Endogenous Policy and Cross-Country Growth Empirics

- Preliminary Version -

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Abstract

This paper presents an accumulation-driven growth model where investment depends on public policy which in turn depends on economically important fundamentals. It is argued that conditioning on factor accumulation in growth regressions that also include policy variables may be problematic. When policy is endogenous the measured effects of policy on growth will generally be biased. Based on the model and OECD data, the signs of the biases are derived. It is shown that the measured effects on growth of tax variables related to the tax base are biased upwards and redistribution variables are generally biased downwards. Based on these signed biases the paper discusses some empirical results that seem puzzling from a theoretical viewpoint.

KEYWORDS: Growth, Public Policy, Cross-Sectional Models

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1 Introduction

Most researchers acknowledge that empirical work on the effects of policy on economic growth may be riddled by endogeneity problems. This paper concentrates on that issue. It attributes any discrepancy of results to the fact that policy is economically endogenous and that treating it as exogenous provides one with a misleading picture of the relationship between fiscal policy and growth.

For instance, many authors have investigated the effects of taxation on long-run growth. Although employing similar theoretical frameworks[1], their conclusions differ widely. See, for example, King and Rebelo (1990), Lucas (1990), Rebelo (1991), Jones, Manuelli and Rossi (1993), Pecorino (1993), (1994), or Stokey and Rebelo (1995).

The link between (re-)distribution and growth has e.g. been analyzed by Bertola (1993), Alesina and Rodrik (1994), Persson and Tabellini (1994), or Perotti (1996). These studies often provide theoretical arguments that redistribution of resources from the accumulated towards the non-accumulated factor of production should be expected to affect growth negatively.

To test these theoretical predictions a large number of contributions has proceeded by taking averages of their data over time and run simple cross-country OLS regressions over these averages.[2]

[1] For instance, Koester and Kormendi (1989), Barro (1991), (1997), Levine and Renelt (1992), Easterly and Rebelo (1993), or Sala-i-Martin (1997) have empirically analyzed the effects of fiscal policy on growth. Most of them find that tax rates or other, tax financed fiscal variables have a negative, but - when controlling for initial income - insignificant effect on growth.

[2] In the paper 'simple cross-country OLS regression' is meant to reflect that procedure of handling the time series dimension of the data. Of course, 'simple' does not mean simplistic, since the availability of data may not allow for another or a 'better' method of analysis. More recently some authors have advocated the use of *dynamic* panel data methods to pay explicit attention to the time series dimension. See e.g. Caselli, Esquivel and Lefort (1996). But the latter methods seem to have their own problems as e.g. argued by Barro (1997), p. 37, Temple (1999), p. 132, and e.g. analyzed by Banerjee, Marcellino and Osbat (2000).

This paper first provides a theoretical model that is based on a simplified version of Alesina and Rodrik (1994). The model features some commonly agreed upon properties. For instance, policy affects factor accumulation which in turn bears on output growth, and redistribution lowers long-run growth in the model. Importantly, public policy is derived from optimizing behaviour which takes account of fundamental economic variables. Thus, policy is endogenous in the paper.

It is generally agreed that productivity differences between countries play a major role in explanations of differences in growth rates. Therefore, the paper focuses on the effects of differences in productivity and takes it as *the* economic fundamental. The paper then derives the theoretical signs of covariances between public policy, the growth rate and that fundamental economic variable.

Coupling productivity data from Hall and Jones (1999), tax data from the OECD and other well-known sources it is found - at least for the OECD countries - that the theoretical signs of the covariances are borne out by the data.

Next, the paper relates the theoretical predictions to common empirical set-ups. In line with most studies it is assumed that productivity differences are unobservable. In this case estimation would suffer from omitted variable bias. First, the theoretical model itself is transformed into a linear regression model. The derived signs of the covariances allows one to *sign* the biases theoretically. These signs are confirmed when calculating the biases using the paper's data.

For more complex growth regressions in the spirit of Mankiw, Romer and Weil (1992) (MRW) it is found that signing the biases for the policy variables must be done by the data at hand. The same holds true for simplified variants of the set-ups used in the model uncertainty literature. See, for instance, Levine and Renelt (1992) or Sala-i-Martin (1997).

It is shown that growth regressions would generally yield misleading results if output growth is conditioned on variables relating to factor accumulation *and* policy. This is because according to the theory policy bears on investment which in turn affects output growth. Thus, including variables for policy and factor accumulation would lead to misspecified models.

Interestingly, the data reveal that the signs of the biases for the policy variables are the same for all the different empirical models studied. Furthermore, they are equal to what the simplest linear empirical formulation of the theory implies. In particular, the data would seem to confirm the following:

The theory predicts that the estimates for the effects on growth of tax rate variables related to the tax base are generally biased upwards and so overestimated. Thus, any reported negative effect of taxes on growth is understated, if measured by these variables.[3]

Under the assumption of endogenous policy, the estimated coefficients of the effect on growth of redistribution are generically biased downwards in the model. That would render the hypothesis that redistribution is bad for growth untestable. This is because the prediction of the theoretical model is that redistributive transfers are bad for growth. However, in the model an increase in efficiency makes an optimizing, redistributing government grant less transfers to the non-accumulated factor of production. This last effect is ignored in growth regressions when one assumes that public policy is exogenous.

For theoretical reasons many researchers expect a negative coefficient for the effect of redistributive transfers on growth. However, many people find positive coefficients (for example, for the effect of social security contributions on growth,

[3]Effect is not meant to be causal. In this paper effect means that some underlying economic fundamental influences policy which in turn bears on growth. Then the 'true' effect of policy on growth is spurious really, but can only be picked up by the estimated coefficients in linear regressions.

see Sala-i-Martin (1996)). As any downward bias of the estimated coefficients may be as large as minus infinity, a reported negative coefficient cannot corroborate the hypothesis that redistribution is bad for growth. On the other hand, any downward bias is perfectly consistent with many empirical findings and the alternative hypothesis that redistribution is not bad for growth.

The main insights to be drawn from the paper are the following. The disentanglement of the interplay of economic fundamentals and policy one the one hand and policy and growth on the other should provide an interesting area for further research. Conditioning on factor accumulation in growth regressions that also include policy variables may be problematic. Furthermore, analyzing biases in growth empirics should not be too difficult and would base some findings on a sounder footing.

The paper is organized as follows: Section 2 presents the theoretical model and derives the signs of the covariances. Section 3 presents empirical evidence for the covariances. Section 4 analyzes the bias problem theoretically for simple set-ups related to the literature. Section 5 presents empirical findings for the biases. Section 6 provides concluding remarks.

