2nd CESifo-EconPol Europe WORKSHOP 2020

Public Policy Evaluation and Optimal Policy Design

Munich, 15–16 October 2020

An Efficiency-Based Rationale for Cross-Country Transfers within the European Union

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June 23, 2020

Abstract

There exist few theoretical justifications for cross-country transfers within the European Union based on aggregate economic gains. I provide a new motivation, where tax-financed public investments are freed from concerns over redistribution between generations. For public investment projects with twice larger expected returns than the average, my simulations show that the Union-wide GDP per capita gains would be nearly twice smaller if cross-country transfers by high-income countries would be used for domestic investments, rather than entirely dedicated to finance public investments by low-income countries.

Keywords: cross-country transfers, EU Cohesion Structural Funds, efficiency, computable general equilibrium
JEL-Classification: C68, E62, F35, F41

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1 Introduction

There are a number of political motivations for cross-country transfers, such as altruism or peace promotion. Motivations based on economic gains for all countries involved are fewer. International transfers within the European Union lead in theory to aggregate efficiency gains when they correct coordination or market failures due to foreign ownership of firms, tax competition or asymmetric business cycle shocks. I provide another, efficiency-based rationale for cross-country transfers, due to the fact that between-households redistribution concerns do not cross borders.

Beyond the reduction of cross-country income differences (for instance, Coate, 1995), there are other political motivations for international transfers, such as the reduction in immigration flows (for instance, Gaytan-Fregoso and Lahiri, 2000) or the reduction in pollution (for instance, Copeland and Taylor, 1994). International transfers can also be motivated for economic reasons, when either goods' markets, capital markets or labor markets are not integrated (for instance and respectively, Turunen-Red and Woodland, 1991; Djajic et al., 1999; Casella, 2005). These economic rationales however do not apply for cross-country transfers within the European Union, given the integration of all three markets across countries.

The literature contains three motivations based on aggregate economic gains for international transfers within the European Union, which can correct the negative efficiency impacts coming from the foreign ownership of firms in low-income countries (Fuest and Huber, 2006), from tax competition (Becker and Fuest, 2010) or from asymmetric business cycle shocks with incomplete insurance markets (for instance, Farhi and Werning, 2017).

I provide a fourth, normative motivation based on aggregate economic gains for cross-country transfers within the European Union, where tax-financed public investments are freed from redistribution concerns between generations. Because the motivation would still apply if all local firms where domestically owned, if there was no tax competition and if there were no business cycle shocks, it is a complement to the three existing normative rationales.

In theoretical and quantitative analyses, I compare tax-financed domestic public investments with tax-financed cross-country transfers of the same magnitude, under the condition that these transfers are entirely used for cross-country income convergence purposes through public investments. Such conditional international transfers correspond to the Cohesion and Structural Funds of the European Union, which make up for 32.5% of the Union budget over the 2014-2020 programming period (European Union, 2014).

When labor supply elasticities are low, the returns of public investments large and two other technical conditions are satisfied, I show analytically that the aggregate efficiency gains of tax-financed domestic public investments are smaller than foreign public investments financed by a cross-country transfer. Using a large-scale multi-country overlapping-generations model covering more than 80% of the population in the European Union, I confirm the finding with numerical simulations in a more general setting. Considering for instance a public investment project which delivers twice larger long-run returns than the empirical average return (as reported in Bom and Ligthart, 2014),

I find that the aggregate GDP per capita gains would be nearly twice larger with an international implementation than with a domestic implementation.

The main reason for the superior aggregate efficiency gains of international implementations is related to the territorial scope of social contracts. Tax-financed public investments initially lead to output and income losses, because public investments take time to generate production gains but tax efforts are immediate. Output and income increase over the long-run when the distortive impact of taxation is low or the returns on public investments projects are high. In that case, tax-financed domestic public investments lead to long-run efficiency gains but also redistribute from old to young generations. In a domestic context, old generations have a degree of altruism but a social contract between generations, enforced by voting, limits the amount of redistribution, and thus the size of the reform. In an international context with no fiscal federalism, there is no such cross-border, cross-generational contract. Instead, donor countries expect beneficiary countries to use all resources for their intended purposes, cross-country income convergence through public investments. The productivity gains from the public investments are thus partially used to mitigate the tax increase in the domestic context, to prevent redistribution across generations to increase beyond socially acceptable levels. In an international context, there is no such need for mitigation and all the productivity gains are used for further public investments, rather than tax decreases, which delivers additional productivity gains.

Both analytical and quantitative results provide an economic, efficiency-based rationale for cross-country transfers within the European Union, as long as public investment projects have higher expected returns than average and all direct and indirect benefits from the transfers are dedicated to the projects. Such a rationale does not apply to fiscal federations, because cross-regional, cross-generational contracts can take place. If the European Union became one day a fiscal federation, the rationale for cross-country transfers may no longer apply.

The paper continues with a short overview of the related literature. Section 3 then provides analytical results and section 4 quantitative results. Policy implications are derived in section 5 and concluding remarks in section 6.

2 Literature overview

This section is an overview of the literature which provides economic rationales for cross-country transfers, with a focus on transfers within the European Union. Summing up, there exists only a few theoretical analyses which provide an efficiency rationale for all or part of Structural and Cohesion Funds, where welfare or output is increased at the aggregate level

The reduction of income differences (e.g. Coate, 1995), pollution (e.g. Copeland and Taylor, 1994) or immigration flows (e.g. Gaytan-Fregoso and Lahiri, 2000) are all motivations for foreign aid which can also be applied to European Union transfers. As the aggregate efficiency impacts of transfers pursuing these goals are unknown, economic efficiency is not part of their motivation. Other foreign aid motivations exist. Cross-

country transfers can mitigate the negative impacts arising in different contexts, such as trade restrictions due to tariffs (e.g. Turunen-Red and Woodland, 1991) and quotas (e.g. Lahiri and Raimondos, 1995), capital markets frictions due to international borrowing constraints (Djajic et al., 1999) and expropriation risk (Asiedu et al., 2009), or policy barriers to migration (Casella, 2005). These justifications however do not apply to European Union transfers, given the integration of the goods, capital and labor markets in the Union, at least in theory.

There exist efficiency-based theoretical rationales for part of cross-country transfers within the European Union. When countries are exposed to asymmetric business cycles shocks within a currency union, international transfers can have an insurance and stabilization property (e.g. Farhi and Werning, 2017). Cross-country transfers for public infrastructure projects can also reduce the negative efficiency impacts of tax competition (Becker and Fuest, 2010). Finally, European Union transfers can prevent suboptimal levels of investment support in low-income countries which is due to the foreign ownership of local firms (Fuest and Huber, 2006).

3 Theoretical analysis

I describe first the model and then provide analytical results comparing the domestic and international implementation of tax-financed public investments.

3.1 Model

There are two identical countries which can trade freely. Some policy options involve a transfer between the governments of the two countries. A country will compare policy options, either purely domestic or involving transfers to the other country, which may come with conditions on the use of the transfer. To ease the presentation, I will use two different indices for this country: when it considers a domestic option, it will be indexed by the letter D; when it considers financing a cross-country transfer, it will be indexed by the letter F. The beneficiary country will always be indexed by the letter B. Country indices are dropped when not needed.

In each country, the basis is a simple overlapping-generations model with exogenous retirement dates, endogenous consumption and labor supply decisions, consistent with the standard model of Auerbach and Kotlikoff (1987). The modelling of government is kept as simple as possible to allow for analytical results. To investigate the role of public investment policies at the domestic or international levels, that model basis is extended with an endogenous growth component taken from Glomm and Ravikumar (1997) and with a two-country integration taken from Buiter (1981). Further, I formalize the political decision-making process, which will define how domestic and international policy options can be compared.

Population: population is identical in the two countries. In each country, population is of constant size. Households live T periods. Children have no economic role so

households start their economic life at age 1, and work until age $R < T$. Age is the only difference between households of the same country.

Households: households make economic and voting decisions to maximize their total lifetime utility $\mathcal{V}^i = V^0 - W^0$, which sums up economic lifetime utility V^0 with political outcome utility W^0. I present first the economic lifetime utility and defer the presentation of the political outcome utility to the end of the section. Given policy choices, households make consumption decisions $\{C_t^a \mid a = 1, ..., T\}$ and labor supply decisions $\{l_t^a \mid a = 1, ..., R\}$ at every age a and period t of their life to maximize their economic lifetime utility V_t^0, where V_t^a is the remaining life-time utility of a household of age a at time t. The analytical results presented in this section hold for various specifications of the household preferences. To fix ideas, I consider the recursive formulation

$$V_t^a = \max \left[(Q_t^a)^\rho + \beta \left(V_{t+1}^a \right)^\rho \right]^{1/\rho},$$

where ρ defines the elasticity of intertemporal substitution $1/(1-\rho)$, β is a time discounting factor and Q_t^a is effort-adjusted consumption. As in Greenwood et al. (1988), Q_t^a captures the utility cost of labor market activity expressed in goods equivalent terms, with

$$Q_t^a \quad = \quad C_t^a - \varphi^L \left(l_t^a \right) \qquad\qquad \varphi^L \left(l \right) \equiv \kappa \frac{l^{1+\varepsilon_L}}{1+\varepsilon_L},$$

and where φ^L represents the disutility of working and $1/\varepsilon_L$ the elasticity of labor supply. Households' decisions respect a budget constraint:

$$A_{t+1}^a = R_{t+1} \left(A_t^a + (1 - \tau_L) w_t l_t^a - C_t^a \right),$$

where A^a represent assets, w the wage rate, τ_L a labor income tax rate and $R = 1 + r$ the gross interest rate.

