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NOTE

NOTE ON CONVERGENCE UNDER INCOME TAX PROGRESSIVITY

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Building on the theoretical prediction that income tax progressivity increases the speed of convergence in neoclassical, open-economy growth models, this paper asks whether tax progressivity is a potential source of differences across regions in convergence rates. In a sample of U.S. data, over the period 1920–1990, regional convergence and tax progressivity are found to be positively correlated, which supports the theoretical results. Moreover, some data on six OECD countries also accord with such a positive relationship. Overall, the model is successful in predicting the large range of available convergence estimates when the tax rate is elastic enough with respect to the tax base.

Keywords: Convergence, Open Economy, Progressive Taxation

1. INTRODUCTION

Two main lessons may be drawn from the empirical literature on growth convergence that has flourished in the past decade. Challenging the early results of Barro and Sala-i-Martin (1992) and Mankiw et al. (1992), several authors have argued that the range of convergence speed estimates is larger than initially thought [Evans and Karras (1996), Quah (1996), Temple (1998), among many others]. On the other hand, the assumption of cross-country homogeneity of the rate of convergence seems to be at odds with OECD data [Bassanini and Scarpetta (2002)].

In this paper, I point at a theoretical mechanism that is ubiquitous in OECD countries and ask whether it may explain both why the range of convergence estimates is large and the heterogeneity across countries. I consider a distortionary tax rate on factor income that is *progressive* (regressive)—such that the marginal rate is higher (lower) than the average rate. This captures some features of the nonlinear tax schedules prevailing in most OECD countries and developing countries.

The author would like to thank, without implicating, Andrea Bassanini, Cecilia Garcia-Peñalosa, Richard Rogerson, Margaret Slade, Jean-François Wen, and two referees for useful comments and suggestions, as well as Amartya Lahiri for stimulating discussions. Previous versions have circulated under the titles "On Convergence in Credit-Rationed Open Economies When Taxes Are Progressive" and "Income Tax Progressivity Fosters Convergence." Address correspondence to: Patrick Pintus, GREQAM, 2 rue de la Charité, 13236 Marseille Cedex, France, e-mail: pintus@univ-aix.fr.

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It is shown that when the income tax rate is progressive (or not too regressive), the convergence speed increases with the degree of progressivity [a conclusion also obtained by Yamarik (2001) in a different setting]. In essence, progressivity makes the tax rate procyclical, so that when a country's income is smaller than the steady-state level, the tax rate is smaller and the incentives to accumulate capital are therefore greater, which fosters convergence. Of some importance is the fact that this conclusion holds true independent of the tax rate, which can be set close to zero.

To focus on plausible levels of convergence speed, I incorporate a progressive tax scheme into the open-economy model proposed by Barro et al. (1995) (who have considered flat-rate taxes) and I follow the formulation with constant residual income progression used by Feldstein (1969). Assuming that households take into account the progressivity of the tax schedule when taking their decisions, it is shown that

> The model predicts a convergence range of (0.015, 0.030), in agreement with some early studies [see, e.g., Barro (1991), Mankiw et al. (1992), Levine and Renelt (1992), Barro and Sala-i-Martin (1992)], provided that the tax rate is not *too elastic* with respect to the tax base—in short, residual income progression [defined by Musgrave and Thin (1948, pp. 507–508) as the elasticity of post-tax income to pretax income] must belong to (0.89, 1.11); see Figure 1 in Section 2.2 below.
>
> However, the model is more successful in predicting the *full* range of available estimates when the tax rate is *elastic enough* with respect to the tax base. For example, a highly progressive tax rate leads to a convergence region of (0.04, 0.08), in agreement with estimates by, for instance, Evans and Karras (1996): residual income progression must then belong to (0.47, 0.79) (see Figure 1). On the other side of the spectrum, a highly regressive tax rate leads to a convergence rate close to zero [in line with some conclusions, arguing against convergence, of Quah (1995, 1996) and Temple (1998), among others; see Figure 1].

In summary, the theoretical prediction may appear to be useful in light of the *broad* range of estimates, as it shows that taxation progressivity is an important mechanism that may help to reconcile theory and facts related to convergence. In particular, my results point at elastic tax rates as a potential source of cross-country differences in convergence rates, provided that the tax rate is elastic enough to the tax base. In fact, in Section 3, I go through a first step toward providing some evidence on the positive relationship between convergence and tax progressivity. This exercise is based on U.S. data for the period 1920–1990, provided by Barro and Sala-i-Martin (1999) and Stephenson (1998). My computations establish that the data are supportive of a positive correlation between income tax progressivity and convergence speed of per capita personal income, in agreement with our theoretical results (see Figure 2). I also show that this positive correlation is robust with respect to changes in the set of estimates of both tax progressivity and convergence speed. The computations also deliver that tax progressivity has ranged over (5%, 11%) for the past 60 years [in accord with some recent evaluations by Bénabou (2002, pp. 501–502) and Cassou and Lansing (2002, p. 11), for example].