2 Theory

Consider a private ownership economy that is populated by two types of price-taking, infinitely lived individuals who are all equally patient. One group of agents, the capitalists (k), owns wealth equally and does not work. The other group of agents, the workers (W), owns (raw) labour equally, but no capital.[4] Population is stationary and each group of agents derives logarithmic utility

[4]The assumption may be justified by various arguments, especially for the long run. See e.g. Kaldor (1956), Pasinetti (1962), Schlicht (1975), Bourguignon (1981), or Bertola (1993).

from the consumption of a homogeneous, malleable good. Aggregate output is produced according to

$$Y_t = A\, K_t^{\alpha}\, G_t^{1-\alpha}\, L_t^{1-\alpha} \quad , \quad 0 < \alpha < 1 \tag{1}$$

where Y_t denotes aggregate output, K_t is the real capital stock, L_t is labour supplied, and G_t are public inputs to production. See Barro (1990). Capital is broadly defined and includes human capital.[5] The index A reflects the economy's state of technology. It depends on cultural, institutional and technological development and captures long-run exogenous factors that play a role in the production process. Labour is inelastically supplied and normalized so that the total labour endowment equals unity, $L_t = 1$. The model abstracts from the depreciation of capital so that output and factor returns are really defined in net terms.

Following Alesina and Rodrik (1994) we use a wealth tax scheme as a metaphor to represent a broad class of redistributive tax arrangements, which distort the investors' incentive to accumulate. In particular, we assume that the government taxes wealth at the constant rate τ, redistributes a constant share λ of its tax revenues to the workers[6] and runs a balanced budget: $\tau K_t = G_t + \lambda\tau K_t$. The LHS depicts the tax revenues and the RHS public expenditures. The workers receive $\lambda\tau K_t$ as transfers and G_t is spent on public inputs to production.

There are many identical, profit-maximizing firms which operate in a perfectly competitive environment. They are owned by the capital owners who rent capital to and demand shares of the firms. The shares are collateralized one-to-one by

[5] This eliminates a separate treatment of how human capital is accumulated. By assumption the economies are perfectly competitive and the return on human capital services equals that of physical capital services. See Mankiw et al. (1992).

[6] Alesina and Rodrik (1994) show that the optimal policies are constant over time and, thus, time-consistent. For convenience constancy of policy is assumed from the beginning in this paper.

capital. The markets for assets and capital are assumed to clear at each point in time. The firms take G_t as given and rent capital and labour in spot markets in each period. The price of output y_t serves as numéraire and is set it equal to one. Profit maximization entails that firms pay each factor of production its marginal product,

$$r = \alpha A[(1-\lambda)\tau]^{1-\alpha} \tag{2}$$

$$w_t \equiv \eta(\tau,\lambda)K_t = (1-\alpha)A[(1-\lambda)\tau]^{1-\alpha}K_t. \tag{3}$$

Because of the productive role of government services policy has a bearing on the marginal products. The return on capital is constant over time while the wages grow with the capital stock. Notice that more redistribution lowers r and η, while higher taxes raise them.

The workers derive utility from consuming their entire income. They do not invest and are not taxed. Their intertemporal welfare is given by

$$\int_0^\infty \ln C_t^W \, e^{-\rho t} dt \quad \text{where} \quad C_t^W = \eta(\tau,\lambda)K_t + \lambda\tau K_t. \tag{4}$$

The capitalists choose how much to consume or invest, and they have perfect foresight about the prices and tax rates, which they take as given. They maximize their intertemporal utility according to

$$\max_{C_t^k} \int_0^\infty \ln C_t^k \, e^{-\rho t} dt \tag{5}$$

$$s.t. \qquad \dot{K}_t = (r-\tau)K_t - C_t^k \tag{6}$$

$$K(0) = \overline{K_0}, \quad K(\infty) = \text{free}, \tag{7}$$

where equation (6) is the capitalists' dynamic budget constraint which depends on their after-tax income $(r-\tau)K_t$. In appendix A it is shown that their consumption and wealth optimally grow at

$$\gamma \equiv \frac{\dot{C}_t^k}{C_t^k} = \frac{\dot{K}_t}{K_t} = (r-\tau) - \rho \tag{8}$$

which is increasing in the after-tax return on capital and constant over time.

2.1 Equilibrium

In steady state the economy is characterized by *balanced growth* at the rate γ, which is first increasing and then decreasing in τ for given λ. Growth is maximized when $\tau = [\alpha(1-\alpha)A]^{\frac{1}{\alpha}} \equiv \hat{\tau}$ and $\lambda = 0$. If taxes higher than $\hat{\tau}$ are levied, then growth is traded off against redistribution when $\lambda > 0$ and $\check{\tau} > \hat{\tau}$.

Furthermore, $r - \tau = \alpha A[(1-\lambda)\tau]^{1-\alpha} - \tau$ so that for *given* policy an increase in efficiency A raises growth.

2.2 Policy

Integrating the agents' welfare functions (5) and (4) under the condition that the growth rate is constant in equilibrium yields the intertemporal welfare of an entirely pro-capital, V^r, resp. entirely pro-labour government, V^l,

$$V^r(C_t^k) = \frac{\ln(\rho K_0)}{\rho} + \frac{\gamma}{\rho^2} \quad \text{and} \quad V^l(C_t^W) = \frac{\ln\left[(\eta(\tau,\lambda) + \lambda\tau)K_0\right]}{\rho} + \frac{\gamma}{\rho^2}. \tag{9}$$

The governments respect the right of private property and maximize the welfare of their clientele under the condition $\lambda \geq 0$. That restricts the governments in that even an entirely pro-capital government does not tax the workers.

The optimal pro-labour policy is derived in appendix B and given by

If $\rho \geq [(1-\alpha)A]^{\frac{1}{\alpha}}$ then:

$$\tau = \rho, \qquad \lambda = 1 - \frac{[(1-\alpha)A]^{\frac{1}{\alpha}}}{\rho}\,. \tag{10}$$

If $\rho < [(1-\alpha)A]^{\frac{1}{\alpha}}$ then:

$$\tau[1-\alpha(1-\alpha)A\tau^{-\alpha}] = \rho(1-\alpha), \qquad \lambda = 0\,. \tag{11}$$

Denote the optimal pro-labour tax rate by $\check{\tau}$ and notice that for a wide range of parameter values there is no redistribution. In particular, if the agents are sufficiently patient or the economy is very efficient, the owners of the non-accumulated factor of production (workers) prefer to have higher growth instead of direct redistribution. This is because high growth may be good for their income stream and so welfare. In that way the model distinguishes between redistributing and non-redistributing governments.

In contrast, the pro-capital government chooses $\tau = \hat{\tau}$, does not redistribute, grants the maximum after-tax return on capital, and acts growth maximizingly in this model.

All optimal policies depend on A, α, and ρ. In that sense policy is endogenous. The rate of time preference will not be considered any further because it is considered a variable, which is very hard to measure. Furthermore, most researchers find that there is not much variability in α. For that reason it is commonly ignored in growth regressions. However, A is usually considered a very important variable for which I find the following[7]

[7]These signs of these effects are derived in appendix C.

Table 1: Growth and Policy Effects

	PC		$PL_{\lambda=0}$		$PL_{\lambda\geq 0}$		
	$\hat{\tau}$	$\hat{\gamma}$	$\check{\tau}$	$\check{\gamma}$	$\check{\tau}$	λ	$\check{\gamma}$
A	+	+	+	+	0	-	+

PC - pro-capital, PL - pro-labour
Sign: (+) - positive, (−) - negative

Thus, an increase in efficiency raises growth, does not imply lower tax rates but calls for lower redistribution under all policies considered. This is due to the positive externality of public inputs. Higher growth requires more tax revenues for productive services channelled into production in order to raise the return on capital and so growth.[8] These are the theoretical predictions of the signs of covariances one should expect in empirical research.

