the US economy, and examine fixed-cost shocks under a variety of parameter values.

In Figure 3 the solid curves labeled “$y$ Base” are the paths of $y(t)$ in the baseline calibration ($\tau = \beta = 0$). The other curves show the effects of permanent shocks to $\tau$ and $\beta$. We first consider a tax increase of 30%. The dashed line in Figure 3a shows the path of $y$ if the variable cost were raised to $(1 + \tau) v_1 = 1.3 v_1$ from $v_1$. As we showed above, the growth rate is not affected, but the level of $y(t)$ falls according to the factor $(1 + \tau)^\alpha = 1.3^4 = .90$ for all $t$.

We now consider an increase in fixed cost $(1 + \beta) v_0$. In Figure 3b, the curve labeled “$y v01$” shows the effects of the policy in which $\beta = .30$. The growth rate $g_y$ falls according to (31) and output $y(0)$ also falls immediately. The gap between the baseline path and the new path grows over time. A much more severe policy is shown by the curve labeled “$y v02$”, for which $\beta = 1$, so that compliance costs and other fixed costs double. In this case, the growth rate actually turns negative: the productivity of learning is so low that human capital accumulation becomes negative.

This calibration, as noted, is basic, and there are only four free parameters — see Appendix D — most of which have been identified in the literature. The main point, which is true for reasonable values of the parameters, is that an increase in $\beta$ has negative level effects as well as negative growth effects. If so, the negative effect of regulation, which raises both $\beta$ and $\tau$, is likely to be much larger than that of taxation, in the short run as well as the long run. When we examine the data next, we expect regulation to have a more serious negative effect on output and growth than taxation.

\(^{13}\)To derive (31), put (27) into (28), then substitute for $A$ from (30) before differentiating.
Figure 3: Tax and Regulatory Shocks
7 Empirics

7.1 Data and Estimation Strategy

Our policy data come from the *Economic Freedom of the World* (EFW) database of the Fraser Institute (see Fraser Institute (2022)), which produces index scores for regulatory and tax environments in several countries over time. The data is broken down into 5 Areas: we focus on Area 5 for regulation and parts of Area 1 for taxation.

There are three components in Area 5 (“Regulation”): Component A (“Credit market regulations”), Component B (“Labor market regulations”), and Component C (“Business regulations”). Each component score for a country-year is calculated as the average of sub-components: there are 3 sub-components for A, 6 for B, and 6 for C. If a sub-component for a country-year observation is missing, the component score is the average of those that are available. Our variable $Reg$ is the simple average of the 3 component scores for each country and year. The original data is scored from 0 to 10 where 10 corresponds to the least regulation; we normalize the index to go from 0 to 1. The variable $Reg$ is quite continuous – as is clear from Figure 1 – since it is composed of 15 sub-indices, all of which are essentially continuous. For more detail, including information on the sources for the sub-components, see Appendix A.

Our taxation variable $Tax$ uses the score for Component D (“Top marginal tax rate”) in Area 1 (“Size of Government”) in the EFW data. Component D is the average of two sub-component scores, one for income taxes only and one for both income and payroll taxes. Table 6 in Appendix A shows how the scoring works for the income tax sub-component: the high scores are found in the Northeast corner (low rate; high thresholds), while the low scores are in the Southwest corner (high rates; low thresholds). The $Tax$ variable is essentially discrete. We normalize $Tax$ to go between 0 and 1 as well, with 1 corresponding to the least onerous tax burden. More detail is provided in Appendix A.

For real output per capita, we use the data from the *Penn World Table* (PWT, v, 10.01). To compare levels of $y$, we use the measure of real output based on expenditure in the PWT; this is the variable called $RGDP^E$. To compare growth rates of $y$ we use the measure based on national accounts called $RGDP^NA$. These are the variables suggested by the current curators of the PWT data for the different tasks (see Feenstra et al. (2015), Table 1). As a control, we use the measure of human capital constructed in the PWT ($HC$). The details are in Appendix A.

Our data is an unbalanced panel. The EFW data goes from 1970 to 2020, but in the years before 2000 it is published only every 5 years. At most, we have 25 years of observations for $Reg$ and $Tax$, but for many countries there are many fewer observations. The PWT data stretches farther back in time, but stops in 2019. For the baseline regression, we have 143 countries. Descriptive statistics for the data that we use in the empirical analysis that follows are shown in Table 1.
Table 1: Summary Statistics of Data

<table>
<thead>
<tr>
<th>Statistic</th>
<th>N</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
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<tr>
<td>ln y</td>
<td>3,544</td>
<td>9.143</td>
<td>1.242</td>
<td>5.527</td>
<td>12.403</td>
</tr>
<tr>
<td>g_y</td>
<td>3,537</td>
<td>0.021</td>
<td>0.047</td>
<td>-0.526</td>
<td>0.455</td>
</tr>
<tr>
<td>Reg</td>
<td>3,760</td>
<td>0.663</td>
<td>0.126</td>
<td>0.100</td>
<td>0.943</td>
</tr>
<tr>
<td>Tax</td>
<td>3,329</td>
<td>0.595</td>
<td>0.259</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>HC</td>
<td>3,292</td>
<td>2.450</td>
<td>0.712</td>
<td>1.015</td>
<td>4.352</td>
</tr>
</tbody>
</table>

Table 1 shows substantial dispersion in our measures for taxation and regulation. Taxation has a standard deviation that is twice that of regulation, and a greater range, due most likely to the discrete nature of the scoring algorithm: 0 and 1 scores are not uncommon. Table 1 also shows substantial dispersion for the natural log of per capita output. The lowest country (Liberia in 1996) has a per capita output level that is about 1,000 times smaller than that of the highest country (the United Arab Emirates in 1970). Table 1 shows per capita income growth averaged 2.1% with a standard deviation of 4.7%, which is not surprising given the negative growth rates for many observations in our sample. The human capital index also has wide variation.\(^{14}\)