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Therefore, the level of income tax progressivity observed in the United States over this period implies a higher convergence speed than the reference value of 2%. In other words, tax progressivity may partly explain why some recent estimates argue in favor of *more rapid* convergence. For example, a range of (5%, 11%) for tax progressivity—that is, a residual income progression belonging to (0.89, 0.95)—translates, given our benchmark parameter values, into a convergence range of (2.6%, 3.1%) [compare with 2% obtained by Barro et al. (1995)], as shown in Figure 1. Moreover, using cross-country data from Barro and Sala-i-Martin (1999) and Wagstaff et al. (1999) for six OECD countries (Italy, France, Germany, Spain, United Kingdom, United States), I illustrate that the positive convergence–progressivity correlation predicted by the model accords with some cross-country observations (see Figure 3).

To check the robustness of the main result, in an expanded version of the paper [Pintus (2005)], I also extend the model to account for an income-elastic tax rate and elastic labor supply, and I perform a sensitivity analysis with respect to parameter values.

A closely related article is Yamarik (2001), where the author shows that nonlinear income taxes increase the convergence speed (but have an ambiguous effect on the growth rate) in a closed-economy Ak model (I thank an anonymous referee for this reference, of which I became aware after this paper was completed). I view my results as complementing those of Yamarik (2001) along several dimensions. First, I focus on an open-economy model and adopt the assumption that the growth rate is *not* affected by tax level or progressivity [which has received some empirical support; e.g., Stokey and Rebelo (1995)]. In addition, the present study calibrates the proposed model and attempts to provide some empirical evidence on the positive impact of tax progressivity on convergence. Finally, my results do not rely on the presence of taxes on income from physical capital, which is assumed here to be mobile across nations. This paper is also related to recent research by Altig et al. (2001), Bénabou (2002), Cassou and Lansing (2002), and Caucutt et al. (2003) that studies the growth effects of nonuniform tax rates. In particular, Cassou and Lansing (2002) and Caucutt et al. (2003) consider progressive taxes on personal income when calibrating their models, therefore ignoring regressive aspects of the actual tax systems. Another difference from the present paper is that the growth rate is not affected, in our exogenous-growth setting, by the level of progressivity. Closest in spirit is the paper by Gokan (2003), which studies how convergence is affected by the way of financing a given stream of government expenditures, including lump-sum taxes, in a monetary economy. However, all authors cited above examine *closed-economy* versions of neoclassical models.

The rest of the paper is organized as follows. Section 2 presents the open-economy model, following Barro et al. (1995), and derives its laws of motion and convergence rate under income tax progressivity. Section 3 presents some empirical evidence indicating that convergence and tax progressivity are positively correlated. Finally, some concluding remarks and directions for future research are gathered in Section 4.

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2. CONVERGENCE IN A CREDIT-CONSTRAINED OPEN ECONOMY

2.1. Model and Dynamics

The economy I consider produces tradeable output Y using three inputs, physical capital K, human capital H, and raw labor L, according to the technology

$$Y = K^{\alpha} H^{\eta} \left(Le^{(n+g)t}\right)^{1-\alpha-\eta}, \tag{1}$$

where $\alpha \geq 0$, $\eta \geq 0$, and $\alpha + \eta < 1$, while $n \geq 0$ is the rate of population growth and $g \geq 0$ is the rate of labor-augmenting technological progress. As is usual, one can view the production function in intensive form; that is,

$$y = k^{\alpha} h^{\eta}, \tag{2}$$

where, for instance, $y \equiv Y/(Le^{(n+g)t})$ denotes output measured in efficient-labor units.

The Ramsey households have preferences represented by

$$\int_0^{\infty} \frac{C(t)^{1-\theta}}{1-\theta} e^{-(\rho-n)t}\, dt, \tag{3}$$

where C is per capita consumption, $\theta \geq 0$ is the inverse of the elasticity of intertemporal substitution in consumption, and $\rho \geq 0$ is the discount factor. The representative consumer owns the three inputs and rents them to firms through competitive markets. Therefore, we can write down, for the sake of brevity, the consolidated budget constraint as

$$\begin{aligned} \dot{k} + \dot{h} - \dot{d} &= (1-\tau)(\omega + R_h h) + (1-\tau_k) R_k k \\ &\quad - (\delta + n + g)(k + h) - (r - n - g)d - c, \end{aligned} \tag{4}$$

where d is the amount of net debt in efficient-labor units, c is consumption in efficient-labor units, τ is the tax rate on both labor income ω and human capital income $R_h h$, to be specified below, $1 \geq \tau_k \geq 0$ is the tax rate on physical capital income $R_k k$, $1 \geq \delta \geq 0$ is the depreciation rate for both types of capital, and $r \geq 0$ is the world interest rate. The initial stocks $k(0) > 0$, $h(0) > 0$, and $d(0)$ and the labor endowment $L^* = 1$ are given to the households.