3 Empirical Evidence I

In this section empirical checks are provided for the theoretical predictions in Table 1. The empirical evidence should be viewed as suggestive only, because reliable data on tax rates and redistribution are in general not easy to obtain for a large set of countries.[9] Therefore, I concentrate on the subset of OECD countries for which data are more readily available.[10]

[8] For example, Bougheas, Demetriades and Mamuneas (2000) or Demetriades and Mamuneas (2000) provide empirical evidence for the positive effect of public infrastructure on intertemporal output.

[9] For a detailed description of the data and the methods used in this paper confer http://www.tu-darmstadt.de/~rehme/endopol/data.htm. The sample is presented in Table 4 on p. 32.

[10] An advantage of this, though, is that they form a homogeneous group so that one does not need to control for regional disparities by means of dummy variables as has so often been done

3.1 The Data

Countries differ widely in the level of development, but reliable data capturing the *level* of development have not been easily available. Recently data for the levels of productivity, A, across countries have, for example, been calculated by Hall and Jones (1999).[11] They derive measures of A for many countries using a *levels accounting* framework based on a production function approach. Their data are used here and the variable measuring productivity is called HJ-A. The productivity differences are expressed relative to the U.S. for which the value is set at unity. For more details see their paper.

Redistribution is measured following Milanovic (2000). Based on household data from the Luxembourg Income Study (LIS) Gini indices are calculated for the distribution of households' factor income and they are compared to the Gini indices for the distribution of disposable income.[12] Redistribution is measured by the difference in these Gini coefficients. For a similar procedure see Rehme (2003). Milanovic provides data for 24, mostly OECD countries with a total of 79 observations. In this paper averages of the period 1970-2000 are taken for these differences in Gini coefficients and the resulting variable is called AVRED and is taken to proxy the model's λ.

To proxy for the tax rate τ I have used data from the OECD Revenue Statistics 1965-2001, OECD (2002). For these years the ratio of tax revenue to GDP is

in cross-country research.

[11] Other sources based on panel regression methods include e.g. Islam (1995) or Islam (2003).

[12] Factor income is defined as pre-transfer *and* pre-tax income, and includes wages income from self-employment, income from ownership of physical and financial capital and gifts. Factor income also includes public pensions. Gross income, in turn, equals factor income *plus* social insurance transfers, which includes sick pay, disability pay, social retirement benefits, child or family allowances, maternity pay, military or veterans benefits and near-cash benefits. Gross income *minus* mandatory employee contributions *minus* income tax equals disposable income. See the Luxembourg Income Study for the variable definitions at http://www.lisproject.org/techdoc/summary.pdf.

provided for 30 countries. Averages for the period 1970-2000 were taken and the variable is called AVTAX.

In order to link up with studies that have identified robust regressors in cross-country work I have followed Sala-i-Martin (1997) and used male primary school attainment in 1960, called MSCHOOL60, and life expectancy in 1960, LIFE-EXP60, as (robust) control variables. Both are taken from Table 10.1, Barro and Sala–i–Martin (1995).

Finally, long-run growth rates, called GR70-00, and the logarithm of initial income in 1970, LNY70, were calculated using the Penn World Table (Mark 6.1) provided by Heston, Summers and Aten (2002).

The following table provides information on some descriptive statistics.

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	No. of Obs.
AVTAX	0.3395	0.0801	30
AVRED	15.8857	4.6481	21
HJ-A	0.7848	0.2739	30
LNY70	9.2054	0.4855	28
MSCHOOL60	6.3078	2.0749	27
LIFEEXP60	68.0577	5.6495	26
GR70-00	0.0232	0.0096	30

For the variables of interest, τ, λ and A, this means that the average tax-revenues-to-GDP ratio AVTAX is about 34 percent with a standard deviation of 8 percentage points. Redistribution AVRED is such that government intervention by means of taxes and transfers reduces the Gini coefficient for factor income by approximately 16 Gini points. Finally, in the sample the average country features a level of productivity, HJ-A, that reaches roughly 79 percent of the level that pertains to the U.S.A.

The next table presents the covariances between the variables.

Table 3: Covariances

	AVTAX	AVRED	HJ-A	LNY70	MSCHOOL60	LIFEEXP60	GR70-00
AVTAX	0.0064	0.1840**	0.0001	0.0176*	0.0662*	0.3290**	-0.0013
AVRED		21.6050	-0.6790*	-0.4760	1.0300	0.5730	-0.0009
HJ-A			0.0750	0.0695**	-0.0564	0.4470	0.0000
LNY70				0.2360	0.5880	2.3030**	-0.0024**
MSCHOOL60					4.3050	7.2540**	-0.0059
LIFEEXP60						31.9170	-0.0214*
GR70-00							0.0001

**. Statistically significant at the 0.01 level. *. Statistically significant at the 0.05 level.

For the variables of interest the theoretically derived signs for the covariances are generally borne out by the data. For example, the covariance between AVTAX and HJ-A is statistically insignificant, but positive (0.001) and that between AVRED and HJ-A is statistically significant at the five percent level and negative (-0.6790). Furthermore, the simple covariances show a positive (simple, uncontrolled) relationship between taxes, AVTAX, and redistribution, AVRED. In addition, the covariances between initial income and AVTAX, AVRED and HJ-A all show the expected signs.

Therefore, the covariances seem to support the model's theoretical predictions. Next, we turn to the implication of the model and the data for cross-country research.

4 Growth Empirics

According to the theory the empirical, long-run relationship between growth and policy for a country i is of the form

$$\gamma_i = f(\tau_i(A_i), \lambda_i(A_i), A_i) = h(A_i) \tag{12}$$

where $f(\cdot)$ is a non-linear function of A_i which is assumed to be country-specific, that is, independent and thus uncorrelated across countries.[13] Notice that (12) represents an equilibrium relationship, because output grows at the same rate as the capital stock. The growth rate of the latter, in turn, depends on policy. Thus, the theoretical model implies that policy bears on factor accumulation, which, in turn bears on output growth.

An analysis of exogenous, once-and-for-all changes in A_i is similar in spirit to models with exogenous technological change, which is commonly thought to be unobservable.[14] Thus, in line with most studies A_i is taken to be unobservable, implying that information on A_i would be contained in the disturbance term and would not feature separately in the regressions. Then the second-best, but operationally viable model would be

$$\gamma_i = \beta_c + \beta_\tau \ \tau_i(A_i) + \beta_\lambda \ \lambda_i(A_i) + v_i \tag{13}$$

where $v_i = v_i(A_i, \epsilon_i)$ is a country-specific disturbance term which depends positively on A_i and also on ϵ_i. The latter is assumed to be uncorrelated with A_i as well as with each of the regressors, and $E(\epsilon_i) = 0$.

If that model were estimated by OLS, multicollinearity and the omission of a relevant variable would be a problem. Thus, reported $t-$statistics will not report the true significance levels and statistical inferences are not really possible.