Markets: households offer labor on the labor market and assets on a capital market. There is no unemployment so the labor supplied by households is entirely used by firms and paid at wage rate w_t. Firms and foreign households may access the capital market. Firms transform household assets at no cost into productive capital. Households may trade with foreigners and accumulate foreign assets. When negative, foreign assets correspond to a debt to foreigners. There is no arbitrage, so the price of capital is identical for firms and foreigners, and equal to the interest rate r_t. Under perfect competition, the wage rate is equal to its marginal product. Because trade is free and firms in the two countries produce the same single composite goods, the goods markets of the two countries are integrated (and unique). As in Buiter (1981), there is one labor market in each country but the capital markets are perfectly integrated and the interest rate is the unique value which clears the goods market over the two countries[1].

[1]Because of the unique single composite good, trade and investment flows are identical. By Walras law, the goods market clears if and only if the capital market clears.

Production: there is a representative firm which combines labor $L_t = \sum_a l_t^a$ and capital K_t to produce a single composite good, which is identical across the two countries. The production function is linearly homogeneous and given by

$$Y_t = TFP_t \cdot F^Y(K_t, L_t),$$

where TFP denotes total factor productivity, which is endogenous and presented next. Firms make investment decisions which, under perfect competition, equate the marginal product of capital with the interest rate, net of the capital depreciation rate.

Growth: households, firms and the government can all influence output growth. Changes in households' labor supply and consumption decisions, as well as changes in firms' investment decisions, lead to changes in the labor and capital stock used in production, as described above.

Government can support economic growth through investments in public infrastructure (such as roads, airports, harbors, or telecommunication capacity) or the provision of productivity-increasing public goods (such as education or health services). Public investments play an important role not only in domestic policies, but also in foreign aid (Chatterjee et al., 2003).

Following Glomm and Ravikumar (1997), all government expenditures represent public investments and accumulate into a public capital stock, which impacts total factor productivity:

$$\begin{aligned} TFP_t &= \xi_0 M_t^{\eta}, \\ M_{t+1} &= (1-\delta^G) M_t + \mu\, CG_t, \end{aligned}$$

where M denotes the public capital stock, δ^G its depreciation rate, CG government consumption (public investments) and ξ_0 is a scaling factor. The parameter η represents the elasticity of total factor productivity with respect to government expenditures, defining the impact of public investments on growth: the higher the elasticity, the larger the impact of public expenditures on total factor productivity and thus production. The elasticity can be interpreted as the average return that one can expect from a public investment project. The parameter μ captures the efficiency of the process transforming government expenditures into productive public capital stock. Said differently, μ captures the fraction of government expenditures which impact economic growth. As I will show in section 3.2, the key parameter is the elasticity η.

Cross-country transfers can impact economic growth in the beneficiary countries, when the government of these countries use the foreign transfers to increase public investments. That modelling approach covers the income convergence goals of the EU Structural and Cohesion Funds, for instance.

Government: households face no risk so there is no social security. The only expenditures for government are public investments CG_t or transfers TR_t to the other country. Transfers are positive for the contributing country and negative for the beneficiary coun-

try. To finance its expenditures, the government raises revenue from labor income taxes, at rate τ_L. The government budget is balanced in each period, so there is no public debt.

Political process: there is a continuum of political parties suggesting policy options, defined by (τ_L, CG, TR) triplets, which interchangeably define political parties and the policy proposals they make. All policy options are scalable, to larger or smaller values. The policy debate which precedes elections and government actions are assumed to be mature, in the following sense: each policy suggestion is economically feasible, sustainable and compared to other policy suggestions; elected politicians implement their policy proposals and commit the expenditures required for public investments to the national budget for the duration of the investments. Thanks to the scalability of policy options and during their comparison, all policy proposals are scaled to the same budget commitment.

Voting takes place on a yearly basis. Households take part in voting with a given probability, make voting decisions, if any, before economic decisions and assume that their voting and economic decisions do not influence each other. A household with political preference i makes economic choices $\left(C^{a,i}, l^{a,i}\right)$ and voting choices $v^i \equiv \left(\tau_L^i, CG^i, TR^i\right)$ to maximize total lifetime utility

$$\mathcal{V}^i\left(C^{a,i}, l^{a,i}, v^i\right) = V^0\left(C^{a,i}, l^{a,i}, \overline{v}\left(v^i\right)\right) - W^{0,i}\left(\overline{v}\left(v^i\right)\right),$$

where $\overline{v}$ represents the result of the elections (i.e. the chosen and implemented policy) and depends on the voting choices v^i of all households of political type i and their voting participation[2]. The economic lifetime utility V^0 has been presented above. The political outcome utility $W^{0,i}$ captures aversion for inequality taking place at domestic and international levels:

$$W^{0,i}(v) = \zeta^i \cdot \mathcal{IA}_D(v) + \xi^i \cdot \mathcal{IA}_{EU}(v),$$

where $\mathcal{IA}_D$ is the average inequality aversion at the domestic level and $\mathcal{IA}_{EU}$ the average inequality aversion at the international (European Union) level. ζ^i and ξ^i represent the respective inequality aversions of a household with political preference i, which are drawn from respective distributions of random variables Υ and Ψ at birth. Neither distributions are observable. Inequality aversion functions $\mathcal{IA}_D$ and $\mathcal{IA}_{EU}$ are separate to reflect differences in information sets (domestic poverty can be seen daily, not poverty abroad), in attachment to different communities or other differences. In the analysis, I will assume that Υ satisfy some stylized observable properties and consider parameters which are likely to play a role in Ψ, which will lead to a comparison process between domestic and international implementations of public investments.

[2]The specification of the voting process, and its outcome, is not required for the analysis in this paper. For a simpler reading, I do not provide such a specification.

3.2 Analytical results

Two policy options are compared, both involving public investments. The first option is a domestic reform, where one country increases labor income taxes to finance additional public investments. The second option is an international reform, where the same country increases labor income taxes to finance a transfer to the other country, under the condition that the second country uses all resources stemming from that transfer to increase public investments. The second option models a vast fraction of cross-country transfers within the European Union, which occur through the co-called Structural and Cohesion Funds and support investment projects in order to reduce income differences across countries.

I will show that the international reform leads to higher aggregate efficiency gains than the domestic reforms in some circumstances, where efficiency is measured by the variation of GDP per capita, a key macroeconomic indicator for policy making[3]. That result constitutes an economic, efficiency-based motivation for cross-country transfers within the European Union.

Preliminary politico-economic observations simplify the results and lead to the definition of reform options. Elementary efficiency results then prepare the ground for the main efficiency results, comparing domestic and international reforms. A discussion of the plausibility of key assumptions closes the section.

3.2.1 Preliminary politico-economic observations

I assume that there are no aggregate level uncertainty nor modifications of the population structure. As yearly votes would always deliver the same outcome, it is sufficient to organize elections only once to choose a unique reform to implement. As a result, the solution of the household maximization problem can be separated in two stages: first, households make voting choices to maximize their total lifetime utility $\mathcal{V}$; second, given the election results and thus policy parameters (τ_L, CG, TR), households make consumption and labor supply choices to maximize their remaining lifetime economic utility V^0. Because the only differences across households is age and because of that two-stage process, consumption and labor supply decisions are identical for different household types i of the same age a, $C^{a,i} = C^a$ and $l^{a,i} = l^a$.

As there is no supranational government, cross-country transfers only take place if some political party in one of the two countries suggests to use them and if that political party is elected by voters of that country, which I call the financing country. It is thus sufficient to consider the political process in that country, where at least one political party makes a policy suggestion involving cross-country transfers $TR > 0$. Because of the continuum of political parties, the maturity of the policy debate and the scaling of policy options to the same budget commitment, that suggestion is compared to a reform of identical budget impact but involving no cross-country transfers, $TR = 0$.

The distribution of the random variable Υ is unobservable but plays a key role in the voting result, as it captures the distribution of political preferences towards domestic

[3]In parts of the literature, efficiency is measured in welfare terms. I refer to efficiency as appears in discussions of equity versus efficiency.

inequality. I thus assume that it satisfies stylized observable properties. Specifically, a policy proposal (τ_L, CG, TR) is ruled out (i.e the political party which makes the proposal is never elected) if it violates the following inequality constraint: a reform (τ_L, CG, TR) must either be a Pareto improvement or prevent an increase of inequality beyond a given bound[4]. In other words, I assume bounded altruism, as political preferences allow a degree of inequality between households of the same country, up to a certain point. Because the only difference between households is age, the inequality bound governs redistribution across generations.

Similarly, the distribution of the random variable Ψ, which captures the distribution of political preferences towards cross-country inequality, as well as the functional specifications for the average domestic inequality aversion $\mathcal{IA}_D$ and for the average international inequality aversion $\mathcal{IA}_{EU}$ are unobservable but play a key role in the voting result. For the sake of generality, I leave the distribution for Ψ and the specifications for $\mathcal{IA}_D$ and $\mathcal{IA}_{EU}$ open but, when comparing reform options before voting, I assume that households take the average efficiency gain of the reform over the two countries into account[5]. For instance, if the mean of Ψ is large and $\mathcal{IA}_{EU}\left(\overline{\mathcal{G}}\right) = -\overline{\mathcal{G}}$, where $\overline{\mathcal{G}}$ is the average efficiency gain over the two countries, the voters will choose the reform which delivers the largest average efficiency gains over the two countries, which is equivalent to the largest aggregate efficiency gains. This would, for instance, correspond to the case of voters being pro-European and putting emphasis on the reduction of income differences across countries. It can also correspond to the case of voters behaving according to the goals of a benevolent supra-national policy maker.

In my analysis, I will thus compare the aggregate efficiency impact of different reform options. Policy implications will take unknowns on aversion for cross-country inequality into account.

3.2.2 Reforms

The analysis will focus on efficient tax-financed public investment reforms with a neutral impact on government budgets, keeping public debts at zero. Because tax increases reduce the incentive to provide labor, they reduce output, ceteris paribus. Public investments increase the public capital stock, total factor productivity and output, ceteris paribus. Which effect dominates in a domestic reform is ambiguous, in general. In efficient reforms, the second effect dominates over the long run. This takes place for instance when labor supply elasticities $1/\varepsilon_L$ are low, such that the distortive impact of taxation is small. It also takes place when the elasticity η of the total factor productivity with respect to public investments (or *public investment elasticity* for short) is high. For the sake of analytical results, I also assume that restrictions on elasticities lead to wage bill increases[6].