Government is assumed to finance public expenditures that do not affect private decisions by taxing factor incomes. To simplify the analysis, I assume that the tax rate on physical capital income τ_k is constant, whereas the nonlinear tax schedule (τ) imposed on labor income and human capital income $(\omega + R_h h)$ is

$$\tau = 1 - \nu x^{-\pi}, \tag{5}$$

where $x = \omega + R_h h$, $0 < \nu < 1$ is a scaling parameter that plays only a minor role in the following analysis, as shown below, whereas $\pi < 1$ is our critical parameter. For instance, one may interpret ν as depending on a base level of income—e.g., the steady-state level—that is taken as given. The important feature here is that the marginal tax rate is higher (resp. lower) than the average tax rate when π is

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positive (resp. negative)—in the present formulation, it is also the case that the tax rate τ increases (resp. decreases) with the tax base when π is positive (resp. negative). Therefore, this tax system exhibits progressivity when π is positive and regressivity when π is negative. Barro et al. (1995) have considered a benchmark case with $\pi = 0$: the tax rate is then constant. As in Guo and Lansing (1998), I assume that households take into account how the tax rate will affect their earnings. To ensure the existence of an interior balanced growth path, I also assume that taxes are not too regressive; that is, $\pi > \overline{\pi}$, where $\overline{\pi}$ is a (negative) lower bound to be determined in the next section (see Proposition 2.1).

The above tax schedule exhibits a property known as constant residual income progression [see Feldstein (1969) for an application in a static model, and Guo and Lansing (1998) and Bénabou (2002) for growth models]. This formulation assumes that the level of tax progressivity is *independent of income* and it should be viewed as a parsimonious benchmark case that is not inconsistent with the data [see Musgrave and Thin (1948)].

Our simplifying assumption that physical capital income is taxed at a constant rate is in line with the observation that there exists a progressivity differential in the U.S. tax code as well as in most OECD tax systems: labor income taxes are more progressive [see, e.g., Hall and Rabushka (1995)]. Moreover, this hypothesis may be justified on the grounds that redistribution policies often rely on income sources that are among the less internationally mobile (such as raw labor and, to some extent, human capital). However, Section 4 in Pintus (2005) shows how peripheral this assumption is, as it concludes that our qualitative results remain valid when taxes on physical capital income are as progressive as labor income taxes.

I also assume, following Barro et al. (1995), that international borrowing is limited to the amount of physical capital; that is, $k \geq d$. This hypothesis is, for instance, fulfilled when only physical capital is accepted as collateral for international credit, whereas human capital is not. As noticed by the referee, an alternative formulation of the debt constraint such that $\overline{d} \geq d$, where $\overline{d}$ is exogenous, would also nest the closed-economy configuration. It remains to be seen how the convergence speed would then be affected.

I focus on the case in which $r = \rho + g\theta$, the interest rate that would prevail in the corresponding closed economy. Moreover, I assume that one has $k(0) + h(0) - d(0) < h^*$, at the outset of the period, where h^* is the steady state value of human capital stock. In other words, the initial net asset position is small enough so that the credit constraint binds, that is, $d = k$ [when the latter inequality does not hold, the economy is rich enough to jump immediately to the steady state; see Barro et al. (1995, p. 109)].

Under physical capital mobility, the after-tax return on physical capital, $(1 - \tau_k)\alpha y/k - \delta$, has to equal the world interest rate r, which yields $k = (1 - \tau_k)\alpha y/(r + \delta)$, and, therefore, by using equation (2) and the condition that $L = 1$ in equilibrium,

$$y = Bh^{\varepsilon}, \tag{6}$$

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where $B = [(1 - \tau_k)\alpha/(r + \delta)]^{\alpha/(1-\alpha)}$ and $\varepsilon = \eta/(1 - \alpha)$. Our assumption that $1 > \alpha + \eta \geq 0$ implies $\alpha + \eta > \varepsilon \geq 0$.