[13]Under the assumption of exogenous policy $\gamma_i = g(\tau_i, \lambda_i, A_i)$ where τ_i and λ_i are independent of the other variables included in $g(\cdot)$. Notice that $h(\cdot)$ and $g(\cdot)$ may be observationally equivalent when particular A_is lead to the same growth rate under either assumption. Thus, assume that empirical and theoretical researchers agree that the Data Generating Mechanism (DGP) is given by the joint probability distribution $D(\gamma, \tau, \lambda, A)$, which is expressed in terms of steady state variables and, thus, ignores any time dependence. That reflects the procedure to take time-averages of data which are considered of interest.

[14]The discussion about the *Solow-Residual* reflects these difficulties. See, for instance, Barro and Sala–i–Martin (1995), chpt. 10.4.

However, here the focus is on the problem caused by assuming that policy is exogenous.

A standard justification for treating policy as exogenous is a randomization argument. For example, Barro (1989) argues that in a large sample public policies may be treated as randomly generated. That comes close to saying that policies are exogenous. But in light of this paper's analysis the argument would not hold. Even if all countries had different governments with different welfare functions so that polices looked randomly chosen, the model predicts that *all* policies would be influenced by the same fundamental economic variables included or not included in the regressions. The paper concentrates on exactly that problem.

In order to see what endogenous policy and biases due to the omission of A_i imply, assume that for the estimation of (13) we use OLS and transform our data to *mean deviation form*. This allows us to calculate expressions for the estimators $\hat{\beta}_j$ where $j = \tau, \lambda$. Then the *expected bias*, called b_j, which bears on $\hat{\beta}_j$ obeys $\hat{\beta}_j = \beta_j + b_j$ where β_j is the true estimator. Thus, $\hat{\beta}_j - \beta_j = b_j$ is the expected bias. It is then pretty straightforward to show that the biases are given by

$$\begin{bmatrix} b_\tau \\ b_\lambda \end{bmatrix} = \begin{bmatrix} a_{\tau\tau} & a_{\tau\lambda} \\ a_{\tau\lambda} & a_{\lambda\lambda} \end{bmatrix}^{-1} \begin{bmatrix} a_{\tau v} \\ a_{\lambda v} \end{bmatrix} \tag{14}$$

where $a_{\tau\tau}$, $a_{\lambda\lambda}$ denote the variances, and $a_{\tau\lambda}, a_{\tau v}, a_{\lambda v}$ represent the covariances of τ, λ and v.[15]

One easily establishes that the covariance matrix above is positive definite and has a positive determinant denoted by D. Using Cremer's Rule we can calculate

[15]Thus, e.g., $a_{\tau\tau} = \dfrac{1}{N}\sum_i^N(\tau_i - \bar{\tau})^2$ and $a_{\tau\lambda} = \dfrac{1}{N}\sum_i^N(\tau_i - \bar{\tau})(\lambda_i - \bar{\lambda})$ where bars over the variables denote sample means.

the expected biases as

$$b_\tau = D^{-1}\left[a_{\lambda\lambda}\ a_{\tau v} - a_{\tau\lambda}\ a_{\lambda v}\right] > 0 \quad \text{and} \quad b_\lambda = D^{-1}\left[-a_{\tau\lambda}\ a_{\tau v} + a_{\tau\tau}\ a_{\lambda v}\right] < 0 \tag{15}$$

since $a_{\lambda\lambda}, a_{\tau\tau}, a_{\tau\lambda}, a_{\tau v} > 0$, and $a_{\lambda v} < 0$. This establishes the following: If (13) is the true model we get an upward bias, and thus an overestimation of the effect of taxes on growth. If we assume that in a large sample countries are not all acting growth maximizingly then we expect to be on the downward sloping branch of the model's inverted U-shaped relationship between taxes and growth. Thus, we would expect $\beta_\tau < 0$, that is, a negative point estimate for the effect of taxes on growth. If we find a positive one, it would not invalidate the theory as the true estimate may still be negative. Notice that the model implies this may apply to all tax rate variables that are related to the tax base.

In turn, we get a downward bias, and thus, an underestimation of the effect of redistribution on growth. As the model lets us expect a negative point estimate, $\beta_\lambda < 0$, the underestimation implies that the hypothesis that redistribution is bad for growth is inherently untestable. This is because the estimate can in principle be biased towards minus infinity. Thus, when we find a negative point estimate this cannot be taken to corroborate the theory that redistribution is bad for growth.

Instead of pursuing the implications of the 'true' model any further, we now concentrate on the predicted covariances as implied by the model.[16]

[16]The theoretical model is supposed to capture essential features of the relationship between fiscal policy and growth. Thus, based on the theory one may derive the covariances with A and the implication for possible biases for other fiscal variables like the ratio of redistributive transfers to GDP or public investment to GDP. This has been done in a related paper, see Rehme (2002).

4.1 Relation to Growth Accounting

A common empirical approach is to take the usual growth accounting equation derived from a production function (see, e.g., Solow (1957)) and estimate it, rather than using factor shares to impute the coefficients on labour and capital growth. For instance, Benhabib and Spiegel (1994) estimate equations of the form

$$\frac{\dot{Y}}{Y} = \beta_0 + \beta_1 \frac{\dot{K}}{K} + \beta_2 \frac{\dot{L}}{L} + \beta_2 x_1 + ...\beta_n x_n + \epsilon$$

where output growth is taken to depend on the growth rates of the capital stock and labour, but also on the control variables $(x_1, ..., x_n)$. If this approach is taken, and the control variables were the tax rates τ and redistribution λ, and the true model is given by (12), the fiscal policy variables would be found to have no effect on growth regression that condition on capital growth. This is because according to the theory policy affects accumulation, that is, capital growth. Thus, we would get a misleading picture of the relationship between output growth and policy. More precisely, according to the model if one assumes that the level of productivity, A, and the policy variables τ and λ are constant over time, but different across countries, the coefficient on capital growth should be unity and that on labour growth should be $1 - \alpha$. In this case the level of productivity, A, would not feature in the residual, it would only bear on the control variables τ and λ and on capital growth. Hence, one conclusion for estimating growth accounting equations is that if one assumes that policy variables are constant over time, then estimating an equation like (16) one will find that policy variables have no explanatory power in a cross-section, if one conditions on capital growth and policy affects output growth through accumulation.

4.2 Relation to Barro-Regressions

A typical cross-country growth regression that analyzes the effect of policy on output growth takes the form

$$\gamma_i = P\beta + X\delta + \zeta y_0 + v'(A_i, \epsilon_i). \tag{16}$$

Here P is a row vector of policy variables, X a row vector of control variables and y_0 is the logarithm of initial income. This formulation goes back to e.g. Barro (1991), Mankiw et al. (1992), Islam (1995), or Caselli et al. (1996). The inclusion of initial income is due to the hypothesis that initially poorer countries have lower subsequent growth. Often initial income is found to be a robust regressor, that is, it is found to be statistically significant in many different model variations. See, for example, Levine and Renelt (1992) and Sala-i-Martin (1997).