[4]The bound depends on the choice of the inequality measurement. For instance, the Gini index for before-tax household earnings should never rise beyond 0.40. As further specification of the inequality constraint is not required for the analysis, I omit it, for simplicity.

[5]In other words, the average efficiency over the two countries is a variable of the function $\mathcal{IA}_{EU}$.

[6]The tax increase drops labor supply incentives, while the public investment increases the wage rate, such that the net effect on the wage bill wL is ambiguous in general. A low labor supply elasticity or high public investment elasticity will lead to an increase.

Because the public capital stock gradually builds over time, the initial increase in output due to public investments is small. The tax effort is however constant and its distortive impact immediate. A domestic reform thus initially reduces output and household income. Overtime, as the public capital stock grows, the reform will have a positive impact on output and income. Old generations suffer while young and future generations benefit from efficient domestic tax-financed public investments, which thus redistribute from the old to the young generations but constitute no Pareto improvements. Old generations however have a degree of altruism and voters accept such reforms up to the point where the inequality bound is met (bounded altruism). Without loss of generality and for ease of presentation, I consider the largest possible domestic reform, which thus leads inequality to equal the bound over the long run[7].

Formally, denote the maximal increase of public investment ΔCG^D in a domestic reform so that the inequality bound is met and the corresponding adjustment of labor income taxes $\Delta\tau_L^D$ made to finance it. Because of the continuum of political parties in the financing country, an international reform is also considered. In that policy proposal, the financing country increases labor income taxes $\Delta\tau_L^F$ and makes a transfer TR to the other, beneficiary, country, under the condition that the transfer is used for public investments only. The beneficiary country then increases its public consumption ΔCG^B, which may be equal to the transfer received $-TR$ or differ, as long as the condition of the transfer is respected, the inequality constraint is met and no public debt is made in that beneficiary country[8].

Note that the inequality constraint in the beneficiary country is readily verified, because the condition of the transfer prevents other usages than public investments, such as tax decreases. With no debt, constant taxes and a positive impact of public investments on wages, the international reform represents a Pareto improvement in the that country. By maturity of the policy debate in the financing country and scalability of policy options, all policy options are scaled to the same budget commitment, so that they are comparable. The cross-country transfer in the international reform is thus equal to the public investment in the domestic reform, $TR = \Delta CG^D$.

3.2.3 Elementary efficiency results

The first result compares the efficiency of the domestic and international reforms in a limit case[9]:

Lemma A. *If there are no government policies in the initial equilibrium ($CG = \tau_L = 0$), the domestic policy is more efficient than the international policy.*

The case is unrealistic but none-the-less instructive. The lemma indeed hints at a role for the initial tax basis, which will be discussed in details below.

[7] It is always possible to define a large enough reform such that the inequality bound is met.

[8] Recall that superscripts reflect the reform case and the countries: D for the domestic reform in the financing country, F for the international reform in the financing country and B for the beneficiary country in the international reform.

[9] Proofs for all results are provided in appendix A.

The second result considers domestic reforms only and characterizes efficient reforms:

Lemma B. *Consider a domestic reform with increased public investment ΔCG^D and the following condition C1:*

$$\frac{CG^D}{Y}\frac{\partial Y}{\partial CG^D}\left[1+\frac{\tau_L}{\Delta\tau_L^D}\frac{w^DL^D-wL}{w^DL^D}\right] > \left|\frac{\tau_L^D}{Y}\frac{\partial Y}{\partial\tau_L^D}\right|$$

Then the domestic reform leads to efficiency gains if the condition C1 holds. Conversely, the domestic reform leads to efficiency losses if the opposite of the condition C1 holds.

Ceteris paribus, note the positive impact of public investment on total factor productivity, wages, labor supply incentives and thus output, while there is a negative impact of labor income taxes on labor supply and thus output, which justifies the use of absolute values in the condition C1. As trivial consequence of the lemma, there are neither efficiency gains nor efficiency losses if the condition C1 holds with equality.

An immediate observation is that the condition C1 is more likely to hold, and the reform to deliver efficiency gains, if the initial tax rate τ_L is large or if the difference in the wage bill $w^DL^D - wL$ is positive and large. Both identify a pivotal role for the tax base. The condition C1 can thus be decomposed as

$$\underbrace{\frac{CG^D}{Y}\frac{\partial Y}{\partial CG^D}}_{\substack{\text{Public}\\ \text{investment}\\ \text{impact}}}\underbrace{\left[1+\frac{\tau_L}{\Delta\tau_L^D}\frac{w^DL^D-wL}{w^DL^D}\right]}_{\substack{\text{Tax base}\\ \text{effect}}} > \underbrace{\left|\frac{\tau_L^D}{Y}\frac{\partial Y}{\partial\tau_L^D}\right|}_{\substack{\text{Tax change}\\ \text{impact}}}.$$

Intuitively, if the (positive) impact of public investments on total factor productivity and thus output is large, ceteris paribus, we would expect the tax-financed public investment reform to deliver efficiency gains and the condition C1 to hold. This would happen, for instance, if the public expenditures elasticity η is large. Similarly, if the (negative) impact of tax increases on labor supply and thus output is small, ceteris paribus, we would also expect the condition C1 to hold and the reform to deliver efficiency gains. This can happen, for example, if the labor supply elasticity $1/\varepsilon_L$ is small.

The last term, the tax base effect, has also an intuitive interpretation. On the one hand, the reform increases public investments, total factor productivity, the marginal product of labor and thus the wage, ceteris paribus. On the other hand, the increase of labor income taxes, required to finance the increase in public investments, decreases net-of-tax wages, ceteris paribus, and thus the incentives to provide labor supply, which has an opposite effect on the wage bill. As spelled out at the start of the section, the analysis is restricted to the case where wage bill increases, $w^DL^D > wL$. In that case, the tax base and thus the labor income tax revenue will increase with constant public debts, even at constant tax rates. That ceteris paribus increase of the tax revenue allows for additional public investments, increasing the likelihood that the reform leads to efficiency gains. The tax base effect thus captures the self-financing dimension of the

reform. The larger the initial tax rate or the wage bill increase, the larger the tax base effect, the larger the self-financing dimension of the reform, the more likely it will lead to efficiency gains.

3.2.4 Main efficiency results

The third result compares the aggregate efficiency of domestic and international reforms in a general case:

Lemma C. *Consider a domestic reform with public investment ΔCG^D, assume that cross-country spillovers are negligible, and define the condition C2 by:*

$$-\frac{\partial Y}{\partial \tau_L}\,\frac{\Delta CG^D + CG}{w^D L^D\, w^F L^F}\,\frac{w^D L^D - w^F L^F}{w^B L^B - wL} \;<\; \frac{\partial Y}{\partial CG}\,\tau_L$$

Then the implementation of the corresponding international reform, where the domestic country is the financing country and makes a cross-country transfer of amount ΔCG^D, leads to higher aggregate efficiency gains than the domestic reform if the condition C2 holds. If the opposite of condition C2 holds, then that international reform leads to smaller aggregate efficiency gains that the domestic reform.

Note that the assumption of small cross-country spillovers is always verified in the simulations performed in this paper (see for instance table 5 in appendix B). Note also that the condition C2 is not trivial, as both sides of the inequality are larger or equal to zero: a ceteris paribus increase of taxes indeed reduces output ($\partial Y/\partial \tau_L < 0$); both wages and labor supply increase in the beneficiary country of the international reform ($w^B L^B > wL$); and the tax increase in the financing country of the international reform leads to a lower labor supply and wage bill than in the domestic reform, where increased public investments and wages counteract the tax increase ($w^D L^D > w^F L^F$).

The first general observation on condition C2 is that it does not hold if there is initially no government role and thus no taxes ($\tau_L = 0$). That observation provides a proof for lemma A and indicates a role for the initial tax base. For further analysis, it is thus useful to rewrite and decompose the condition C2 as follows:

$$\underbrace{\left|\frac{\tau_L}{Y}\frac{\partial Y}{\partial \tau_L}\right|}_{\text{Tax change impact}}\quad\underbrace{\frac{\tau_L^F}{\tau_L}\frac{wL}{w^D L^D}\frac{w^D L^D - w^F L^F}{w^B L^B - wL}}_{\text{Relative tax base effect}}\quad<\quad\underbrace{\frac{CG}{Y}\frac{\partial Y}{\partial CG}}_{\text{Public investment impact}}$$

I provide a discussion of each of the three terms of the decomposition in turn, starting with the tax change impact. If the financing side of the international reform plays a prominent role, that is if the elasticity of output with respect to labor income taxes is large, then the increase of labor income taxes in the financing country will lead to a large decrease of output in that country, reducing the aggregate efficiency of the international

reform, and thus increasing the likelihood that the international reform is less efficient than a domestic reform. As the decomposition shows, the condition C2 is also less likely to hold. Turning to the public investment impact: if on the other hand the public investment side of the international reform plays a prominent role, that is if the elasticity of output with respect to public investment is large, then the increase in public investment in the beneficiary country has a large impact in the output of that country, increasing the aggregate efficiency of the international reform and thus the likelihood that this reform is more efficient than the domestic reform. Again, the decomposition of C2 shows the condition is more likely to hold.