Therefore, the budget constraint (4) may be written

$$\dot{h} = (1 - \tau)(1 - \alpha)y - (\delta + n + g)h - c, \tag{7}$$

by observing that $\omega + R_h h = y - R_k k = (1 - \alpha)y$ and that both $(r + \delta)d = (r + \delta)k$ and $\dot{d} = \dot{k}$ when $d = k$. Households decisions are then obtained by maximizing (3) subject to the budget constraint (7), using equations (6) and (5), given the initial stock $h(0)$, assumed to be less than h^*. Using that, under (5), $(1 - \tau)(1 - \alpha)y = \nu((1 - \alpha)y)^{1-\pi}$, the first-order Euler condition is then

$$\theta\frac{\dot{c}}{c} = \nu(1 - \alpha)^{1-\pi}\varepsilon(1 - \pi)\frac{y^{1-\pi}}{h} - \rho - \delta - \theta g. \tag{8}$$

We may rewrite the budget constraint, from (7) and (5), as

$$\frac{\dot{h}}{h} = \nu(1 - \alpha)^{1-\pi}\frac{y^{1-\pi}}{h} - \delta - n - g - \frac{c}{h}. \tag{9}$$

Equations (8) and (9) characterize the dynamics of intertemporal equilibria. It is not difficult to check that the associated transversality constraint is met in the following analysis, provided that $\rho - n + g(\theta - 1) > 0$, as I consider orbits that converge towards the interior steady state in a monotonous way. Moreover, direct inspection of equations (5) and (6) reveals that after-tax income is concave in h whenever $\varepsilon(1 - \pi) < 1$, that is, $\pi > (\alpha + \eta - 1)/\eta$ (when the tax rate is not too regressive).

2.2. Convergence When Taxes Are Progressive

In this section, I discuss how the level of progressivity of the income tax schedule affects the convergence rate of the credit-constrained open economy. From equations (6), (8), and (9), one can get the basic intuition behind my results: the human capital share now multiplies a factor $(1 - \pi)$ that is smaller than one when π is positive, but greater than one when π is negative. Remember that Barro et al. (1995) consider the benchmark case with flat-rate taxation, that is, $\pi = 0$. The higher the level of tax progressivity π, the smaller the after-tax capital share $\varepsilon(1 - \pi)$, that is, the more quickly diminishing returns set in. This is easily explained: in essence, progressivity makes the tax rate procyclical. As a consequence, when a country's income is smaller than the steady-state level, the tax rate is smaller and the incentives to accumulate capital are therefore greater, which *fosters convergence*. Of some importance is the fact that this conclusion holds true independent of the steady-state tax rate, which can be set close to zero. Notice that this differs from the main result by Yamarik (2001), which states that tax progressivity has an *ambiguous* impact on the growth rate, whereas our model takes as an assumption that the growth rate is unaffected by progressivity.

The appendix derives the convergence rate by linearizing equations (6), (8), and (9) around the unique interior steady state. For a steady state to be feasible, I need the additional condition that $\rho + \delta + g\theta > \varepsilon(1 - \pi)(\delta + n + g)$ to be met, which

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imposes a negative lower bound on π; that is, $\pi > \overline{\pi} \equiv 1-(\rho+\delta+\theta g)/[\varepsilon(\delta+n+g)]$. Under the latter assumption, one gets, after some computations, the following β-convergence rate [which is defined as the opposite of the negative eigenvalue of the Jacobian matrix of equations (8) and (9), evaluated at the steady state].

PROPOSITION 2.1 (Convergence Rate and Tax Progressivity). *In the economy with tax progressivity, the convergence rate is given by*

$$\beta \equiv 0.5\left\{\left(\phi^2+4(\rho+\delta+\theta g)\left(\frac{1-\varepsilon(1-\pi)}{\theta}\right)\right.\right.$$
$$\left.\left.\times\left[\frac{\rho+\delta+\theta g}{\varepsilon(1-\pi)}-\delta-n-g\right]\right)^{0.5}-\phi\right\}, \tag{10}$$

where $\phi = \rho - n + g(\theta-1) > 0$.

Under the assumption that the tax rate is not too regressive, that is, $\pi > \overline{\pi} \equiv 1-(\rho+\delta+\theta g)/[\varepsilon(\delta+n+g)]$, *the convergence rate* β *given by equation* (10) *increases, when positive, with the progressivity parameter* π.

In particular, convergence is more rapid (resp. less rapid) than in the case of a constant tax rate when the tax rate is progressive (resp. regressive). The convergence speed tends to zero when π *approaches the negative value* $(\alpha+\eta-1)/\eta$.

I now study the quantitative implications of our progressive tax schedule and, to facilitate direct comparison, use the benchmark parameter values reported by Barro et al. (1995, p. 107); that is,

$$n = 0.01, \quad g = 0.02, \quad \delta = 0.05, \quad \theta = 2, \quad \rho = 0.02, \quad \alpha = 0.3, \quad \eta = 0.5. \tag{11}$$

In the following analysis, the second root of the characteristic polynomial is positive, hence unstable. Therefore, the steady state is a saddle when $\beta > 0$ and is unstable (that is, a source) when $\beta < 0$. Note that the scaling parameter ν—see equation (5)—does not appear in equation (10) and is, therefore, not relevant in the following analysis.