Our main specification for the level of real output per capita is:

\[
\ln y_{it} = \alpha_1 + \beta_1 Reg_{it-1} + \gamma_1 Tax_{it-1} + \delta_1 HC_{it-1} + \mu_i + \omega_t + \epsilon_{1it} \quad (32)
\]

where \(\ln y_{it}\) is the natural log of per capita real output for Country \(i\) in Year \(t\); and \(HC_{it}\) is the index of human capital. As is standard in the literature, we measure the level of per capita output using the natural logarithm.\(^{15}\) We lag the regressors by one year to lessen the chance of endogeneity, which we address in more detail below. We also allow for both country and time fixed-effects, \(\mu_i\) and \(\omega_t\), which we may consider part of a composite error, whose other component \(\epsilon_{1it}\) is assumed to be normally distributed with mean zero. Although we expect that the estimated coefficients \(\hat{\beta}_1 > 0\) and \(\hat{\gamma}_1 > 0\), it is possible that they turn out to be negative. If so, then more stringent regulations (and higher taxes) would be associated with higher per capita incomes – the “public interest theory” of public policy Djankov et al. (2002).

\(^{14}\)One might worry that \(Reg\) and \(Tax\) are too highly correlated to produce precise estimates of their separate effects. While they are positively correlated, if we ignore country heterogeneity and pool all our observations, the correlation coefficient is only about \(\rho = 0.22\). Moreover, the \(R^2\) in the regression of \(Tax\) on \(Reg\) is only about .05, so the effect of multicollinearity on the variance of the estimated coefficients will not be large. If we take means of \(Reg\) and \(Tax\) by country, then the correlation of those means is even smaller, only \(\rho = 0.085\) (and \(R^2\) is a mere .01). Finally, there are 138 countries (out of 159 in the pooled regression) that have at least some variation in \(Tax\) over time (all 159 have variation in \(Reg\) over time). If we correlate \(Reg\) and \(Tax\) separately for each country, we find that 21 have \(\rho < 0\) and 117 have \(\rho > 0\). The 138 \(\rho\) values are fairly widely dispersed in the interval \(\rho = (-0.79, 0.97)\).

\(^{15}\)See, for example, Hall and Jones (1999), Djankov et al. (2002), and Acemoglu and Johnson (2005).
The main estimating equation for the growth rate $g_y$ is:

$$g_{y,it} = \alpha_2 + \beta_2 Reg_{it-1} + \gamma_2 Tax_{it-1} + \lambda y_{0i} + \delta_2 HC_{it} + \mu_i + \omega_t + \epsilon_{2it} \quad (33)$$

where $g_{y,it}$ is the growth rate of $y$ in Country $i$ and Year $t$ and is measured as the year-on-year difference in the natural log of $y$: $g_y \equiv \Delta \ln y$. This equation has the same form as (32) except we add initial per capita output to capture any transitional dynamics, a standard practice in estimating growth equations across countries; it is expected that $\lambda < 0$. For estimation with country fixed-effects, however, we will not be able to estimate $\lambda$, since the data for initial output vanishes when we take the deviation from the mean over time. In the growth regression, we expect $\beta_2 > 0$ and $\gamma_2 = 0$. Unlike in the level equation, tax policy should not affect the growth rate ($\gamma_2 = 0$).

Endogeneity – in the form of simultaneity – is likely to bias our coefficients. That is, the policy variables $Reg$ and $Tax$ may well be influenced by our outcome $\ln y$. We lag them in equations (32) and (33) to emphasize the direction of causality implied by our theoretical model, and to give them a chance to impact the outcome $y$ empirically. This, however, is not likely to eliminate the bias. To be more specific, to take the case of regulation, we assume that:

$$Reg_{it-1} = \alpha_3 + \pi \ln y_{it} + \kappa Z_{R,it} + u_{it} \quad (34)$$

where $Z_{R,it}$ is a control that is uncorrelated with $u_{it}$ in (34) and $\epsilon_{it}$ in (32). Given these assumptions, $Z_{R,it}$ is a good instrument for $Reg_{t-1}$ in equation (32). We address simultaneity in Section 7.3.

### 7.2 Estimation: OLS

In this section, we assume that $\pi = 0$ in (34) and present results of OLS regressions. The results for $\ln y$ are shown in Table 2. The first three columns show the results without fixed effects; the last three columns show the results with both country and time fixed effects. Table 3 shows the OLS results for the growth rate $g_y$; this table includes initial $\ln y$ to control for possible transitory dynamics.

Consider, first, the results for $\ln y$ in Table 2. These are consistent with our theory for both $Reg_{t-1}$ and $Tax_{t-1}$: high values for both (that is, light regulation and taxation) are associated with high levels of output per capita. This is especially true for regulation, in all specifications. While taxation has a positive coefficient, it is not significant when included with regulation — although it is nearly significant at the 10% level in the fixed-effects specification in Col (6).\(^{16}\) Moreover, it is positive and quite significant when we omit either $Reg_{t-1}$, or $HC_{t-1}$, or both.