Finishing with the last term of the decomposition, note that the relative tax base effects in lemma C (condition C2) are related to the tax base effects of the pure domestic reform in lemma B (condition C1), but not identical. As the decomposition of C1 shows, the larger the increase of the wage bill due to the domestic reform, the larger the increase in the tax base and labor income tax revenue, at constant tax rate. The self-financing part of the domestic reform allows then larger public investments. The decomposition of C2 shows that the international reform is likely to be more efficient than the domestic reform if the wage bill (tax base) increase in the domestic reform is not much greater than that of the wage bill (tax base) in the financing country of the international reform (small $w^D L^D - w^F L^F$). In that case, the self-financing part of the domestic reform does not play an important role in the domestic reform, explaining why the domestic reform is not very efficient, increasing the likelihood that the international reform is more efficient. The relative tax base term in C2 also shows that the international reform is likely to be more efficient than the domestic reform if the increase of the wage bill (tax base) in the beneficiary country is especially large (large $w^B L^B - wL$). In that case, there is a large top-up self-financing effect in the beneficiary countries, increasing the efficiency of the international reform and the likelihood that it is more efficient than the domestic reform. Finally, the relative tax base term in C2 shows that the international reform is less likely to be more efficient than the domestic reform if the increase in labor taxes in the financing country, which has a negative impact on the output of that country, is large (large τ_L^F/τ_L). All these effects conform with intuition and are formalized in lemma C and its condition C2.

The fourth and last result, which combines the previous two results, compares the aggregate efficiency of domestic and international reforms when certain conditions on elasticities and variations of the capital stock are satisfied:

Lemma D. *Consider a domestic reform with public investment ΔCG^D which leads to efficiency gains and assume that cross-country spillovers are negligible, that the capital stock varies little, that labor supply elasticities $1/\varepsilon_L$ are small and that the elasticity of total factor productivity with respect to public expenditures is larger or equal to 1, $\eta \geq 1$. Then the implementation of the corresponding international reform, where the domestic country is the financing country for a cross-country transfer of amount ΔCG^D, leads to higher aggregate efficiency gains than the domestic reform.*

Lemmas C and D provide an efficiency-based conditional theoretical rationale for cross-country transfers within the European Union: when conditions provided in the lemma are verified, an international implementation of tax-financed public investments is more efficient than a domestic implementation. Note that the conditions provided in lemma D are sufficient, but not necessary conditions: the result may also hold with large labor supply elasticities, small public investment elasticities and significant variations of the capital stock. The condition on the public investment elasticity, as spelled out in the lemma, is however unrealistic.

The intuition for lemma D is the following. The low labor supply elasticities and high public investment elasticity lead to a favorable trade-off, with low distortive impacts of taxation and a high productivity impact of public investments. Initial public investments boost the marginal product of labor, the wages and thus the tax base. The international reform exploits the trade-off to a greater extent, because the initial increase of the tax base is used for a further increase in public investments, delivering large gains. The government in the beneficiary country has indeed made the pledge to use all direct and indirect benefits of the cross-country transfer for their intended convergence purposes, rather than tax reductions or other reforms, and thus re-invests all fiscal gains. By contrast, the initial increase of the tax base is used by the domestic reform to mitigate the hike in the tax rate, which only delivers small gains. In the domestic reform indeed, lawmakers need to stick to the inequality constraint. A further increase of public investments would increase the benefit of young generations even more, violating the initial cross-generational redistribution contract.

Summing up, efficient tax-financed public investments have two notable effects. Because they are efficient, they lead to a long-run increase of output and income. Because time is needed for investments to generate their benefits but tax efforts are required from the start, they redistribute from old to young generations. In a domestic context, the second effect act as a bound on the magnitude of the reforms, because a social contract prevents cross-generational redistribution beyond a socially accepted level, enforced via voting. With an international implementation, the generational impact in the financing country is neutral, as public investments take place abroad. Although young generations benefit more than old generations in the beneficiary country, there is no redistribution from old to young generations within that country. Instead, the beneficiary country commits to using cross-country transfers for their sole convergence purposes. While the cross-generational contracts limit the extent of the reform in a domestic context, the commitment to dedicate resources to their convergence purpose maximizes the extent of reforms financed by cross-country transfers. Substituting the cross-generational domestic contract by a cross-country commitment to use resources for their sole intended purposes allows thus the implementation of larger, efficient tax-financed public investments, delivering larger efficiency gains for the same budgetary impact in financing countries[10].

[10]Similar results might not hold within a fiscal federation, because cross-generational, cross-regional social contracts are possible. Because the European Union is not a fiscal federation however, cross-generational cross-country social contracts do not take place.

3.2.5 Plausibility

I finish the section with a discussion of the plausibility of the conditions appearing in key analytical results. As its expression in lemma C shows, the condition C2 depends on a number of factors, including fiscal policy parameters and general equilibrium effects. Whether or not the condition C2 holds in reality is thus an empirical question. The verification of that condition can not be made readily, as it involves general equilibrium effects. Further, some of the sufficient (but not necessary) conditions in lemma D are unrealistic. To shed light on the validity of conditions for lemma C and D, a simple numerical evaluation of the condition C2 can however be performed.

That condition can also be expressed as

$$\left|\frac{\tau_L}{Y}\frac{\partial Y}{\partial \tau_L}\right| \frac{CG^D CG}{w^D L^D w^F L^F}\frac{w^D L^D - w^F L^F}{w^B L^B - wL} < \frac{CG}{Y}\frac{\partial Y}{\partial CG}\left(\tau_L\right)^2.$$

Assume that wage bill differentials $w^D L^D - w^F L^F$ and $w^B L^B - wL$, which are of equal magnitude, are close. Further assume that the elasticity of labor supply with respect to net-of-tax wages (all in practice close to a value $1/\varepsilon_L$) is a good approximation of the output elasticity with respect to labor income taxes $\left|\frac{\tau_L}{Y}\frac{\partial Y}{\partial \tau_L}\right|$ and that the elasticity of total factor productivity with respect to public investment η is a good approximation of the output elasticity with respect to public investment $\frac{CG}{Y}\frac{\partial Y}{\partial CG}$. Then the condition C2 is approximately equivalent to

$$\varepsilon_L \frac{CG^D CG}{w^D L^D w^F L^F} < \eta\left(\tau_L\right)^2 \qquad \Longleftrightarrow \qquad \tau_L > \sqrt{\frac{CG^D CG}{w^D L^D w^F L^F}\frac{1/\varepsilon_L}{\eta}}.$$

The following values for the remaining parameters are either taken from the model calibration (presented in section 4.1) or empirically plausible for developed economies and public investments:

$$\begin{array}{lll} 1/\varepsilon_L = 0.15 & CG = 0.10 \times Y & w^D L^D = 2/3 \times Y \\ \eta = 0.1 & CG^D = 0.12 \times Y & w^F L^F = 3/5 \times Y, \end{array}$$

noting that the wage bill, or labor income share of production, is larger after a tax-financed domestic increase of public investments ($w^D L^D$), than in the case of the tax financing of an international transfer policy ($w^F L^F$). Plugging values, the condition C2 is approximately equivalent to

$$\tau_L > \sqrt{\frac{0.12 \times Y \times 0.10 \times Y}{2/3 \times Y \times 3/5 \times Y}\frac{0.15}{0.1}} = 0.21.$$

In other words, a simple evaluation of the condition C2 indicates that international reforms are more efficient than domestic reforms in developed economies as soon as the labor income tax rate is larger than 21%. In reality, average labor income taxes are below that level in some developed countries, and above that level in other developed countries. The analysis however abstracted from other types of taxes. If countries in

reality only used labor income taxes as financing instrument, it is likely that their labor income tax rates would always be above that threshold. Further, the conditions of lemma D are sufficient and unrealistic, but not necessary. International reforms may be more efficient even if those conditions are not verified. Because of the strong simplification steps used in the numerical evaluation and to investigate relative efficiencies of domestic and international reforms when the conditions of lemma D are not met, a comprehensive quantitative analysis is required.

I perform such a comprehensive quantitative analysis in realistic circumstances in the next section. A quantitative analysis in illustrative circumstances with a large-scale overlapping-generations model, provided in appendix B, find a larger efficiency in international reforms and show the importance of tax base effects.

4 Quantitative analysis

The analytical comparison from the previous section shows that the international implementation of tax-financed public investments is sometimes, but not always, more efficient than a domestic implementation. The section provides analytical conditions for the international reform to be more efficient, which may or may not be satisfied in reality. Further, the model was kept simple in order to obtain analytical results. There are thus two reasons to use an extended model, with features closer to reality, in order to perform a quantitative comparison of the two reform types. This section provides such a comparison. The same reforms are considered but the model is extended.

4.1 Model extension

I use a large-scale multi-country overlapping-generations model which is applied on a regular basis for policy evaluation. The basis is the same as in section 3.1 but the model is more complete. I summarize the extension here and refer to online appendix C for details on the model and to online appendix D for details on its calibration.

Financing public investments with increases in labor income tax might be more difficult in countries with large welfare states, because of the larger overall tax burden and thus potential damage of further increases of taxes. Components of the welfare states are thus modelled in details: unemployment (and thus unemployment insurance), longevity risk (and thus public, pay-as-you-go earnings-related pensions), disability (and thus welfare benefits for non-participants to the labor market) are all contained in the model. Redistribution may also influence the efficiency of tax-financed public investments, as increases of taxes may have more detrimental effects in countries with progressive tax systems, which put the burden, and thus labor supply disincentives, on the most productive workers. The model thus sorts households into three skill classes in an exogenous fashion and differentiates tax and social security contribution rates by skill level. Government also collect taxes on other bases than labor income, namely capital income, consumption and firms profit. Households take labor supply decisions along extensive and intensive margins, because social security benefits are not symmetric across margins[11].

[11] Lower participation, for instance, increases welfare benefits but not fewer working hours.

Elasticity	Value	Interpretation
Participation	(0.250, 0.175, 0.100)	% increase in participation rate for 1% increase in labor income, by skill level (low, medium, high)
Hours worked	(0.100, 0.090, 0.080)	% increase in hours for 1% increase in wage rate, by skill level (low, medium, high)
Public investment	0.110	% increase in total factor productivity for a 1% increase in public expenditures

Table 1: Key elasticity parameters

The model is calibrated for 14 European countries[12] and two Rest-of-the-World regions, one rich and one poor, to capture the dampening effect of worldwide markets on factor prices within the European sample. The level of details on the welfare states and the country coverage both lead to computational complexity. That complexity is reduced by considering only 8 age groups.