Figure 1 reports the convergence rate β, computed using (10), as a function of the progressivity parameter $\pi > \overline{\pi} = -0.925$. It shows that β is quite sensitive to π: β belongs to the range (0.015, 0.030) only if π is confined to $(-0.11, 0.11)$. When π is outside this range, then the convergence rate is either higher or smaller, depending on the sign of π, as shown in Proposition 2.1: for example, $\beta = 0.1$ when $\pi = 0.62$ and $\beta = 0$ when $\pi = (\alpha+\eta-1)/\eta = -0.4$ (see Proposition 2.1).

Three important conclusions can be drawn from this experiment. First, the model's predictions regarding the convergence speed are consistent with the range of estimates obtained by Barro and Sala-i-Martin (1992) and Mankiw et al. (1992) only if the tax rate is *almost flat*. Second, the model delivers a broader range for the convergence speed, provided that the tax rate is quite responsive to the taxable base. For instance, the predicted range is (0.04, 0.08), in agreement with estimates

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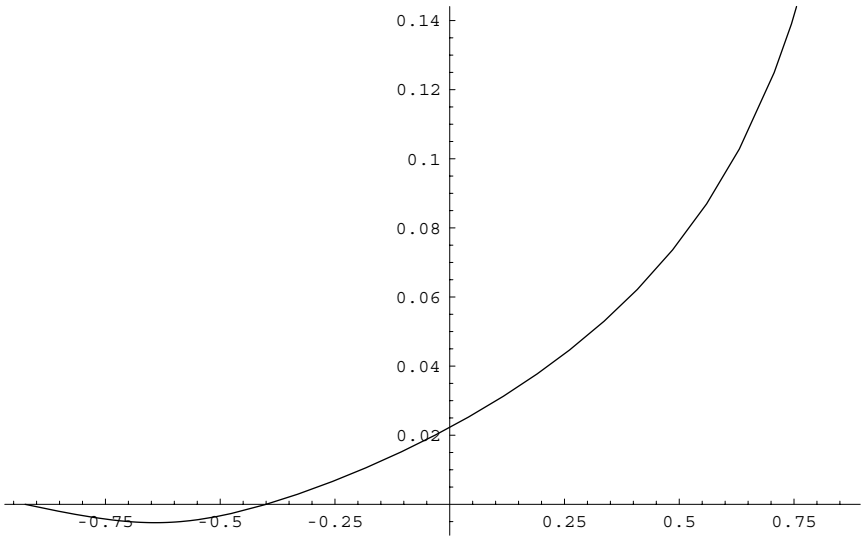


FIGURE 1. The convergence rate β as a function of the tax progressivity π.

by Evans and Karras (1996), if π belongs to (0.21, 0.53). On the other hand, Temple (1998) shows that assessing the robustness of growth regressions casts some serious doubt on the estimated narrow range of the convergence rate, while Quah (1996) argues against the evidence of convergence in data. My analysis shows that when tax progressivity is considered, the predicted convergence range is much broader and consistent with this view. It may help to reinterpret the quantitative implications of our results by discussing them in terms of the *residual income progression* [see Musgrave and Thin (1948, pp. 507–508)], or, alternatively put, the disposable income–taxable income elasticity. In view of equation (5), disposable income is $(1 - \tau)x = \nu x^{1-\pi}$ if x denotes taxable income. Therefore, residual income progression is given by $1 - \pi$. When progressivity is high, the latter elasticity is close to zero, whereas it is larger than one when taxes are regressive. More precisely, the disposable income–taxable income elasticity must belong to (0.89, 1.11) in order for the model to predict the convergence region of (0.015, 0.030). The convergence speed is close to zero when the latter elasticity is close to 1.4, whereas the predicted convergence range is (0.04, 0.08) when the disposable income–taxable income elasticity belongs to (0.47, 0.79).

The main lesson from this experiment is that the model predicts a large convergence range when taxes are *elastic enough* with respect to the tax base.