Table 2 also supports the idea that regulation is more powerful than taxation: a unit increase in $Reg_{t-1}$ — a reduction in regulation — has a greater effect on $\ln y$ than does a

\(^{16}\)In that case the $t$–value is 1.54 and the $p$–value is .126.
Table 2: Dependent Variable: ln y. Pooled OLS and FE

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
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<tbody>
<tr>
<td>Regt−1</td>
<td>1.377***</td>
<td>1.831***</td>
<td>1.252***</td>
<td>1.270**</td>
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<tr>
<td></td>
<td>(0.151)</td>
<td>(0.181)</td>
<td>(0.400)</td>
<td>(0.516)</td>
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<tr>
<td>Taxt−1</td>
<td>0.075</td>
<td>-0.093</td>
<td>0.215**</td>
<td>0.150</td>
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<tr>
<td></td>
<td>(0.063)</td>
<td>(0.061)</td>
<td>(0.108)</td>
<td>(0.098)</td>
<td></td>
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</tr>
<tr>
<td>H Ct−1</td>
<td>1.275***</td>
<td>1.393***</td>
<td>1.208***</td>
<td>0.530***</td>
<td>0.335*</td>
<td>0.364**</td>
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<tr>
<td></td>
<td>(0.023)</td>
<td>(0.019)</td>
<td>(0.027)</td>
<td>(0.154)</td>
<td>(0.183)</td>
<td>(0.162)</td>
</tr>
<tr>
<td>Constant</td>
<td>5.143***</td>
<td>5.751***</td>
<td>5.080***</td>
<td>7.148***</td>
<td>8.534***</td>
<td>7.591***</td>
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<tr>
<td></td>
<td>(0.074)</td>
<td>(0.062)</td>
<td>(0.090)</td>
<td>(0.405)</td>
<td>(0.468)</td>
<td>(0.470)</td>
</tr>
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<td>Year FE</td>
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<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Country FE</td>
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<td>NO</td>
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<td>YES</td>
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<tr>
<td>Obs.</td>
<td>3,149</td>
<td>2,779</td>
<td>2,775</td>
<td>3,149</td>
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<tr>
<td>Adjusted R²</td>
<td>0.664</td>
<td>0.619</td>
<td>0.640</td>
<td>0.578</td>
<td>0.529</td>
<td>0.562</td>
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</table>

Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

comparable increase in Taxt−1: the coefficient $\hat{\beta}_1 = 1.270$ in Col. (6) of Table 2 is 8.46 times greater than $\hat{\gamma}_1 = .1501$. If we standardize the coefficients, the effect of regulation is still 3.83 times greater than that of taxation. The standardized $\hat{\beta}_{1st} = .1482$, so a one standard-deviation increase in Regt−1 (which, in the regression sample, is an increase in the Reg score of .1167 points out of a maximum of 1.0) would be associated with an increase in ln y of about .15. That is, y would be about 16% higher if the relationship were causal.

Turning to the results for the growth rate in Table 3, we see that our theory has support here as well. In particular, the effect of Regt−1 on $g_y$ is positive and highly significant in all specifications, while that of Taxt−1 is zero whenever it is included with Regt−1. In our preferred fixed-effects case, the standardized coefficient on Regt−1 is $\hat{\beta}_{2st} = .0091$, so a one standard deviation increase in Regt−1 would be associated with a rise in the growth rate of about .91 percent (exponential).

We also ran a cross-section regression where the dependent variable was the average growth rate from the beginning observation to 2019. The regressors were the average levels of Reg, Tax, and HC, as well as the initial value of ln y. The coefficient on Reg was .045 and was significant at about 2%. The Tax coefficient was very small and insignificant. Initial per capita output was also significant and, as expected, negative.

These results support the idea that regulations — whatever good they do for society — are associated with lower levels of per capita output and a lower growth rate. Taxation has

$^{17}$Standardized relative coefficients are calculated as $\frac{\hat{\beta}_1}{s_R} \times \frac{s_T}{\hat{\gamma}_1}$ where $s_R$ and $s_T$ are the sample standard deviations of, respectively, Regt−1 and Taxt−1. Standardized coefficients express the effect of the regressor on the outcome in standard-deviation units.
Table 3: Dependent Variable: $g_y \equiv \Delta \ln y$. OLS and FE

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
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<tr>
<td>$Reg_{t-1}$</td>
<td>0.039***</td>
<td>0.037***</td>
<td>0.078***</td>
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<tr>
<td></td>
<td>(0.012)</td>
<td>(0.014)</td>
<td>(0.028)</td>
<td>(0.035)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Tax_{t-1}$</td>
<td></td>
<td>0.005*</td>
<td>0.002</td>
<td>0.002</td>
<td>-0.001</td>
<td></td>
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<td></td>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.011)</td>
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<tr>
<td>$HC_{t-1}$</td>
<td>0.004*</td>
<td>0.007***</td>
<td>0.003</td>
<td>-0.036***</td>
<td>-0.027**</td>
<td>-0.025**</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.010)</td>
<td>(0.011)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>$\ln y_{t=0}$</td>
<td>-0.009***</td>
<td>-0.008***</td>
<td>-0.008***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.060***</td>
<td>0.066***</td>
<td>0.055***</td>
<td>0.054*</td>
<td>0.087***</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.008)</td>
<td>(0.011)</td>
<td>(0.029)</td>
<td>(0.028)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>Year FE</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Country FE</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Obs.</td>
<td>3,149</td>
<td>2,779</td>
<td>2,775</td>
<td>3,149</td>
<td>2,779</td>
<td>2,775</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.11</td>
<td>0.11</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

similar, but weaker, effects on per capita output, and hardly any effect on growth. It is noteworthy that we have controlled for human capital, a variable that often drives out the significance of other variables.\(^{18}\)

The OLS coefficients, however, are biased if $\pi$ in (34) is non-zero, since in that case $Reg_{t-1}$ and $\epsilon_1$ in (32) would be correlated.\(^{19}\) It is important to establish whether the bias is likely to be positive or negative. We believe that the bias is negative, so that our estimate $\hat{\beta}_1$ likely underestimates $\beta_1$, the true effect of regulations on $\ln y$. Our reasoning is as follows.