First notice that the arguments of the previous section apply to the types of equation in (16) as well. Hence, conditioning on variables like investment or investment in terms of GDP in a regression that includes policy variables will find that policy variables have no explanatory power, if policy is taken to bear primarily on factor accumulation.

Next, suppose we wanted to test the predictions of the theoretical model using the Barro set-up. For simplicity, assume that the variables in X are orthogonal to the policy variables in P and to initial income y_0. This would be a rather desired property for estimation. Furthermore, we will look at the following two model variants as examples that capture the essential features what is being done in the literature.

$$\gamma_i = \beta_\tau \tau_i + \beta_{x_i} x_i + \beta_y y_0 + v'(A_i, \epsilon_i) \tag{17}$$

$$\gamma_i = \beta_\tau \tau_i + \beta_\lambda \lambda_i + \beta_y y_0 + v'(A_i, \epsilon_i) \tag{18}$$

The first model in (17) represents in an abbreviated form an example of what authors like Levine and Renelt (1992) or Sala-i-Martin (1997) do when they study model uncertainty. The typical procedure is to identify robust regressors like initial income y_0 and some other control variables like x (e.g. life expectancy or an indicator of human capital) to check whether adding variables of interest (here τ) are associated with growth in a statistically significant way.

The second model in (18) draws on a simple version of regressions that are derived from the Solow model. This approach has primarily been popularized by Mankiw et al. (1992) (MRW). Here the coefficients on τ and λ measure the effect on the steady state growth rate, whereas the coefficient on y_0 measures (conditional) $\beta-$convergence, that is, how far countries are from their long-run positions. The expectation is that β_y is negative, that is, initially poorer countries should exhibit higher subsequent growth.

The expected biases for the MRW model in (18) are given by

$$\begin{bmatrix} b_\tau \\ b_\lambda \\ b_y \end{bmatrix} = \begin{bmatrix} a_{\tau\tau} & a_{\tau\lambda} & a_{\tau y} \\ a_{\tau\lambda} & a_{\lambda\lambda} & a_{\lambda y} \\ a_{\tau y} & a_{y\lambda} & a_{yy} \end{bmatrix}^{-1} \begin{bmatrix} a_{\tau v} \\ a_{\lambda v} \\ a_{yv} \end{bmatrix} \tag{19}$$

where a_{ij} represents the covariances of variables i and j.

The covariance matrix is positive definite and has a positive determinant denoted by D'. Using Cremer's Rule we can calculate the expected biases as

$$\begin{aligned}
b_\tau &= \frac{(a_{\lambda\lambda}a_{yy} - a_{\lambda y}^2)a_{\tau v} - (a_{\tau\lambda}a_{yy} - a_{y\lambda}a_{\tau y})\ a_{\lambda v} + (a_{\tau\lambda}a_{\lambda y} - a_{\lambda\lambda}a_{\tau y})\ a_{yv}}{D'} \\
b_\lambda &= \frac{-(a_{\tau\lambda}a_{yy} - a_{\tau y}a_{\lambda y})\ a_{\tau v} + (a_{\tau\tau}a_{yy} - a_{\tau y}^2)\ a_{\lambda v} - (a_{\tau\tau}a_{\lambda y} - a_{\tau\lambda}a_{\tau y})\ a_{yv}}{D'} \\
b_y &= \frac{(a_{\lambda\lambda}a_{\tau\tau} - a_{\tau\lambda}^2)a_{yv} - (a_{\tau\tau}a_{y\lambda} - a_{y\tau}a_{\tau\lambda})\ a_{\lambda v} + (a_{\tau\lambda}a_{\lambda y} - a_{\lambda\lambda}a_{\tau y})\ a_{\tau v}}{D'}
\end{aligned}$$

where $a_{\lambda\lambda}, a_{\tau\tau}, a_{yy}, a_{\tau\lambda}, a_{yv}, a_{\tau v} > 0$, and $a_{\lambda y}, a_{\lambda v} < 0$. The sign of these expected biases cannot unambiguously be determined from the model. For example, the theory predicts that the first two terms in the numerator expression for b_τ should be positive, but the third expression should be negative. Therefore, the biases for the model in (18) have to be determined by empirical evidence.

The model in (17) concentrates on taxes and features the additional regressor x, which is taken to be a robust regressor:

$$\begin{bmatrix} b_\tau \\ b_y \\ b_x \end{bmatrix} = \begin{bmatrix} a_{\tau\tau} & a_{\tau y} & a_{\tau x} \\ a_{\tau y} & a_{yy} & a_{yx} \\ a_{\tau x} & a_{yx} & a_{xx} \end{bmatrix}^{-1} \begin{bmatrix} a_{\tau v} \\ a_{yv} \\ a_{xv} \end{bmatrix} \tag{20}$$

where a_{ij} represents the covariances of variables i and j. Invoking our earlier assumption that x is orthogonal to τ, initial income y, and efficiency v implies $a_{\tau x} = a_{yx} = a_{xv} = 0$. Under that assumption

$$b_\tau = \frac{[a_{yy}\ a_{xx}]\ a_{\tau v} - [a_{\tau y}\ a_{xx}]\ a_{yv}}{D''} \tag{21}$$

$$b_y = \frac{-[a_{\tau y}\ a_{xx}]\ a_{\tau v} + [a_{\tau\tau}\ a_{xx}]\ a_{yv}}{D''}, \tag{22}$$

where D'' denotes the positive definite determinant of the covariance matrix.

Empirical evidence must also establish the sign of the biases for that model.

The only thing one can show is that b_τ and b_y cannot both be negative. But other combinations are possible so that the bias for the coefficient on τ may be positive or negative.[17]

From these examples one may conclude that a theoretical model that incorporates many features found empirically allows one to sign the biases only up to a certain point. For more complicated empirical models one has to check the signs of biases using the data at hand.

5 Empirical Evidence II

In this section empirical evidence is provided that serves to show the direction of the biases. For simplicity it is assumed that the covariances in Table 3 are all based on the same number of observations. That allows one to ignore problems of missing values that may have an impact on estimation.[18] Against this assumption I will now analyze various empirical models that are all linear.

Let us start with the simplest model, called model 1.

$$GR70-00 = \beta_0^1 + \beta_1^1 AVTAX + \beta_2^1 AVRED + \nu^1$$

where ν is the country specific error term that depends on A.[19]

Many cross-country studies have found that fiscal policy variables do not affect growth in a statistically significant way. This really means that the estimators for, for instance, the coefficients β_1^1 and β_2^1, called $\hat{\beta}_1^1$ and $\hat{\beta}_2^1$, are assuming values

[17] In a similar vein one can establish that in a model concentrating on redistribution λ only, i.e. $\gamma_i = \beta_\lambda \lambda_i + \beta_{x_i} x_i + \beta_y y_0 + v'(A_i, \epsilon_i)$, the biases would also have to be determined by empirical evidence.

[18] The maximum number of observations in the sample is thirty. Thus, we assume that all covariances are based on 30 observations.

[19] The superscript indicates which model is being estimated.

that are statistically close to zero. From this it is then concluded that the true coefficients β_1^1 and β_2^1 are likely to be zero.