3. SOME EVIDENCE ON CONVERGENCE SPEED AND TAX PROGRESSIVITY

To the best of my knowledge, no attempt has been made to uncover what the data reveal about the relationship between tax progressivity and convergence

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TABLE 1. Convergence speed and tax progressivity in the United States: 1920–1990

Decade	Convergence speed (%)	Tax progressivity
1920–1930	−1.49	−0.022
1930–1940	1.41	−0.025
1940–1950	4.31	0.012
1950–1960	1.90	0.018
1960–1970	2.46	0.010
1970–1980	1.98	0.007
1980–1990	0.11	−0.007

Source. Barro and Sala-i-Martin (1999, Table 11.1, p. 388) and author's computations based on Stephenson (1998, Table 1, p. 391).

speed. This section presents a first attempt in this direction and provides some evidence on the *positive* correlation between both variables. This exercise imposes the following difficulty: computing convergence speed seems relevant only over sufficiently long time intervals (say, a decade at minimum). This inevitably implies that only a *small* sample can be obtained, even in developed countries. Our primary data are provided by Barro and Sala-i-Martin (1999) and Stephenson (1998) and are described in a more detailed way in Appendix C of Pintus (2005). Although I focus on a particular data set in this section, I discuss in Appendix C of Pintus (2005) the robustness of the results when alternative estimates are used.

In Barro and Sala-i-Martin (1999, Table 11.1, p. 388), I find some estimates of the convergence rate of per-capita income for the U.S. states, over decades from 1920 to 1990, which I reproduce in the second column of Table 1.

On the other hand, Stephenson (1998, Table 1, p. 391) provides some estimates, for the United States, of both the average tax rate and the marginal tax rate on income. I then compute, from these data, estimates of tax progressivity, as I now describe, and then average them over a decade. From equation (5), it is not difficult to compute the marginal tax rate $\tau_m = \partial(\tau x)/\partial x$, which can be written as $\tau_m = \tau + \pi \nu x^{-\pi}$. Therefore, one can get a steady-state estimate of tax progressivity, π, from average tax rate, τ, and marginal tax rate, τ_m: it is simply given by $\pi = (\tau_m - \tau)/(1-\tau)$ (on the other hand, residual income progression is measured by $1-\pi = (1-\tau_m)/(1-\tau)$). The corresponding estimates appear in the third column of Table 1. Finally, Figure 2 reports, in a scatter plot of convergence speed against tax progressivity, the estimates of Table 1. Figure 2 also reproduces the linear trend obtained from ordinary least-squares linear regression. The slope is positive, in agreement with the positive correlation predicted by our analysis of Section 2.2.

To illustrate whether the positive convergence–progressivity correlation may explain, at least partially, the cross-country difference in convergence speed, I plot in Figure 3 some data for six OECD countries (Italy, France, Germany, Spain, United Kingdom, United States). Estimates for rates of convergence are borrowed

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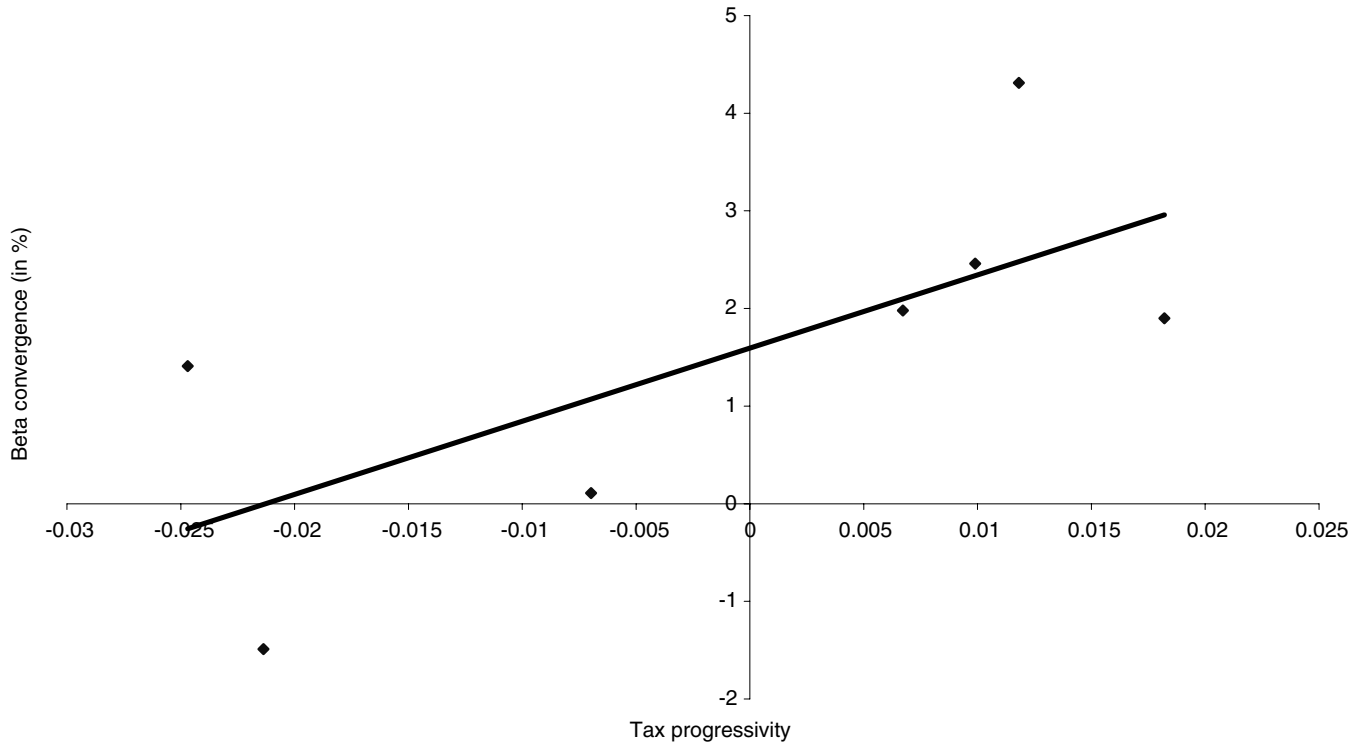