The sign of the asymptotic bias of the OLS estimator of $\beta_1$ is the same as that of the covariance between $Reg_{t-1}$ and $\epsilon_1$ in (32).\(^{20}\) That covariance is:

$$C_{Re} \equiv \text{Cov} (Reg_{t-1}, \epsilon_1) = \left( \frac{\pi}{1 - \pi \beta_1} \right) \sigma_1^2$$  \hspace{1cm} (35)

where $\sigma_1^2 = \text{Var} (\epsilon_1)$. A sufficient condition for the covariance to be negative is that $\pi < 0$

---

\(^{18}\) Acemoglu and Johnson (2005), for example, do not include $HC$ as a regressor because doing so renders their institutional variable of interest insignificant. In addition, we found that our main estimates are robust to further controls such as latitude, measured with the absolute distance from the Equator, and culture, proxied by the fraction of the population speaking one of the major languages of Western Europe. The results are available upon request.

\(^{19}\) To see that $Reg_{t-1}$ depends on $\epsilon_1$, insert (32) into (34) and solve for the reduced-form $Reg_{t-1}$.

\(^{20}\) The covariance in (35) is derived under the assumption that $\epsilon_1$ and $u$ are uncorrelated. For clarity, we are considering a simplified model in which $Tax$ and the fixed effects do not appear, or are exogenous and uncorrelated with the error terms.
and $\beta_1 > 0$. We have already made the case, theoretically and with the OLS results, that $\beta_1 > 0$. Now we argue that $\pi < 0$ so that $CRe < 0$.

When, typically, do countries deregulate (raise $Reg$)? Does deregulation happen when the economy has a recent history of decline or prosperity? We think that deregulation is almost always a response to economic difficulty, a decline in $\ln y$. This means that $\pi < 0$. For example, Sweden deregulated its economy (raised $Reg$) in the last quarter of the 20th Century in response to low growth and faltering international competitiveness. Its $Reg$ score went from .53 in 1975 to .82 in 2017, before falling back to .76 in 2020. That is a two-standard deviation increase. Deregulation of the US rail and trucking system in 1975 provides another example. Reforming the Interstate Commerce Commission (ICC) only became possible after years of high prices, declining traffic and profit, nationalization of the railroads, and the subsequent huge losses that showed up on the federal budget (Peltzman (2021)). A few years later, the US airline industry was deregulated after mounting inefficiencies, as the Civil Aeronautics Board (CAB) had the power to set prices and distribute routes, resulting in sky-high prices and half-full airplanes. No new carriers were permitted in the US between 1938 and 1978, when the Act was put into practice. The US $Reg$ score jumped from .68 in 1970 to .83 in 1975 to .86 in 1980, reaching a peak of .90 in 2017.

Prosperous countries, on the other hand, are tempted to regulate (reduce $Reg$) to achieve policy goals, because the prosperity itself makes the costs seem manageable and regulations impose costs that, unlike taxation, can be difficult to attribute to particular groups. If we are right (so $\pi < 0$) then the estimates in Table 2 are smaller than the true values.

### 7.3 Estimation: Instrumental Variables

It is common practice in cross-section and panel studies of economic development to use an instrumental variable with the properties we assigned to $Z_R$ in (34). Typically, the instrument is a variable rooted in the past. Hall and Jones (1999) use European language variables and predicted trade shares as instruments for social infrastructure. Acemoglu and Johnson (2005), in their study of the primacy of property rights institutions (over contracting institutions), use settler mortality and population density before colonization as instruments for these institutions. Mauro (1995) uses the measure of ethnolinguistic fractionalization (ELF) to instrument for corruption. Breuer and McDermott (2011) use variables measuring religion, state antiquity, and civil liberties as instruments for cultural values representing respect and responsibility.

In this study, we use an index of Protection of Property Rights ($Prop$) as our instrument $Z_R$. The motivating idea is that $Prop$ is a proxy for a fundamental societal attitude toward the use of government, built up over time. Nations that place high value on individual prop-

---

21See Englund (1990) and Heyman et al. (2019).
22This data is from the World Economic Forum and the World Bank, as compiled by the EFW. See the Data Appendix.
property should also be reluctant to impose burdensome regulations on the use of that property. The higher is \( Prop \) the higher is \( Reg_{t-1} \) – the less onerous is the regulatory burden. In other words, we assume that \( \kappa > 0 \) in (34).

It is well-known that a good instrument has two properties: (i) it is highly correlated with the independent variable of interest (here, \( Reg_{t-1} \)); but (ii) not correlated with the error in the main structural equation (here, \( \epsilon_1 \) in (32)). The former can be tested empirically, but the latter cannot. Instead, it must be argued logically that such covariance is zero, or at least minimal. We think that \( Prop \) works principally, if not exclusively, through a country’s regulatory structure. Regulation is the manifestation of the value a country places on individual rights. In macro panel studies like ours, however, it is difficult to argue on purely logical grounds that any instrument is perfect in the sense of (ii). Any historical or cultural variable is likely to affect prosperity along multiple pathways. Nevertheless, we first present our results using \( Prop \) as an instrument for \( Reg \) and then discuss the implications if (ii) fails to hold.

In Table 4, we present results for the first stage. There, we see that \( Reg \) is highly positively correlated with \( Prop \). The F-statistic is above 50 in all three of the specifications. The fact that the estimated \( \kappa \) coefficient in column (3) is smaller than the others suggests that there is more variation across countries than within countries.