However, biases due to the omission of A may render such a conclusion invalid. To see what the biases imply assume that estimating model 1 by OLS yields statistically insignificant values for the coefficients. For simplicity assume that $\hat{\beta}_1^1 = 0$ and $\hat{\beta}_2^1 = 0$.

Again denote the biases by $b_j^i = \hat{\beta}_j^i - \beta_j^i$, where i represents the model under study and j indicates which regressor the coefficient pertains to.

When $\hat{\beta}_1^1 = 0$ and $\hat{\beta}_2^1 = 0$ the biases are given by $b_1^1 = -\beta_1^1$ and $b_2^1 = -\beta_2^1$. Using the covariances from Table 3 allows one to calculate the biases. They are given by

$$\begin{bmatrix} b_1^1 \\ b_2^1 \end{bmatrix} = \begin{bmatrix} 0.0064 & 0.1836 \\ 0.1836 & 21.6050 \end{bmatrix}^{-1} \begin{bmatrix} 0.0001 \\ -0.6790 \end{bmatrix} = \begin{bmatrix} 1.2100 \\ -0.0417 \end{bmatrix} \tag{23}$$

The first thing to notice is that the biases for both variables are quite large.

For instance, there is a huge overestimation of the effect of taxes on growth in this model. Given the positive bias and a point estimate that is approximately zero implies that the taxes really co-vary *negatively* with growth. Quantitatively this means that an increase of one standard deviation in the ratio of tax revenues to GDP (approx. $\sqrt{0.0064} = 0.08$, that is, 8 percentage points) would lower growth by roughly $1.21 * 0.08 \approx 0.1$, that is, 10 percentage points under the assumption that the estimated coefficient is zero. Thus, the presence of the bias seems to be a non-trivial problem for model 1.

For redistribution we find a negative bias. Thus, we can expect that redistribution really co-varies *positively* with growth under the maintained assumption that the estimated coefficient is zero. The quantitative implication is that according to model 1 a one-standard-deviation change in AVRED (approx. $\sqrt{21.6050} \approx 4.7$ Gini points) would change growth by roughly $-0.0417 * 4.7 \approx -0.19$, that is, it would really raise growth by 19 percentage points under the maintained assumption.

Of course, the quantitative effects are only so strong because they hold under the assumption that the estimated coefficients are close to zero. The magnitude of the biases seems very high, however. But what is of main interest in this context is that the direction of both biases confirms what was predicted theoretically.[20]

Next, we contemplate a simple model in the spirit of Mankiw et al. (1992) by adding initial income as an additional regressor. The expectation is that the biases will be reduced by adding more regressors. In particular, our model 2 is given by

$$GR70 - 00 = \beta_0^2 + \beta_1^2 AVTAX + \beta_2^2 AVRED + \beta_3^2 LNY70 + \nu^2$$

With the covariances from Table 3 I have calculated the biases using MATLAB. They are given by

$$\begin{bmatrix} b_1^2 & b_2^2 & b_3^2 \end{bmatrix}' = \begin{bmatrix} 0.2250 & -0.0285 & 0.2206 \end{bmatrix}' \tag{24}$$

Taking account of the biases implies that AVTAX is really expected to co-vary *negatively* with growth and the association between redistribution AVRED and growth is *positive*. The quantitative effects are as follows.

A one-standard-deviation change in the tax rate (8 percentage points) reduces

[20] Recall it was found that the coefficients on τ should be biased upwards and that for λ should be biased downwards.

growth by 1.8 percentage points when one assumes that the estimated coefficients are zero. This effect is not negligible in the long run. Similarly, changing redistribution by one standard deviation would raise growth by 13.2 percentage points, which is clearly a strong effect.

Comparing the models 1 and 2 yields that the addition of initial income as a further regressor reduces the biases and, therefore, mitigates their quantitative impact on any measured effect of the two fiscal policy variables on economic growth.

The last model contemplated is related to the papers by Levine and Renelt (1992) and Sala-i-Martin (1997). These studies identify robust regressors like male school attainment, MSCHOOL60, initial income, LNY70, and life expectancy, LIFEEXP60, and then add variables of interest to see if they are statistically significant. Their robustness checks are an important step forward in identifying relevant determinants of growth. These authors usually find that policy variables are non-robust regressors that are mostly associated with long-run growth in a statistically insignificant way. To relate to these works we now contemplate model 3.

$$\begin{aligned} GR70-00=\beta_0^3 &+ \beta_1^3 AVTAX+\beta_2^3 AVRED+\beta_3^3 LNY70 \\ &+ \beta_4^3 MSCHOOL60+\beta_5^3 LIFEEXP60+\nu^3 \end{aligned}$$

The associated biases are now given by

$$\begin{bmatrix} b_1^3 & b_2^3 & b_3^3 & b_4^3 & b_5^3 \end{bmatrix}' = \begin{bmatrix} 0.6757 & -0.0234 & 0.4765 & -0.0610 & -0.0131 \end{bmatrix}' \tag{25}$$

Again the biases are not small. For instance, a one-standard-deviation change in AVTAX (8 percentage points) reduces growth by 5.4 percentage points. In turn, changing redistribution, AVRED, by one standard deviation (4.7 Gini points) increases growth by roughly 10.9 percentage points. Both of these effects hold when one assumes that the estimated coefficients are zero.

Moving from model 2 to 3 one might expect that that the bias problem is reduced by adding more regressors. But as the example shows that is not necessarily the case, because the bias for AVTAX is larger in model 3.

From all this one may conclude that the presence of biases appears to make the estimated coefficients quite imprecise. This has, of course, implications for any t-statistic so that arguments based on them may be problematic.

Furthermore, this paper's data when used for different model specifications provide suggestive evidence that the coefficients on tax rate variables that are related to the tax base (the model's τ) appear to be biased upwards. That means that one should expect tax rate variables such as the ratio of tax revenue to GDP to co-vary negatively with growth. On the other hand, the data provide suggestive evidence that redistributional variables might be biased downwards. This means that the hypothesis that redistribution slows down growth may be inherently untestable. This finding would call models into question that argue that redistribution is bad for long-run growth.

6 Conclusion

Within a common theoretical framework it is shown how policy affects investment which in turn affects output growth. In the model optimizing governments take account of fundamental economic variables when making their decisions. This makes public policy economically endogenous and has interesting effects on long-run growth. Several findings of the paper are noteworthy.

First, growth regressions which study the effect of policy on growth should not be conditioned on variables for factor accumulation. This is because policy may work through investment so that including policy and investment variables would yield misleading results.

Second, when policy is endogenous and an important economic fundamental like productivity is omitted in growth regressions, the estimated coefficients on policy variables are generically biased. This has important implications for arguments based on statistical significance.

Third, for different empirical models the signs of the biases are analyzed theoretically and empirically. It is found that the coefficients on tax rate variables related to the tax base are generally biased upwards and those for redistribution are generally biased downwards.

For the latter this implies the following: If policy is economically endogenous, the effect of redistributive transfer variables on growth are generally underestimated so that the hypothesis that redistribution is bad for growth may not be testable. The downward bias is, however, perfectly consistent with empirical findings in the literature which find a positive association between redistributive transfers and growth. It may also represent corroboration of the hypothesis that redistribution is not bad for growth.