FIGURE 2. Some estimates of convergence speed and tax progressivity in U.S. data (seven decades, 1920–1990).

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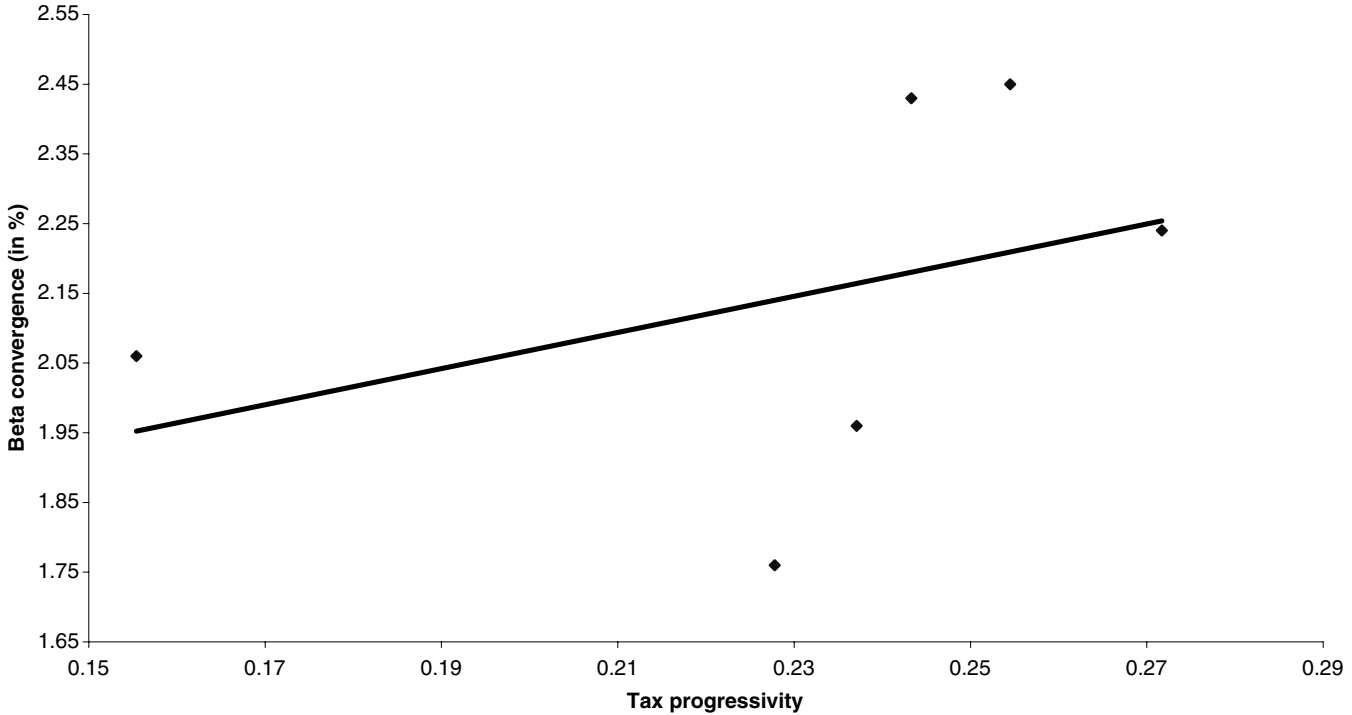


FIGURE 3. Some estimates of convergence speed and tax progressivity in six OECD countries (italy, France, Germany, Spain, United Kingdom, United States).

from Barro and Sala-i-Martin (1999, Table 11.7, p. 411), whereas the estimates of tax progressivity are those of Wagstaff et al. (1999, Table 3, p. 82) [see Appendix C of Pintus (2005)]. Figure 3 suggests that the positive convergence–progressivity correlation predicted by the model is not rejected by the data.