Table 5 presents the second-stage results. The estimated IV coefficient \( \tilde{\beta}_1 \) in the fixed-effects specification for \( \ln y \) is large – \( \tilde{\beta}_1 = 6.334 \) in column (3) – and highly significant. Compared with the OLS fixed-effects \( \hat{\beta}_1 \) (Table 2, column (4) ), the coefficient is about 5 times greater. If the IV estimate is close to the true structural effect, then regulations have
Table 5: Second Stage. Dependent variable: ln \( y \); ∆ln \( y \)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Reg_{t-1} )</td>
<td>8.381**</td>
<td>-0.026</td>
<td>6.334***</td>
<td>0.396*</td>
</tr>
<tr>
<td></td>
<td>(0.498)</td>
<td>(0.031)</td>
<td>(2.024)</td>
<td>(0.212)</td>
</tr>
<tr>
<td>( HC_{t-1} )</td>
<td>0.716***</td>
<td>0.008**</td>
<td>0.355**</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.003)</td>
<td>(0.166)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>ln ( y, t=0 )</td>
<td>-0.007***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.752***</td>
<td>0.079***</td>
<td>4.032**</td>
<td>-0.262</td>
</tr>
<tr>
<td></td>
<td>(0.229)</td>
<td>(0.016)</td>
<td>(1.676)</td>
<td>(0.172)</td>
</tr>
<tr>
<td>Year FE</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Country FE</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Obs.</td>
<td>2,769</td>
<td>2,769</td>
<td>2,769</td>
<td>2,769</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* \( p < 0.10 \), ** \( p < 0.05 \), *** \( p < 0.01 \)

an extremely important effect on prosperity.

We have reason to believe, however that \( \hat{\beta}_1 \) is on average larger than the true \( \beta_1 \). While \( Prop \) might affect ln \( y \) primarily through \( Reg \), it is unlikely to be completely uncorrelated with \( \epsilon_1 \) in (32). If so, the IV estimator \( \hat{\beta}_1 \) will contain a bias that is proportional to \( corr(Prop, \epsilon_1)/corr(Prop, Reg) > 0 \). The denominator is positive (as shown by the Stage 1 results) and the numerator will be positive if property rights protections have a positive influence on output, not just via \( Reg \), but also directly or through a third variable. If this argument is correct then \( \hat{\beta}_1 > \beta_1 \). Our instrument may be imperfect, but it might well establish an upper bound to the true value of \( \beta_1 \).

We conclude that the true value of \( \beta_1 \) probably lies somewhere between the OLS and IV estimates found above: \( 1.24 < \beta_1 < 6.33 \).

8 Conclusion

Regulations are necessary to operationalize laws and formalize official procedures. Taxes are necessary for funding the basic services required of a modern society. Keeping order, organizing defense, enforcing laws and contracts, fighting communicable disease, and many other functions, require efficient rules and a steady stream of revenue. Regulations and taxes are also designed to influence or constrain individual behavior. Gasoline taxes discourage driving in order to reduce CO2 in the atmosphere. Regulations have been used to prevent discriminatory actions.

Regulations can, at times, substitute for taxes that are meant to change behavior. In the
clean air example, the government could instead mandate cars with low tail-pipe emissions or high mileage; or it could cap individual driving miles. Regulations of this type may be favored by governments since, although the regulation might raise cost by more than the tax, it is often not clear who bears the cost. Regulations, however, are often not as efficient as taxes in operating on the margin to influence behavior. Gasoline taxes raise cost per mile driven; catalytic converters increase the fixed cost of the trucking fleet regardless of the number of miles driven. So, while regulations may be favored by governments, they may be sub-optimal because they impose fixed costs instead of variable costs. This difference – the preponderance of fixed costs from regulations — appears to be much more general than just the case of clean air.

We use a model of increasing returns to scale to show that the fixed cost associated with regulations can have a more harmful effect on output compared to taxation. The reason is that an increase in fixed-cost reduces specialization, the variety of intermediate input firms in operation. This reduces output directly and, as in the work of Lucas, reduces the efficiency of human capital accumulation. Both current output and growth fall. Taxation reduces output, but does not change the rate of growth.

We estimated the effect of tax and regulation on per capita GDP and its growth rate. We found that regulation was strongly related to per capita output and growth in the way suggested by the theory. Taxation was weakly associated with output and hardly associated with growth at all. Countries like Sweden, which have high taxes but light regulations (in our data), may have hit upon the right combination of policies to raise revenue and influence behavior. Our results suggest that nations that can reduce onerous regulations may be able to increase their growth and levels of per capital output.

Appendix

A Data

Our data comes primarily from two sources: the Penn World Table, v. 10.01, and the data compiled by the Fraser Institute (2022) into the Economic Freedom of the World dataset. The latter is a compilation of index data from several different sources. Our variables, their meaning, and the principal sources are as follows:

- **Reg**: Index of Regulatory Severity; higher value means less onerous regulation. Simple average of RegC, RegL, and RegB below. Lowest score is 0; highest is 1. Reg = 1 is least onerous regulatory burden. **Source**: Economic Freedom of The World dataset (EFW). See below and Fraser Institute (2022).