The paper argues that more work is needed for the disentanglement of the interplay of long-run economic fundamentals and policy on the one hand, and policy and growth on the other. Furthermore, paying more attention to the bias problem in growth empirics may be worthwhile. This should not be too difficult and would base some findings on a sounder footing.

A The capitalists' optimum

The current value Hamiltonian for the problem (5) - (7) is given by

$$H = \ln C_t^k + \mu_t((r-\tau)K_t - C_t^k). \tag{A1}$$

The necessary first order conditions for its maximization are given by (6), (7) and

$$\frac{1}{C_t^k} - \mu_t = 0 \tag{A2a}$$

$$\dot{\mu}_t = \mu_t \rho - \mu_t (r-\tau) \tag{A2b}$$

$$\lim_{t\to\infty} K_t \mu_t e^{-\rho t} = 0, \tag{A2c}$$

where the positive co-state variable μ_t represents the instantaneous shadow price of one more unit of investment at date t.

From (A2a) and (A2b) consumption grows at $\gamma \equiv \frac{\dot{C}_t^k}{C_t^k} = R - \rho$ where $R \equiv (r-\tau)$ and constant. Thus, $C_t = C_0\ e^{(R-\rho)t}$ where C_0 remains to be determined. Substituting for C_t in (6) implies $\dot{K}_t = R\ K_t - C_0\ e^{(R-\rho)t}$ which is a first order, linear differential equation in K_t and solved as follows

$$\begin{aligned} \dot{K}_t - R\ K_t &= -C_0\ e^{\gamma t} \\ e^{-Rt}\left(\dot{K}_t - R\ K_t\right) &= -e^{-Rt}\ C_0\ e^{\gamma t} \\ \int e^{-Rt}\left(\dot{K}_t - R\ K_t\right) dt &= -\int C_0\ e^{-\rho t} dt. \end{aligned}$$

The last equation is an exact differential equation with integrating factor e^{-Rt}. The LHS is solved by $K_t\ e^{-Rt} + b_0$ and the RHS is solved by $\frac{C_0}{\rho}\ e^{-\rho t} + b_1$, where b_0, b_1 are arbitrary constants. Thus, $K_t = \frac{C_0}{\rho}\ e^{(R-\rho)t} + b\ e^{Rt}$ where $b = b_1 - b_0$. Substituting this into the transversality condition implies

$$\frac{1}{C_0} \lim_{t\to\infty} \left(\frac{C_0}{\rho}\ e^{(R-\rho)t} + b\ e^{Rt}\right)\ e^{-Rt} = \lim_{t\to\infty}\left(\frac{1}{\rho}\ e^{-\rho t} + \frac{b}{C_0}\right) = 0$$

which holds if the arbitrary constant b is set equal to zero. Then $K_t = \frac{C_0}{\rho}\ e^{\gamma t} \Rightarrow \gamma_k = \gamma = R - \rho$ so that consumption and wealth grow at the same constant rate in the optimum. Furthermore, the optimal level of consumption at each date is given by $C_t = \rho K_t$.

B Optimal Policies

The government solves: $\max_{\tau,\lambda}\ (1-\beta)\,V^r + \beta\,V^l$ s.t. $\lambda \geq 0$ where β is the social weight attached to the workers' welfare. The FOCs are

$$\beta\,\frac{\eta_\tau + \lambda}{(\eta+\lambda\tau)\rho} + \frac{\gamma_\tau}{\rho^2} = 0 \quad , \quad \lambda\left(\beta\,\frac{\eta_\lambda + \tau}{(\eta+\lambda\tau)\rho} + \frac{\gamma_\lambda}{\rho^2}\right) = 0.$$

Notice that γ_τ must be negative for the first equation to hold, so in the optimum $\tau > \hat{\tau}$. Concentrating on an interior solution for λ, simplifying, rearranging and division of the resulting two equations by one another yields

$$\frac{\eta_\tau + \lambda}{\eta_\lambda + \tau} = \frac{\gamma_\tau}{\gamma_\lambda}. \tag{B1}$$

Then $\gamma_\lambda = r_\lambda$ and $\gamma_\tau = r_\tau - 1$ imply $(\eta_\tau + \lambda) r_\lambda = (\eta_\lambda + \tau)(r_\tau - 1)$ which upon multiplying out becomes $\eta_\tau r_\lambda + \lambda r_\lambda = r_\tau \eta_\lambda + r_\tau \tau - \eta_\lambda - \tau$. Notice $r_\lambda \eta_\tau = r_\tau \eta_\lambda$ and $\eta = \frac{1-\alpha}{\alpha} r$. Then $\lambda r_\lambda = r_\tau \tau - \frac{1-\alpha}{\alpha} r_\lambda - \tau$ and so

$$\left(\lambda + \frac{1-\alpha}{\alpha}\right) r_\lambda = \tau r_\tau - \tau \quad \Leftrightarrow \quad \left(\lambda + \frac{1-\alpha}{\alpha}\right) = \frac{\tau r_\tau}{r_\lambda} - \frac{\tau}{r_\lambda}.$$

Recall $r_\tau = \alpha E(1-\lambda), r_\lambda = \alpha E(-\tau)$ where $E = (1-\alpha)A[(1-\lambda)\tau]^{-\alpha}$. Thus, $\frac{\tau r_\tau}{r_\lambda} = -\frac{\tau \alpha E(1-\lambda)}{\alpha E \tau} = -(1-\lambda)$ and $\lambda + (1-\lambda) + \frac{1-\alpha}{\alpha} = -\frac{\tau}{r_\lambda} \ \Leftrightarrow\ \frac{r_\lambda}{\alpha} = -\tau$ and so

$$\tau = \frac{[(1-\alpha)A]^{\frac{1}{\alpha}}}{1-\lambda}. \tag{B2}$$

Notice that for this τ we have $E = 1$. For the first order condition for τ we note that $\eta = (1-\alpha)A[(1-\lambda)\tau]^{1-\alpha} = E[(1-\lambda)\tau] = [(1-\alpha)A]^{\frac{1}{\alpha}}$. Furthermore, $\eta_\tau = (1-\alpha)(1-\lambda),\ r_\tau = \alpha(1-\lambda)$. Eqn. (B2) implies $\lambda = 1 - \frac{[(1-\alpha)A]^{\frac{1}{\alpha}}}{\tau}$ so that

$$\eta + \lambda\tau = [(1-\alpha)A]^{\frac{1}{\alpha}} + \tau\left(1 - \frac{[(1-\alpha)A]^{\frac{1}{\alpha}}}{\tau}\right) = \tau.$$

Then the first order condition for τ becomes

$$\beta\,\frac{\eta_\tau + \lambda}{(\eta + \lambda\tau)} = -\frac{\gamma_\tau}{\rho} \quad \Leftrightarrow \quad \frac{\eta_\tau + \lambda}{\tau} = -\frac{\gamma_\tau}{\beta\rho} \quad \Leftrightarrow \quad \frac{\eta_\tau + \lambda}{\gamma_\tau} = -\frac{\tau}{\beta\rho}.$$

But from above $\frac{\eta_\tau+\lambda}{\gamma_\tau} = \frac{(1-\alpha)(1-\lambda)+\lambda}{\alpha(1-\lambda)-1} = -1$ so that $\tau = \beta\rho$. Thus,

$$\tau = \beta\rho \quad \text{and} \quad \lambda = 1 - \frac{[(1-\alpha)A]^{\frac{1}{\alpha}}}{\beta\rho}. \tag{B3}$$

which is equation (10) when $\beta = 1$. Recall that these equations hold for $\lambda \geq 0$, thus for $\beta\rho \geq [(1-\alpha)A]^{\frac{1}{\alpha}}$.