Because labor supply elasticities and the public investment elasticity play a key role in analytical results (see section 3) and because of the range of elasticity values in the empirical literature, I consider several elasticity cases. Baseline values, taken respectively from Immervoll et al. (2007) and from Bom and Ligthart (2014), are provided in table 1. Other cases consider either twice smaller or twice larger values. Because the survey Bom and Ligthart (2014) covers more than 500 estimates produced in 68 empirical studies, the baseline public investment elasticity can be interpreted as the average return of public investment projects.

4.2 Quantitative results

After presenting the simulation setup, I provide elementary results with baseline elasticity values, which serve as basis for the general results.

4.2.1 Setup

The two tax-financed public investment implementations from section 3, domestic and international, are compared quantitatively. In the domestic implementation, a reform country raises labor income taxes to finance an increase in public investment. In the international implementation, that country transfers the resources levied by the labor income tax increase to the European Union, which dispatches the proceeds to low-income countries for public investment, in inverse proportion to GDP per capita. The international implementation is consistent with the actual cross-country transfers operated by the European Union under the Structural and Cohesion Funds.

The aggregate efficiency impacts of the domestic and international reforms, over the entire European Union, are compared. In international reforms, the seven countries from

[12] Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Poland, Slovakia, Spain, Sweden and the UK.

the sample with above average GDP per capita will be net contributors and finance the cross-country transfers. The other seven countries, with lower GDP per capita than the average, will be net beneficiaries and use the cross-country transfers for public investments. Consistent with the reality of cross-country transfers, the overall budget operated by the European Union amounts to 1% of aggregate GDP. Each country makes a gross contribution of 1% of its GDP and the total central budget is split in opposite proportion to GDP per capita[13, 14]. I finally assume that the European Union can operate the cross-country transfers at no administrative costs, an important point for policy implications.

To have a meaningful comparison, the domestic reforms are implemented in all net contributing countries of the international reform[15]. Consistent with section 3, the amount of public investments in the domestic reform is the same as the amount transferred by the financing country in the international reform[16].

In all scenarios, public debts are kept constant: net contributing countries adjust labor income tax rates, given a public spending or cross-country transfer target; net beneficiary countries spend the entirety of the transfer in public investments, keeping their tax rates constant.

In total 10 reform scenarios are considered: two implementation types (domestic, international) times five elasticity values (baseline, low labor supply elasticities, high labor supply elasticities, low public investment elasticity, high public investment elasticity).

4.2.2 Results with baseline elasticities

Figure 1 provides the impact of the international reform and table 2 the impacts of the domestic and international reforms in two countries. To illustrate, outcomes are provided first for the Czech Republic, one of the largest net recipients of European Union transfers, and for the Netherlands, one of the largest net contributors, relative to economic size.

The figure provides the time path of the main macroeconomic indicator, the variation of GDP per capita compared to its pre-transfer value[17]. Without surprise, the Czech Republic, a recipient of net transfers, benefits from the policy, as opposed to the Netherlands, who is a net contributor and thus shifts resources abroad[18]. Because public investments only build the public capital stock slowly over time, and because the total factor productivity depends on the public capital stock rather than public investments, the GDP only increases slowly over time in the Czech Republic.

[13] Formally, each country j receives a transfer $EU_j = CB \;/\; (GDP_j/N_j) \cdot \overline{GDP/N}$, where CB is the size of the central budget (total transfers) and $\overline{GDP/N}$ is the average GDP per capita across countries. Negative transfers correspond to payments by net contributing countries, $TR_j = -EU_j$.

[14] Contribution and transfer values are permanent and based on the pre-policy equilibrium.

[15] The analytical results from section 3.2, obtained when there is only one net contributing country, apply readily when there are more than one net contributing country.

[16] Formally, $\Delta CG_j^D = TR_j = -EU_j$.

[17] Because cross-country transfers take place between governments and because redistribution between households is a responsibility of governments in the reality, I ignore possible redistribution between households and thus abstract from a welfare analysis.

[18] The experiment thus provides a case where the transfer paradox (e.g. Galor and Polemarchakis, 1987) does not apply.

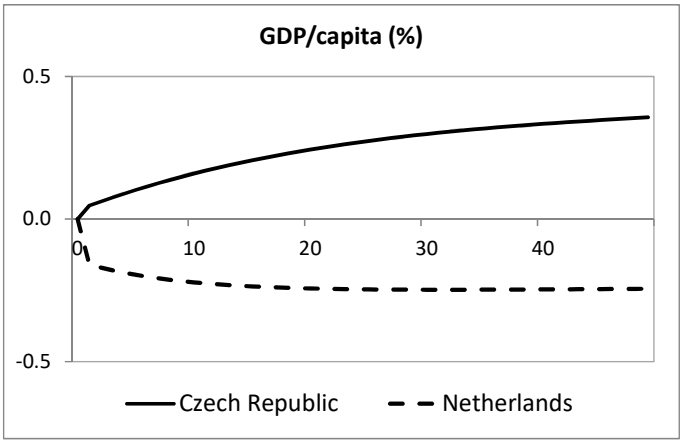

Figure 1: GDP impact, baseline elasticities, international reform, Czech Republic and the Netherlands

	Domestic reform	International reform	
	Netherlands	Netherlands	Czech Republic
Net EU transfer (% GDP)	0.00	-0.20	0.31
Pub. investment (pp GDP)	0.20	0.00	0.35
Labor tax (%)	6.09	7.28	0.00
Gross wages (%)	0.12	0.08	0.10
Labor/capita (%)	-0.14	-0.19	0.03
Interest rate (%)	0.02	0.00	0.00
Private Capital stock (%)	-0.07	-0.12	0.07
Cons./capita (%)	-0.50	-0.72	0.18
GDP/capita (%)	-0.09	-0.23	0.25
GDP/capita FSS (%)	0.01	-0.24	0.39

Legend: yearly average values 20 years following the policy change, except: *GDP/capita FSS* = values in final steady state. *Net EU transfer* = net EU transfer received by the government (in % of GDP); *Pub. investment* = increase in public investment (in percentage points of GDP*); (%)* = percentage change compared to pre-reform equilibrium.

Table 2: Macroeconomic impacts, baseline elasticities, Czech Republic and Netherlands

Table 2 provides labor market, public finance and production outcomes for the domestic and international reforms, still restricting reports to the Czech Republic and the Netherlands. All values but one are averaged over the first 20 years, to focus over the medium and long run. Averaged over the first 20 years, the Czech GDP per capita increases 0.25% in the international reform. The GDP per capita in the Netherlands drops 0.09% with the domestic reform. Over the long run, impacts in the final steady state in the international reform are consistent, at respectively 0.39% and -0.24%, given the time required for the public capital stock to build and contribute to total factor productivity. In the domestic reform, the buildup of the capital stock is sufficient to increase the Dutch GDP per capita lightly, by 0.01%.

The table illustrates the importance of behavioral reactions and the tax base. In the Czech Republic, GDP per capita increases 0.39% but the net transfers only correspond to 0.31%. Behavioral reactions explain the difference. The total factor productivity influences positively not only output, but also the marginal products. Wages increase for instance 0.10%. Factors' supply is thus stimulated, leading to a 0.03% increase of labor supply and 0.07% of the private capital stock, contributing to the rise of output.

In the Netherlands, gross wages also increase, but the labor supply drops, because the labor tax increase reduces net-of-tax wages. This leads to a drop in output in the international reform. Note in that case that output drops more than labor supply (-0.24% versus -0.19%) because the increase in the capital-labor ratio increases the marginal product of capital, which reduces investment incentives and thus the private capital stock (-0.12%). In the domestic reform, the increase in public investment, public capital stock and total factor productivity is barely sufficient to compensate for the reduction in labor supply, a point I will discuss below. Note also for future reference that the labor income tax rate increases to a smaller extent in the domestic reform than in the international reform (+6.1% versus +7.3%). A tax base effect explains that difference: with the domestic reform, the larger increase of the total factor productivity, gross wages, labor supply and thus the tax base, relative to the international reform, allows for labor taxes to be increased to a lower extent to generate the same amount of public resources.

Table 3 provides the macroeconomic impacts for all European countries in the simulation sample, as well as public investment variations and the net transfers received. A negative sign indicates a net transfer made to the European Union central fund, which identifies net contributing countries.

As for the Czech Republic and the Netherlands, the table shows that the international reform leads to GDP per capita increases in net beneficiary countries and GDP per capita losses in net contributing countries. Consistent with intuition, the larger the net transfer, the larger the GDP per capita variation. The table also provides the average GDP per capita over all European countries in the sample, weighted by economic size. In both domestic and international reform cases, the average long-run impact is next to zero.

The aggregate efficiency rate is defined as the average GDP per capita impact over the size of the central budget which operates the cross-country transfers. An aggregate efficiency rate of 10% means for instance that a central budget of size 2% of GDP would lead on average to a GDP per capita increase of 0.2% across all EU countries. In the

	Domestic reform		International reform		
	Pub. Invest.	GDP/ capita (%)	Net EU transfer	Pub. Invest.	GDP/ capita (%)
Austria	0.16	0.00	-0.16	0.00	-0.19
Belgium	0.10	0.00	-0.10	0.00	-0.11
Czech Republic	0.00	0.00	0.31	0.40	0.39
Denmark	0.19	-0.04	-0.19	0.00	-0.34
Finland	0.08	0.01	-0.08	0.00	-0.09
France	0.00	0.00	0.00	0.00	0.00
Germany	0.13	0.00	-0.13	0.00	-0.14
Italy	0.00	0.00	0.08	0.11	0.10
Netherlands	0.20	0.01	-0.20	0.00	-0.24
Poland	0.00	0.00	0.61	0.74	0.68
Slovakia	0.00	0.00	0.44	0.54	0.54
Spain	0.00	0.00	0.18	0.24	0.25
Sweden	0.16	-0.01	-0.16	0.00	-0.21
United Kingdom	0.00	0.00	0.01	0.01	0.01
14EU average GDP (%)		0.000			0.003
Aggregate efficiency rate (%)		0.0			0.0

Legend: values in final steady state following the policy change, baseline elasticity values; *14EU average GDP (%)* = Average GDP/capita impact (in %) for the 14 European countries in the simulation sample (weighted by economic size); *Aggregate efficiency rate* = 14EU average GDP (%) / EU central fund size.