- **RegC**: Index of regulation on Credit. From EFW, Area 5 (Regulation), Component A (Credit Market Regulations). Average of available sub-Components, i (Ownership of banks), ii (Private sector credit), iii (Interest rate controls). **Source**: World Bank (World Development Indicators; Bank Regulation and Supervision Survey); World Economic Forum (Global Competitiveness Report), International Monetary Fund, (International Financial Statistics); CIA, (The World Factbook). Plus other sources: See FrasINS.
- **RegL**: Index of regulation on Labor Market. From EFW, Area 5 (Regulation), Component B (Labor Market Regulations). Average of available sub-Components, i (Minimum wage), ii (Hiring/Firing), iii (Bargaining), iv (Hours regulations), v (Dismissal cost), vi (Conscription). **Source**: World Bank (Doing Business), World Economic Forum (Global Competitiveness Report), International Institute for Strategic Studies (The Military Balance), War Resisters International (World Survey of Conscription and Conscientious Objection to Military Service).

- **RegB**: Index of regulation on Business. From EFW, Area 5 (Regulation), Component C (Business Regulations). Average of available sub-Components, i (Administrative requirements), ii (Bureaucracy costs), iii (Starting a business), iv (Public administration), v (Licensing restrictions), vi (Cost of tax compliance). **Source**: World Bank (Doing Business), World Economic Forum (Global Competitiveness Report), HIS Markit (Regulatory Burden Risk Ratings), V-Dem Institute, Varieties of Democracy (Rigorous and Impartial Public Administration).

- **Tax**: Index of Marginal Tax Severity; higher value means less onerous taxation. Average of TaxI and TaxP below. Lowest score is 0; highest is 1. Tax = 1 is least onerous taxation burden. See Table 6 for scoring. **Source**: Pricewaterhousecoopers (Worldwide Tax Summaries Online; Individual Taxes: A Worldwide Summary), Ernst and Young (Worldwide Personal Tax and Immigration Guide), Deloitte International Tax Source (Guide to Fiscal Information: Key Economies in Africa). All data collected, compiled, and scored by Economic Freedom of The World dataset (EFW) by Fraser Institute (2022).

- **TaxI**: Income tax index. Score is lower the higher the marginal tax rate on income and the income threshold at which it begins to apply: See Table xxx in the text.. **Source**: EFW, Area 1 (Size of Government), Component D (Top Marginal Tax Rate), Sub-Component i (Top marginal income tax rate).

- **TaxP**: Income and Payroll Tax Index. Score is lower the higher the marginal tax rate on income and payroll (wages) and the thresholds at which they begin to apply. **Source**: EFW, Area 1 (Size of Government), Component D (Top Marginal Tax Rate), Sub-Component ii (Top marginal income and payroll tax rates).

- **y**: Per capita real output. $y = (Y/Pop)$ where $Y = RGDPe$ and $Pop = population$ in millions. $RGDPe$ is real output based on expenditure in US$ of 2017. **Source**: PWT, v. 10.01.

- **$g_y$**: Annual log growth rate of per capita real output. $g_y = \Delta \ln y^n$, where $y^n$ is $RGDP^n/Pop$. **Source**: PWT, v. 10.01.

- **HC**: Human capital Index from 0 (least) to 5 (most). Rescaled data on schooling from Barro-Lee (95 countries) and Cohen-Soto-Leker (55 countries). **Source**: PWT, v. 10.01.

- **Prop**: Protection of Property Rights. Average of scaled index from both sources below, if available. If not, uses whichever is available. Rescaled to go from 0 to 1. **Source**: EFW, Area 2 (Legal System and Property Rights), Component C (Protection of Property Rights). Data is from the World Economic Forum (Global Competitiveness Report); and the World Bank (Country Policy and Institutional Assessment).

## B Zero-Profit Equilibrium in the Conventional Sector

Here we provide more details of the production equilibrium in Section 4. The first step is to find the value $\tilde{x}$ that each intermediate firm produces for sale to final-good firms, when $M$ is given (along with $e_w$, $h$, and $N$). To do so, solve (10) for $e_x$:

$$ e_x = \frac{M (v_0 + v_1 x)}{hN} \quad (36) $$
Table 6: Construction of Tax Score

<table>
<thead>
<tr>
<th>Income Threshold at Which the Top Marginal Rate Applies (1983 US$)</th>
<th>top tax rate</th>
<th>&lt;$25,000</th>
<th>$25,000 – &lt;$50,000</th>
<th>$50,000 – &lt;$150,000</th>
<th>$150,000+</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 21%</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>21% – &lt;26%</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>26% – &lt;31%</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>31% – &lt;36%</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>36% – &lt;41%</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>41% – &lt;46%</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>46% – &lt;51%</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>51% – &lt;56%</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>56% – &lt;61%</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>61% – &lt;66%</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>66% – &lt;70%</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

To find $\tilde{x}$, first use (6) and (7) to substitute for $p$ and $w_b$ in the markup condition (9); then substitute $e_w - e_x = e_y$ in the result. Finally, use (36) to substitute for $e_x$, and solve for $x$:

$$\tilde{x} = \frac{\alpha^2 (e_w hN - v_0 M)}{(1 - \alpha + \alpha^2) v_1 M} \equiv X (e_w hN, M)$$

(37)

We call the function that represents intermediate output $\tilde{x} = X (e_w hN, M)$. The $X(\ldots)$ function allows us to find $e_x/e_w$ (using (36)) and $e_y/e_w = 1 - e_x/e_w$ as functions of $e_w hN$ and $M$. Because $e_w$ is given at this point, we can then find $e_y$ and $e_x$ separately, which allows us to find $w_b$, $p$, and $Y$ using the structural equations. The value of $\tilde{x}$ as a function of $M$ is represented by the EQ locus in Figure 2.

Our base case assumes that intermediate firms earn no profit in equilibrium. That is, when profit is positive new firms will enter the intermediate-good market and increase the number of specialized inputs, which drives profit to zero. $M$ is endogenous.