Suppose $\lambda = 0$, then the first order condition becomes

$$\frac{\eta_\tau}{\eta} = -\frac{r_\tau - 1}{\beta\rho} \quad \Leftrightarrow \quad \frac{(1-\alpha)E}{\tau E} = -\frac{\alpha E - 1}{\beta\rho} \quad \Leftrightarrow \quad (1-\alpha)\beta\rho = \tau - \alpha\tau E$$

so that the solution with $\lambda = 0$ is given by

$$(1-\alpha)\beta\rho = \tau\left[1 - \alpha(1-\alpha)A\tau^{-\alpha}\right] \tag{B4}$$

which holds only if $\beta\rho < [(1-\alpha)A]^{\frac{1}{\alpha}}$. For $\beta = 1$ this is equation (11) in the text.

If $\beta = 0$, then $\tau = \hat{\tau}$. Thus, the pro-capital policy maximizes growth.

C Reactions under Endogenous Policy

Pro-Capital. $\hat{\gamma} = \frac{\alpha}{1-\alpha}\frac{\hat{\tau}}{} - \rho$ and $\hat{\tau} = [\alpha(1-\alpha)A]^{\frac{1}{\alpha}}$. Clearly, $\frac{d\hat{\tau}}{dA} > 0$ and $\frac{d\hat{\gamma}}{dA} > 0$.

Redistributing, Pro-Labour. By equation (10) $\check{\tau} = \rho$ so that $\frac{d\check{\tau}}{dA} = 0$. As $\lambda = 1 - \frac{[(1-\alpha)A]^{\frac{1}{\alpha}}}{\rho}$ it follows that $\frac{d\lambda}{dA} < 0$. From equation (10) $r = \alpha A[(1-\lambda)\tau]^{1-\alpha} = \frac{\alpha}{1-\alpha}[(1-\alpha)A]^{\frac{1}{\alpha}}$ so that $\frac{d\check{\gamma}}{dA} > 0$ under that policy.

Non-Redistributing, Pro-Labour. For $\lambda = 0$ the optimal tax rate $\check{\tau}$ solves equation (11), that is, $z = \frac{\tau}{1-\alpha} - \alpha A\tau^{1-\alpha} - \rho = 0$. Furthermore,

$$z_\tau = \frac{1}{1-\alpha} - (1-\alpha)\alpha A\tau^{-\alpha}$$

and is positive for all $\tau > \hat{\tau}$. As $z_A < 0$ it follows that $\frac{d\check{\tau}}{dA} = -\frac{z_A}{z_\tau} > 0$ under that policy. For the growth rate one finds $\frac{d\gamma}{dA} = r_A + (r_\tau - 1)\frac{d\tau}{dA} > 0$ if

$$\begin{aligned} \alpha\tau^{1-\alpha} &> \left(1 - \alpha(1-\alpha)A\tau^{-\alpha}\right)\left[\alpha(1-\alpha)\tau\left(\tau^\alpha - \alpha(1-\alpha)^2A\right)^{-1}\right] \\ \tau^\alpha - \alpha^2(1-\alpha)^2A &> (1-\alpha)\tau^\alpha - \alpha^2(1-\alpha)^2A \end{aligned}$$

which is equivalent to $1 > 1 - \alpha$ and true. Thus, $\frac{d\check{\gamma}}{dA} > 0$ if $\lambda = 0$ in (11).

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Table 4: The Sample

	AVTAX	AVRED	HJ-A	LNY70	MSCHOOL60	LIFEEXP60	GR70-00
Canada	0.3337	10.82	1.03	9.56	7.93	71.1	0.0213
Mexico	0.1702	n.a.	0.93	8.61	2.69	57.3	0.0155
United States	0.2708	9.78	1.00	9.71	8.59	69.8	0.0234
Autralia	0.2681	14.13	0.86	9.60	9.01	70.7	0.0184
Japan	0.2645	n.a.	0.66	9.34	7.20	67.7	0.0257
Korea	0.2116	n.a.	0.58	7.93	4.58	54.2	0.0581
New Zealand	0.2741	n.a.	0.63	9.52	9.76	71	0.0106
Austria	0.4029	n.a.	0.98	9.32	4.08	68.8	0.0252
Belgium	0.4262	24.93	0.98	9.40	7.62	69.7	0.0227
Czech Republic	0.3986	22,0	0.24	n.a.	n.a.	n.a.	0.0165
Denmark	0.4581	18.85	0.71	9.67	9.14	72.2	0.0172
Finland	0.4064	13.88	0.73	9.33	7.6	68.5	0.0248
France	0.4100	15.52	1.13	9.41	4.21	70.4	0.0201
Germany	0.3662	15.59	0.91	9.42	7.83	69.4	0.0207
Greece	0.2798	n.a.	0.67	9.02	5.36	68.8	0.0190
Hungary	0.4212	21.70	0.29	8.59	7.13	68.4	0.0222
Iceland	0.3110	n.a.	0.93	9.29	5.86	n.a.	0.0275
Ireland	0.3244	17.90	0.71	8.89	6.3	69.7	0.0429
Italy	0.3462	12.75	1.21	9.32	4.96	69.4	0.0223
Luxembourg	0.3938	14.30	1.1	9.62	n.a.	n.a.	0.0359
Netherlands	0.4227	14.68	0.95	9.49	5.63	73.3	0.0204
Norway	0.4136	15.07	0.70	9.32	5.91	73.4	0.0296
Poland	0.3829	13.85	0.24	8.42	7.38	67.3	0.0237
Portugal	0.2654	n.a.	0.76	8.75	2.41	63.7	0.0310
Slovak Republic	0.3607	22.10	0.24	n.a.	n.a.	n.a.	0.0122
Spain	0.2710	11.30	1.11	9.11	3.69	68.9	0.0231
Sweden	0.4815	22.22	0.90	9.60	7.7	73.2	0.0157
Switzerland	0.2996	7.10	0.88	9.92	7.28	71.3	0.0086
Turkey	0.1951	n.a.	0.50	8.20	2.75	50.5	0.0212
United Kingdom	0.3556	15.15	1.01	9.40	7.71	70.8	0.0204
Mean	0.3395	15.88	0.78	9.20	6.31	68.1	0.02
SD	0.08	4.65	0.27	0.40	2.07	5.6	0.0096

The growth rates for the Czech and Slovak Republic were calculated using data for former Czechoslovakia. The details on how the data were obtained can be found at http://www.tu-darmstadt.de/∼rehme/endopol/data.htm.