Table 3: Selected impacts, baseline elasticities, European countries

	Aggregate efficiency rate (%)	
	Domestic reforms	International reforms
Low labor supply elasticities	1.1	1.7
Low public investment elasticity	-3.0	-3.2
Baseline elasticities	0.0	0.0
High labor supply elasticities	-3.0	-3.6
High public investment elasticity	6.0	11.7

Legend: *Aggregate efficiency rate* = average impact on GDP (%) weighted by economic size / EU central fund size. For instance, with an aggregate efficiency rate of 10%, cross-country transfers operated by a central budget of size 1% of GDP would lead on average to a GDP per capita increase of 0.1% across all EU countries.

Table 4: Long-run aggregate efficiency impacts

two cases from table 3, that rate is zero. It will differ from zero when other elasticity values are considered, next.

4.2.3 All results

Table 4 delivers the main results of the quantitative analysis. The table provides the aggregate efficiency rate for all 10 simulation scenarios.

The first general observation is that tax-financed public investments sometimes lead to aggregate efficiency gains, and sometimes to aggregate efficiency losses, whether they are implemented at a domestic or an international level. Consistent with intuition, there are gains (resp. losses) when the labor supply elasticities are low (resp. high) or when the public investment elasticity is high (resp. low). On the one hand, the increase in labor income taxes required to finance the reform reduces labor supply incentives, a negative impact on output, ceteris paribus. On the other hand, public investments (slowly) raise total factor productivity, a positive ceteris paribus impact on output. Which effect dominates is open, in general. When the labor supply elasticities are low, the labor supply disincentive is small and the second effect dominates. When the public investment elasticity is high, the total factor productivity increase is large, so that the second effect dominates.

The fact that there are neither aggregate efficiency gains nor losses in the baseline case is a coincidence, rather than an economic mechanism. For the first and second effects to cancel out is purely a matter of parameter choices, which have been made independently in the calibration of the model. The labor supply elasticity, which defines the strength of the negative impact of taxation on labor supply incentives, is taken from the empirical literature on labor supply, which is independent from the empirical literature on growth, from which the elasticity of public investments is taken.

The second, and main, general observation relates to differences between domestic and international implementation. For instance, when public investment elasticities are twice as large as in the baseline case, table 4 shows that the aggregate efficiency gains is 6.0% with the domestic implementation, and 11.7% with the international implementation. In other words, efficiency gains at the European Union level are almost twice as

large when public investments are financed by cross-country transfers than when they are domestically financed, taking the financing costs into account. Similar observations hold for other scenarios, leading to:

Finding 1. *The magnitude of aggregate efficiency gains (respectively losses) of tax-financed public investments is greater with international implementations than with domestic implementations.*

The finding is consistent with the analytical results from section 3. Lemma D in particular predicts higher aggregate efficiency gains of the international implementation of the reform when the labor supply elasticities are small, the public investment elasticity is larger than 1 and two other technical conditions. As table 4 shows, the international implementation leads in the simulations to greater aggregate efficiency gains when the labor supply elasticities are twice smaller than the baseline or when the public investment elasticity is twice larger than the baseline.

The explanation for finding 1 is the same as for Lemma D. In short, when tax-financed public investments lead to efficiency gains, a larger reform leads to larger absolute efficiency gains. Tax-financed public investments also redistribute from old to new generations. In a domestic context, old generations have a degree of altruism but a social contract between generations limits the amount of redistribution, and thus the size of the reform. In an international context with no fiscal federalism, there is no such cross-border, cross-generational contract. Instead, donor countries expect beneficiary countries to use all resources for their intended purposes, cross-country income convergence through public investments. The productivity gains from the public investments are thus partially used to mitigate the tax increase in the domestic context, to prevent redistribution across generations to increase beyond socially acceptable levels. In an international context, there is no such need for mitigation and all the productivity gains are used for further public investments.

5 Discussion

Two policy implications are derived from the theoretical and quantitative analyses, economic rationale and minimal efficiency.

Economic rationale: if a tax-financed public investment leads to efficiency gains in a domestic setting, I find that the aggregate efficiency gains would be even larger if the economic policy was implemented across countries and all related gains dedicated to public investments (Lemma D, Finding 1). For instance, public investment projects with twice larger expected returns than the average would lead to long-run aggregate GDP per capita gains equal to 11.7% of the cross-country transfer with an international implementation, compared to 6.0% if the cross-country transfer was instead used for domestic investments. This finding provides an efficiency-based economic rationale for cross-country transfers similar to the Structural and Cohesion Funds from the European

Union[19]. That economic rationale complements other rationales for Structural and Cohesion Funds of a political nature, such as altruism (reduction of income differences) or the promotion of peace. It also complements other efficiency-based rationales identified by the literature, foreign ownership of firms (Fuest and Huber, 2006), tax competition (Becker and Fuest, 2010) and risk-sharing (e.g. Farhi and Werning, 2017). Like some of these studies, the rationale I provide is related to fiscal policy. However, it also applies when there is neither tax competition nor business cycle shocks.

Note that the economic rationale relies on the absence of cross-country, cross-generational social contracts, as is the case in the European Union. The rationale will thus not apply to fiscal federations, where social contracts may have such dimensions. If the European Union became a fiscal federation, the economic rationale I provide may no longer apply.

Minimal efficiency: simulations find an aggregate efficiency loss when the growth potential of public investment projects is low in net beneficiary countries, even greater for international implementations than domestic implementations. While the economy would still grow in beneficiary countries, the economies in net contributing countries would shrink at a higher rate, resulting in aggregate efficiency losses (Table 4, low public investment elasticity).

Cross-country transfers within the European Union should thus not subsidize public investment projects with low expected returns, even if such projects have a positive (limited) contribution for net beneficiary countries. Instead, transfers should be restricted to public investment projects with above-average expected returns.

6 Concluding remarks

Efficient tax-financed public investments lead over the long-run to output and income gains. They also lead to short-run losses, because public investments take time to deploy their effects but the tax effort is immediate, and thus redistribute from old to young generations. I compare public investments of similar magnitude which are either financed by domestic tax revenues or by cross-country transfers typical of the European Union. Under some technical conditions, I show analytically that tax-financed public investments lead to greater aggregate GDP per capita gains if they are financed by cross-country transfers and all fiscal gains from the transfers are used for further public investments. In contrast, domestically financed investments lead to smaller aggregate GDP per capita gains, because fiscal gains resulting from the public investments are partially used to mitigate the tax burden, in order to honor a social contract on acceptable amounts of redistribution across generations. Key is the absence of cross-border, cross-generational contracts in the European Union.

The analysis provides sufficient (but not necessary) conditions for the results to hold, and depends on extreme labor supply and public investment elasticities, some of which may not hold in practice. Simulations with a large-scale, multi-country overlapping-

[19]That conclusion implicitly assumes that voters in net contributing countries give some value to EU-level economic outcomes, an assumption consistent with the related literature on the efficiency of cross-country transfers, which typically assumes benevolent, EU-level social planners.

generations model covering 14 European countries confirm the analytical findings, in a wider context with realistic elasticity values.

The paper thus provides a new, normative, efficiency-based economic rationale for cross-country transfers within the European Union, such as those operated by the Cohesion and Structural Funds. It complements existing rationales, based on foreign ownership of firms (Fuest and Huber, 2006), tax competition (Becker and Fuest, 2010) and risk-sharing (e.g. Farhi and Werning, 2017).

The model I use for the analytical and quantitative results assumes that the returns to public investment projects are the same in high- and low-income countries. In reality, returns may be higher in low-income countries. Building modern hospitals may lead to greater health and productivity gains in countries with poor medical infrastructure than in well-equipped countries, for instance. Integrating such differences in the analysis could widen the elasticity spectrum where international implementations of public investments lead to higher aggregate economic gains than domestic implementations. Such an extension is left for future research.

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A Appendix: proofs of theoretical results

Proof of lemma B: The domestic reform leads to efficiency gains if and only if $\Delta Y/\Delta R^D = \frac{\partial Y}{\partial CG^D}\Delta CG^D + \frac{\partial Y}{\partial \tau_L^D}\Delta\tau_L^D > 0$. Because the only state expenditure is public consumption, there are no public debts and the only financing instrument is labor income taxes, we have $CG = \tau_L wL$, so $\Delta CG^D = \left(\tau_L + \Delta\tau_L^D\right) w^D L^D - \tau_L wL = \Delta\tau_L^D w^D L^D + \tau_L\left(w^D L^D - wL\right)$.