Given $e_w$, $h$, and $N$, the ZP locus in Figure 2 shows the momentary zero-profit combinations of $x$ and $M$ in the intermediate-good sector. To derive the ZP locus set profit (8) to zero, and substitute for $p$, $w_b$, $e_y$, and $e_x$ as above to yield:

$$x = \frac{\alpha e_w hN - v_0 M}{v_1 M}$$

(38)

The ZP locus is also downward sloping.

The ZP locus crosses the EQ locus once from above. Intermediate firm’s profits are positive below the ZP locus, and negative above. Hence, the free-entry, zero-profit monopolistically competitive equilibrium in the conventional sector is unique and stable at point A in Figure 2. Equate (37) and (38) to see that the equilibrium number of firms (range of
specialization) is given by \( M^* = \frac{\alpha(1-\alpha)}{v_0} e_w h N \), which appears as Equation (14) in the text. Substitute \( M^* \) back into either (37) or (38) to get \( x^* = \frac{\alpha v_0}{(1-\alpha) v_1} \), which is (11) in the text. Another way to find \( x^* \) is to substitute (3) and (9) into the profit expression (8) and set the result to zero.

In the text, we found the equilibrium allocations of effort (13) and (12). As a check, we can also use (36) after substituting the expressions for \( M^* \) and \( x^* \). This yields \( e_x = \alpha e_w \) from which it follows that \( e_y = (1-\alpha) e_w \). Finally, to obtain the equilibrium, reduced-form base wage \( w_b \) in (15) in the text, we use (7) and then substitute in the equilibrium values for \( e_y, x, \) and \( M \) that we have found in this appendix.

### C Intertemporal Optimization

The representative household maximizes (18) in the text subject to two constraints, a time constraint, \( 1 = e_w + e_l \), and a resource budget constraint, \( c = w_b h e_w \), where \( e_w = e_y + e_l \). Individuals consider the base wage \( w_b \) to be given, even though it depends on aggregate effort. Accumulating \( h \) allows them to increase their actual wage \( w_s = w_b h \) in a manner that they perceive to be proportional.

The Hamiltonian for the problem is:

\[
\mathcal{H} = u(c) + \lambda \left( L^\gamma h^{1-\gamma} e_l - \eta h \right) + \\
+ \theta_1 (w_b h e_w - c) + \\
+ \theta_2 (1 - e_w - e_l)
\]

where \( \lambda \) is the co-state, shadow price of \( h \), we attach the constraints with Lagrangian multipliers \( \theta_1 \) and \( \theta_2 \), and utility is assumed to be logarithmic: \( u(c) = \ln c \).

There are three static FOC’s:

\[
\frac{\partial \mathcal{H}}{\partial c} = 0 \Rightarrow \frac{1}{c} = \theta_1 \tag{39}
\]

\[
\frac{\partial \mathcal{H}}{\partial e_w} = 0 \Rightarrow \theta_1 w_b h = \theta_2 \tag{40}
\]

\[
\frac{\partial \mathcal{H}}{\partial e_l} = 0 \Rightarrow \lambda L^\gamma h^{1-\gamma} = \theta_2 \tag{41}
\]

In addition, the shadow utility price \( \lambda \) of human capital must change constantly to equate the cost and benefit of accumulating human capital:

\[
\dot{\lambda} = (\rho - \eta) \lambda - \frac{\partial \mathcal{H}}{\partial h}
\]

\[
= (\rho - \eta) \lambda - \lambda \left( (1 - \gamma) L^\gamma h^{-\gamma} e_l - \eta \right) - \theta_1 w_b e_w \tag{42}
\]
Finally, we require the transversality condition (19) in the text.

The second differential equation is given by the learning technology (4), which we repeat here for convenience:

\[ \dot{h} = L^\gamma h^{1-\gamma} e_l - \eta h \]  

(43)

where, from (5):

\[ L \equiv \frac{M}{\bar{e}_w N} \]  

(44)

The representative household takes \( L \) and the economy-wide averages \( \bar{h} \) and \( \bar{e}_w \) as given when undertaking the maximization. After that, we impose aggregate consistency so that the representative household’s choices match economy-wide averages: \( \bar{h} = h \) and \( \bar{e}_w = e_w \).

We now show how to simplify (42) and (43) to obtain the system in the text, (23) and (24).

First, divide (43) by \( h \) to see that

\[ \frac{\dot{h}}{h} = \left( L \right)^\gamma e_l - \eta. \]

As noted in the text, substitute (14) into (44) to see that \( \left( \frac{L}{h} \right)^\gamma \) is a constant, which we call \( A \). That is,

\[ A \equiv \left( \frac{L}{h} \right)^\gamma = \left( \frac{\alpha (1-\alpha)}{v_0} \right)^\gamma \]  

(45)

This means we can write the accumulation equation as:

\[ \dot{h} = h \left( A e_l - \eta \right) \]  

(46)

The first-order conditions (39) - (41), with the constraint \( c = w_b e_w h \), and the definitions of \( A \) and \( z \), yield:

\[ e_w = \frac{1}{zA} \]  

(47)

It follows that:

\[ e_l = 1 - \frac{1}{zA} \]  

(48)

so that the accumulation equation is:

\[ \dot{h} = h \left( A - \frac{1}{z} - \eta \right) \]  

(49)

This is (23) in the text.