4. CONCLUSION

This paper has studied a neoclassical open-economy growth model with progressive income taxation and has shown that the predicted convergence rate increases with, and is sensitive to the level of progressivity. In particular, the model's predictions include a "narrow" range of estimates [supported, for instance, by Barro and Sala-i-Martin (1992) and Mankiw et al. (1992)] provided that the tax rate is not too elastic with respect to the tax base. However, the model predicts a larger convergence range, which includes more recent estimates [see, e.g., Evans and Karras (1996), Quah (1996), and Temple (1998)] when the tax rate is *elastic enough* with respect to income. A tentative attempt to assess the empirical evidence on the convergence speed–tax progressivity correlation reveals a positive relationship, in agreement with our theoretical analysis.

However, there are, in the real world, a number of other taxes with possibly different effects on convergence. First, some progressivity may presumably come into play through transfers, although this is not measured in most studies. On the other hand, some other features of actual tax systems introduce regressivity into otherwise progressive income tax schedules, most notably through proportional consumption taxes, upper bounds that are imposed on social security contributions, and absent or low capital income taxes [especially in developing countries; see, e.g., Tanzi and Zee (2001)]. Therefore, one cannot rule out the case of effective taxes indeed being regressive, even though estimates that would capture all these effects do not seem to be available yet. The model predicts that regressive taxes lead to *slow* convergence, in agreement with still another piece of evidence in the literature. This prediction could be usefully taken to cross-country data, following Bassanini and Scarpetta (2002).

One important lesson of the paper is that although international capital mobility tends to raise the speed of convergence toward the balanced growth path, in comparison with the closed-economy configuration, different open economies may converge rapidly or slowly, depending on the way taxation responds to income. In the real world, countries seem to differ significantly with respect to their tax systems for various reasons, including distribution concerns [see Bénabou (2002)]. Therefore, an interesting direction for future research would be to estimate such a model with tax progressivity and to assess its predictions with respect to the speed of convergence. My results point at tax progressivity as a potential source of cross-country differences in convergence rates, and this conclusion should be quantified. Finally, in view of the recent switch from capital to labor taxes in EU countries documented by Quadrini (2005), one could ask the model to predict the impact on the convergence speed.

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On the theoretical side, a relevant extension of our analysis would be to assume, in agreement with existing tax schedules, that capital income taxes are somewhat less progressive than labor income taxes. Moreover, it would also be relevant to take into account the fact, documented by some studies [e.g., Krusell et al. (2000)], that skilled labor and physical capital are complements whereas raw labor and physical capital are substitutes. In view of some results by Barro et al. (1992, pp. 23–28), one expects that the stronger the complementarity between physical and human capital, the higher the convergence rate. Therefore, adding tax progressivity to the model would probably lead us to predict that convergence will be slow provided that the tax rate is not too progressive.

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APPENDIX

DERIVING THE CONVERGENCE RATE β

This appendix derives the expression for the convergence rate β. The dynamical system describing intertemporal equilibria consists of equations (6), (8), and (9). By rewriting the latter equations in logs, it is easy to get

$$\begin{aligned} \theta\dot{\hat{c}} &= \nu(1-\alpha)^{1-\pi}\varepsilon(1-\pi)e^{\lambda_0+\lambda_1\hat{h}} - \rho - \delta - \theta g, \\ \dot{\hat{h}} &= \nu(1-\alpha)^{1-\pi}e^{\lambda_0+\lambda_1\hat{h}} - \delta - n - g - e^{\hat{c}-\hat{h}}, \end{aligned} \tag{A.1}$$

with $\lambda_0 = (1-\pi)\ln B$ and $\lambda_1 = \varepsilon(1-\pi) - 1$. It is not difficult to show that the associated dynamical system has a unique interior steady state if $\rho + \delta + g\theta > \varepsilon(1-\pi)(\delta + n + g)$, that is, if $\pi > \overline{\pi} \equiv 1 - (\rho + \delta + \theta g)/[\varepsilon(\delta + n + g)]$. The Jacobian matrix associated with equations (A.2), evaluated in the steady state, has trace T and determinant D such that

$$\begin{aligned} T &= \rho - n + g(\theta - 1), \\ D &= -(\rho + \delta + \theta g)\left(\frac{1 - \varepsilon(1-\pi)}{\theta}\right)\left[\frac{\rho + \delta + \theta g}{\varepsilon(1-\pi)} - \delta - n - g\right]. \end{aligned} \tag{A.2}$$

When it exists, the negative eigenvalue of the Jacobian matrix is $0.5\{T - (T^2 - 4D)^{0.5}\}$, which gives, in view of equations (A.1), the expression for the convergence rate $\beta = -0.5\{T - (T^2 - 4D)^{0.5}\}$ in equation (10).

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