Since a ceteris paribus increase of labor income taxes leads to a drop in labor supply and thus output, $\partial Y/\partial\tau_L < 0$. By assumption, $w^D L^D > wL$. Then

$$\frac{\Delta Y}{\Delta R^D} = \frac{\partial Y}{\partial CG^D}\left[\Delta\tau_L^D w^D L^D + \tau_L\left(w^D L^D - wL\right)\right] + \frac{\partial Y}{\partial \tau_L^D}\Delta\tau_L^D.$$

The sign of $\Delta Y/\Delta R^D$ is thus equal to the sign of

$$\frac{\partial Y}{\partial CG^D}\left[w^D L^D + \frac{1}{\Delta\tau_L^D}\tau_L\left(w^D L^D - wL\right)\right] + \frac{\partial Y}{\partial \tau_L^D}$$

which is equal to the sign of

$$\frac{CG^D}{Y}\frac{\partial Y}{\partial CG^D}\left[\frac{\tau_L^D}{CG^D}w^D L^D + \frac{1}{CG^D}\frac{\tau_L^D}{\Delta\tau_L^D}\tau_L\left(w^D L^D - wL\right)\right] - \left|\frac{\tau_L^D}{Y}\frac{\partial Y}{\partial \tau_L^D}\right|.$$

Since $CG^D = \tau_L^D w^D L^D$, that sign is equal to the sign of:

$$\frac{CG^D}{Y}\frac{\partial Y}{\partial CG^D}\left[1 + \frac{\tau_L}{\Delta\tau_L^D}\frac{\left(w^D L^D - wL\right)}{w^D L^D}\right] - \left|\frac{\tau_L^D}{Y}\frac{\partial Y}{\partial \tau_L^D}\right|.$$

Proof of lemma C: Assume that the condition C1 holds. We will show that the international reform leads to higher average aggregate efficiency gains than the domestic reform:

$$\frac{1}{2}\left(\frac{\Delta Y^B}{\Delta R_I} + \frac{\Delta Y^F}{\Delta R_I}\right) > \frac{1}{2}\left(\frac{\Delta Y^D}{\Delta R_D} + 0\right),$$

noting that the aggregate impacts in the non-reforming country under the domestic reform are zero, thanks to the assumption that cross-country spillovers are negligible. We have:

$$\begin{aligned}
\frac{\Delta Y^B}{\Delta R_I} &= \frac{\partial Y}{\partial CG}\Delta CG^B \\
\frac{\Delta Y^F}{\Delta R_I} &= \frac{\partial Y}{\partial \tau_L}\Delta\tau_L^F \\
\frac{\Delta Y^D}{\Delta R_D} &= \frac{\partial Y}{\partial CG}\Delta CG^D + \frac{\partial Y}{\partial \tau_L}\Delta\tau_L^D.
\end{aligned}$$

As in the proof of lemma B, we have $CG = \tau_L wL$ and $\Delta CG^D = \Delta\tau_L^D w^D L^D + \tau_L \left(w^D L^D - wL\right)$, so

$$\Delta\tau_L^D = \frac{\Delta CG^D}{w^D L^D} - \frac{\tau_L \left(w^D L^D - wL\right)}{w^D L^D}.$$

In the beneficiary country of the international reform, the increase in public expenditure ΔCG^B sums up the cross-country transfer received from the financing country and any additional tax revenue generated by the reform, because the only state expenditure is public consumption and because the beneficiary country has made the pledge to use all direct and indirect benefits of the cross-country transfer for convergence purposes (rather than tax reductions or other reforms), and thus re-invest all fiscal gains. The transfer is equal to ΔCG^D. Because the only financing instrument is labor income taxes, the additional tax revenue equals $\tau_L \left(w^B L^B - wL\right)$, so

$$\Delta CG^B = \Delta CG^D + \tau_L \left(w^B L^B - wL\right).$$

In the financing country with the international reform, the cross-country transfer ΔCG^D is financed by additional tax revenue. Again because the only financing instrument is labor income taxes, the additional tax revenue equals $\left(\tau_L + \Delta\tau_L^F\right) w^F L^F - \tau_L wL$, so $\Delta CG^D = \left(\tau_L + \Delta\tau_L^F\right) w^F L^F - \tau_L wL$ and thus

$$\Delta\tau_L^F = \frac{\Delta CG^D}{w^F L^F} - \frac{\tau_L \left(w^F L^F - wL\right)}{w^F L^F}.$$

The international reform is more efficient than the domestic reform if and only if

$$\frac{\Delta Y^B}{\Delta R_I} + \frac{\Delta Y^F}{\Delta R_I} > \frac{\Delta Y^D}{\Delta R_D},$$

which holds if and only if

$$\frac{\partial Y}{\partial CG}\left(\Delta CG^D + \tau_L \left(w^B L^B - wL\right)\right) + \frac{\partial Y}{\partial \tau_L}\left(w^F L^F - \frac{\tau_L \left(w^F L^F - wL\right)}{w^F L^F}\right) > \frac{\partial Y}{\partial CG}\Delta CG^D + \frac{\partial Y}{\partial \tau_L}\left(\frac{\Delta CG^D}{w^D L^D} - \frac{\tau_L \left(w^D L^D - wL\right)}{w^D L^D}\right)$$

or, using $CG = \tau_L wL$,

$$\frac{\partial Y}{\partial CG}\left(\tau_L \left(w^B L^B - wL\right)\right) > \frac{\partial Y}{\partial \tau_L}\left(\frac{\Delta CG^D}{w^D L^D} + \frac{\tau_L wL}{w^D L^D} - \frac{\Delta CG^D}{w^F L^F} - \frac{\tau_L wL}{w^F L^F}\right) = \frac{\partial Y}{\partial \tau_L}\left(\frac{\left(\Delta CG^D + CG\right)\left(w^F L^F - w^D L^D\right)}{w^D L^D w^F L^F}\right).$$

Note that the beneficiary country in the international case does not have to raise taxes but sees an increase in public investments, and thus an increase in total factor productiv-

ity, marginal product of labor, wages and labor supply, so $w^B L^B > wL$. The efficiency condition thus holds if and only if

$$\begin{aligned}\frac{\partial Y}{\partial CG}\tau_L &> \frac{\partial Y}{\partial \tau_L}\left(\frac{\left(\Delta CG^D + CG\right)\left(w^F L^F - w^D L^D\right)}{w^D L^D w^F L^F}\right)\frac{1}{\left(w^B L^B - wL\right)} \\ &= -\frac{\partial Y}{\partial \tau_L}\frac{\Delta CG^D + CG}{w^D L^D w^F L^F}\frac{\left(w^F L^F - w^D L^D\right)}{\left(w^B L^B - wL\right)}.\end{aligned}$$

Proof of lemma D: Let

$$A = 1 + \frac{\tau_L}{\Delta \tau_L^D}\frac{\left(w^D L^D - wL\right)}{w^D L^D} \qquad B = \frac{\tau_L^F}{\tau_L}\frac{wL}{w^D L^D}\frac{\left(w^F L^F - w^D L^D\right)}{\left(w^B L^B - wL\right)}.$$

By the decomposition of condition C1 and lemma B, a domestic reform leads to aggregate efficiency gains if and only if

$$\frac{CG^D}{Y}\frac{\partial Y}{\partial CG^D}A > \left|\frac{\tau_L^D}{Y}\frac{\partial Y}{\partial \tau_L^D}\right|.$$

By the decomposition of condition C2 and lemma D, an international reform leads to higher aggregate efficiency gains than the corresponding domestic reform if and only if

$$\left|\frac{\tau_L}{Y}\frac{\partial Y}{\partial \tau_L}\right| B < \frac{CG}{Y}\frac{\partial Y}{\partial CG}.$$

Assume that a domestic policy delivers efficiency gains and that $\frac{1}{A} \geq B$. Note that $A > 0$, since $w^D L^D > wL$. Then

$$\frac{CG^D}{Y}\frac{\partial Y}{\partial CG^D} \quad > \quad \frac{1}{A}\left|\frac{\tau_L^D}{Y}\frac{\partial Y}{\partial \tau_L^D}\right| \geq B\left|\frac{\tau_L^D}{Y}\frac{\partial Y}{\partial \tau_L^D}\right|.$$

In other words, if a domestic policy delivers efficiency gains and if $\frac{1}{A} \geq B$, condition C2 holds, and thus the international policy delivers higher aggregate efficiency gains than the domestic policy. The rest of the proof shows that $AB \leq 1$. Because $\tau_L^F = \tau_L + \Delta\tau_L^F$,

$$AB \quad = \quad \left[1 + \frac{\tau_L}{\Delta \tau_L^D}\frac{\left(w^D L^D - wL\right)}{w^D L^D}\right]\left[1 + \frac{\Delta \tau_L^F}{\tau_L}\right]\frac{wL}{w^D L^D}\frac{\left(w^F L^F - w^D L^D\right)}{\left(w^B L^B - wL\right)}.$$

Note (see the proof of lemma C) that, for $j = D, F$,

$$\Delta \tau_L^j = \frac{\Delta CG^D}{w^j L^j} - \frac{\tau_L\left(w^j L^j - wL\right)}{w^j L^j}$$

and

$$\Delta CG^B = \Delta CG^D + \tau_L\left(w^B L^B - wL\right).$$

Consider small elasticities of labor supply, with $1/\varepsilon_L \to 0$. Then labor supply is little responsive, so $L^j \to L$ for $j = D, B, F$. Add on top of that a constant capital stock.