To derive (24), use (42), along with (39), (45) and the definition \( z \equiv \lambda h \) to get:

\[ \frac{\dot{\lambda}}{\lambda} = \rho - (1 - \gamma) A e_l - \frac{1}{z} \]  

(50)

To get the motion equation for \( z \), recall that \( \dot{z} = \frac{\dot{x}}{x} \). Use (48) in (50), then add to (49) to get:

\[ \dot{z} = z \left( \rho - \eta + \gamma A \right) - (1 + \gamma) \]  

(51)
The dynamic system comprises (49) and (51) which appear as (23) and (24) in the text.

**D Calibration and Fixed Cost**

In this appendix we show that the level of $y$ falls when the fixed cost $(1 + \beta)v_0$ rises.

There are no transitional dynamics so we can fully characterize the path of per capita output with values for initial $y$ and the growth rate: $y(t) = y(0)e^{gyt}$. We first calibrate the model to an arbitrary index of $y(0) = 100$ and a growth rate of $gy = .018$, which corresponds roughly to US experience in the last century, and then show that for any feasible set of parameters, the effect of raising $\beta$ on $y(0)$ is negative.

The growth rate is determined by four elementary parameters: $\rho$, $\eta$, $\alpha$, and $\gamma$. We set the rate of time discount to $\rho = .04$, which is in the range of estimates that appear in the literature, and the rate of population growth at $\eta = .013$, which is close to the US average over the last century. Our qualitative results are not sensitive to $\rho$, but it is necessary for an optimal policy that $\rho - \eta > 0$.

We assume for our baseline that $\alpha = .4$, which is approximately equal to capital’s share in the US economy. However, below we consider a wide range of values for $\alpha$. To calibrate $\gamma$, we note that population growth over US history does not appear to have had much influence on the growth rate of per capita output.\(^{23}\) Therefore, we set $\gamma$ to ensure that $\partial g_y/\partial \eta = 0$ using (28). This yields $\gamma = 1 - \alpha = .6$. It follows that when we vary $\alpha$ in the sensitivity analysis, we also vary $\gamma$.

The above four parameters are sufficient to find the value of $A$ by using (27) and (28) along with our empirical observation that US growth was about $g_y = .018$ over the last century. In fact, if $\gamma = 1 - \alpha$, as we assume, then the expression for $A$ reduces to $A = g_y + \rho$.\(^{24}\) Using the value $g_y + \rho = .058$, we find $v_0 = 27.6162$ from (45).

To find the path of $y(t)$, we also require values for $v_1$, and the stocks $h(0)$ and $N(0)$. Use the expression for $y$ in (17), our assumption that $y(0) = 100$, and arbitrary values $h(0) = 10$ and $N(0) = 10,000$.\(^{25}\) These values gives us $v_1 = 1.185$.

Now we demonstrate that $\frac{\partial y}{\partial v_0} < 0$ for a wide range of parameter values. The level of $y$ at any instant is given by (17), which we can express as:

$$y = bh^{2-\alpha}N^{1-\alpha}\left(\frac{1}{v_0^{1-\alpha}}\right)e^{2-\alpha}$$

where $b \equiv \frac{\alpha^{1+\alpha}(1-\alpha)^{2(1-\alpha)}}{v_1^\alpha}$. Now use (26) for $e_w$ and (20) for $A$ to show how $e_w$ depends on

\(^{23}\)For evidence of this, see Goodfriend and McDermott (2021).

\(^{24}\)That is, substitute (27) into (28); then set $\gamma = 1 - \alpha$ and solve for $A$.

\(^{25}\)These values are not quite arbitrary; they deliver values for variable cost $v_1$ that are much smaller than the fixed cost $v_0$, which fits our intuition.
\( y(v_0) = bh^{2-\alpha}N^{1-\alpha}\left(\frac{1}{v_0^{1-\alpha}}\right)\left(\frac{(\rho - \eta) v_0^\gamma}{(1 + \gamma) [\alpha (1 - \alpha)]^\gamma} + \frac{\gamma}{1 + \gamma}\right)^{2-\alpha} \)  

(53)

The object \( b \) and the stocks \( h \) and \( N \) do not change with a rise in \( v_0 \). The sign of the derivative, then, only concerns the last term, and is independent of the values of \( v_1, h, \) and \( N \).

From our calibration strategy, set \( \gamma = 1 - \alpha \). Then take the derivative of (53) with respect to \( v_0 \). The derivative, which is quite complicated, depends only on \( \alpha, v_0, \) and \( \rho - \eta \). Keeping \( \rho - \eta \) unchanged, call the derivative:

\[
\frac{\partial y}{\partial v_0} = bh^{2-\alpha}N^{1-\alpha} f(\alpha, v_0) 
\]

(54)

Recall that \( v_0 \) depends on \( \alpha \) in our calibration. That is, \( v_0 = \frac{\alpha(1-\alpha)}{(g_y + \rho)^{1-\alpha}} \), which uses the results from our calibration that \( \gamma = 1 - \alpha \) and that \( A = g_y + \rho \). Make this substitution in (54) to eliminate \( v_0 \) from the derivative, leaving:\textsuperscript{26}

\[
\frac{\partial y}{\partial v_0} = bh^{2-\alpha}N^{1-\alpha} g(\alpha) 
\]

(55)

We evaluate \( g(\alpha) \) numerically for values of \( \alpha \) between .1 and .9, in steps of .05. In all cases \( g(\alpha) < 0 \).

This demonstrates that an increase in the fixed cost \( v_0 \) reduces the level of \( y \) in the short run for a wide range of feasible parameters, since as we vary \( \alpha \), we are also varying \( \gamma \) and \( v_0 \) to ensure compliance with our basic calibration. As noted in the text, the rate of growth \( g_y \) falls according to (31).

References


\textsuperscript{26}The expression \( g(\alpha) \) is long and complicated. It is available upon request.