Then the wage variations, which are equal to the variations of the marginal product of labor, are driven by the variations in total factor productivity, as capital stock and labor supply tend to be constant. Then

$$w^F \to w \qquad w^D \to \frac{TFP^D}{TFP} w \qquad w^B \to \frac{TFP^B}{TFP} w.$$

Further note that $TFP^D = TFP\left(1+\eta\frac{\Delta CG^D}{CG}\right)$ and $TFP^B = TFP\left(1+\eta\frac{\Delta CG^B}{CG}\right)$. Then

$$\begin{aligned}
AB &\to \left[1+\frac{\tau_L}{\Delta\tau_L^D}\frac{\left(\frac{TFP^D}{TFP}w-w\right)L}{\frac{TFP^D}{TFP}wL}\right]\left[1+\frac{\Delta\tau_L^F}{\tau_L}\right]\frac{wL}{\frac{TFP^D}{TFP}wL}\frac{\left(\frac{TFP^D}{TFP}w-w\right)L}{\left(\frac{TFP^B}{TFP}w-w\right)L} \\
&= \left[1+\frac{\tau_L}{\Delta\tau_L^D}\frac{\left(\frac{TFP^D}{TFP}-1\right)}{\frac{TFP^D}{TFP}}\right]\left[1+\frac{\Delta\tau_L^F}{\tau_L}\right]\frac{1}{\frac{TFP^D}{TFP}}\frac{\left(\frac{TFP^D}{TFP}-1\right)}{\left(\frac{TFP^B}{TFP}-1\right)} \\
&= \left[1+\frac{\tau_L}{\Delta\tau_L^D}\left(1-\frac{1}{1+\eta\frac{\Delta CG^D}{CG}}\right)\right]\left[1+\frac{\Delta\tau_L^F}{\tau_L}\right]\frac{1}{1+\eta\frac{\Delta CG^D}{CG}}\frac{\left(1+\eta\frac{\Delta CG^D}{CG}-1\right)}{\left(1+\eta\frac{\Delta CG^B}{CG}-1\right)} \\
&= \left[1+\frac{\tau_L}{\Delta\tau_L^D}\left(\frac{\eta\frac{\Delta CG^D}{CG}}{1+\eta\frac{\Delta CG^D}{CG}}\right)\right]\left[1+\frac{\Delta\tau_L^F}{\tau_L}\right]\frac{1}{1+\eta\frac{\Delta CG^D}{CG}}\frac{\Delta CG^D}{\Delta CG^B}.
\end{aligned}$$

We also have, with $CG = \tau_L wL$,

$$\begin{aligned}
\Delta\tau_L^D &\to \frac{\Delta CG^D}{\frac{TFP^D}{TFP}wL} - \frac{\tau_L\left(\frac{TFP^D}{TFP}wL - wL\right)}{\frac{TFP^D}{TFP}wL} \\
&= \tau_L\frac{TFP}{TFP^D}\left(\frac{\Delta CG^D}{CG} - \frac{TFP^D}{TFP}+1\right)
\end{aligned}$$

and

$$\Delta\tau_L^F \to \frac{\Delta CG^D}{wL} - \frac{\tau_L\left(wL-wL\right)}{wL} = \tau_L\frac{\Delta CG^D}{CG}$$

as well as

$$\Delta CG^B \to \Delta CG^D + \tau_L\left(\frac{TFP^B}{TFP}w - w\right)L = \Delta CG^D + \left(\frac{TFP^B}{TFP}-1\right)CG.$$

Note also that

$$TFP^B = TFP\left(1+\eta\frac{\Delta CG^B}{CG}\right) \to TFP\left(1+\eta\frac{\Delta CG^D + \left(\frac{TFP^B}{TFP}-1\right)CG}{CG}\right)$$

so

$$\frac{TFP^B}{TFP} \to 1+\eta\frac{\Delta CG^D + \left(\frac{TFP^B}{TFP}-1\right)CG}{CG} = \frac{1-\eta+\eta\frac{\Delta CG^D}{CG}}{1-\eta}.$$

Then

$$
\begin{aligned}
AB &\rightarrow \left[1+\frac{\tau_L}{\Delta\tau_L^D}\left(\frac{\eta\frac{\Delta CG^D}{CG}}{1+\eta\frac{\Delta CG^D}{CG}}\right)\right]\left[1+\frac{\Delta\tau_L^F}{\tau_L}\right]\frac{1}{1+\eta\frac{\Delta CG^D}{CG}}\frac{\Delta CG^D}{\Delta CG^B} \\
&\rightarrow \left[1+\frac{\tau_L}{\tau_L\frac{TFP}{TFP^D}\left(\frac{\Delta CG^D}{CG}-\frac{TFP^D}{TFP}+1\right)}\left(\frac{\eta\frac{\Delta CG^D}{CG}}{1+\eta\frac{\Delta CG^D}{CG}}\right)\right]\left[1+\frac{\tau_L\frac{\Delta CG^D}{CG}}{\tau_L}\right]\times \\
&\quad \frac{1}{1+\eta\frac{\Delta CG^D}{CG}}\frac{\Delta CG^D}{\Delta CG^D+\left(\frac{TFP^B}{TFP}-1\right)CG} \\
&= \left[1+\frac{\eta}{1-\eta}\right]\left[1+\frac{\Delta CG^D}{CG}\right]\frac{1}{1+\eta\frac{\Delta CG^D}{CG}}\frac{\Delta CG^D}{\Delta CG^D+\left(\frac{TFP^B}{TFP}-1\right)CG} \\
&\rightarrow \left[1+\frac{\eta}{1-\eta}\right]\left[1+\frac{\Delta CG^D}{CG}\right]\frac{1}{1+\eta\frac{\Delta CG^D}{CG}}\frac{\Delta CG^D}{\Delta CG^D+\left(\frac{1-\eta+\eta\frac{\Delta CG^D}{CG}}{1-\eta}-1\right)CG} \\
&= \left[1+\frac{\eta}{1-\eta}\right]\left[1+\frac{\Delta CG^D}{CG}\right]\frac{1}{1+\eta\frac{\Delta CG^D}{CG}}\frac{\Delta CG^D}{\Delta CG^D+\left(\frac{\eta\Delta CG^D}{1-\eta}\right)} \\
&= \frac{CG+\Delta CG^D}{CG+\eta\Delta CG^D}.
\end{aligned}
$$

If $\eta \geq 1$, then

$$AB \rightarrow \frac{CG+\Delta CG^D}{CG+\eta\Delta CG^D} \leq 1.$$

The same conclusion holds if the labor supply elasticities are small enough but different than 0 or if the capital stock is not constant, but varies little.

B Appendix: a two-country quantitative comparison

This appendix provides a quantitative analysis of the domestic and international reforms investigated in the theoretical section 3. The same large-scale overlapping model is used as in the quantitative analysis in section 4, except two ex-ante identical countries are used instead of 14 different countries. I present results where the model is calibrated to Germany, assuming low labor supply elasticities[20]. Similar results are obtained for other countries.

Table 5 provides the long-run macroeconomic impact in the two countries for the two tax-financed public investment reforms considered in section 3. The magnitude of the reforms is defined by the increase in public investment ΔCG^D in the domestic case, equal to an 0.18% of GDP increase. As in section 3, the cross-country transfer equals that amount, $TR = \Delta CG^D$, in the international reform.

The table shows that the average efficiency gains in the domestic policy is lower than in the international policy, output in the two countries increasing on average 0.10% in the first policy and 0.16% in the second policy.

The table also illustrates the importance of the tax base and general equilibrium

[20]I also assume no initial trade between the two countries, to have identical patience parameters and thus savings' behavior in the experiment in the two countries.

	Domestic case		International case	
	Reform country	Other country	Tax increase country	Pub. spending increase country
GDP/capita (%)	0.20	0.00	-0.07	0.39
TFP (%)	0.19	0.00	0.00	0.30
Interest rate (%)	0.04	0.04	0.06	0.06
Private capital stock (%)	0.10	-0.01	-0.05	0.19
Net EU transfer (pp GDP)	0.00	0.00	-0.18	0.18
Pub. investment (pp GDP)	0.18	0.00	0.00	0.29
Labor tax (%)	2.00	0.00	3.20	0.00
Revenue income tax (pp GDP)	0.16	0.00	0.22	0.03
Revenue SSC (pp GDP)	0.04	0.00	0.00	0.06
Revenue VAT (pp GDP)	0.01	0.00	-0.04	0.05
Gross wages (%)	0.25	-0.01	0.03	0.36
Net wages (%)	-0.07	-0.01	-0.43	0.35
Labor/capita (%)	0.00	0.00	-0.04	0.04
Aggregate efficiency impacts	0.099		0.158	

Legend: the table shows % variations in the final steady state, compared to the initial steady state, except: *(pp GDP)* = variation as percentage points of GDP; *SSC* = Social security contributions; *Aggregate efficiency impacts* = average GDP variation over the two countries.

Table 5: Domestic and international tax-financed public investments, 2 countries

effects. Output in the beneficiary country of the international reform indeed increases 0.39%, but the total factor productivity only increases 0.30%. What is more, the country only received a transfer of 0.18% of GDP. The outcome is explained both by tax base and general equilibrium effects. Note first that the transfer allows for an increase in public investment, increasing total factor productivity, the marginal product of labor and thus wages, which rise 0.36%. This also stimulates labor supply, which increases 0.04%. The resulting tax base growth leads to an increase of labor income tax revenue of 0.03% of GDP and an increase in social security contributions of 0.06%, which allow the beneficiary country to increase its public consumption to 0.29% of GDP, significantly larger than the 0.18% of GDP transfer. Second, note that the rise in total factor productivity also increases the marginal product of capital and thus investment incentives, leading to an increase of investment and the capital stock of 0.19%. The combined rise of total factor productivity, labor and capital stock leads to the 0.39% output increase.

The larger efficiency of the international reform can be explained as lemma D in section 3.

APPENDICES FOR ON-LINE PUBLICATION ONLY

C Online Appendix: large-scale model description

The multi-country model is obtained by expansion of a single-country basis. The single-country model is an overlapping-generations model in the Auerbach and Kotlikoff (1987) tradition. Unemployment and skill distribution vary across countries, which can influence cross-country spillovers. These two features are thus included in the model. The single-country model starts from Jaag et al. (2010), an overlapping-generations model with imperfect labor markets, and is further extended to include three skill classes with exogenous education decisions. As one of the purposes of cross-country transfers within the European Union is to stimulate growth in low-income countries, the model has an endogenous growth component tied to public investments, following Chatterjee et al. (2003). As in Boersch-Supan et al. (2006), perfectly integrated capital markets give the model its multi-country dimension.

The single-country basis is presented first and then its multi-country extension. Country differences are only mentioned when relevant. As in section 3, the model can be solved in two separate steps, first voting decisions on policy parameters, then economic decisions, taking policy parameters as given (see subsection 3.2.1). Because the first step is identical to section 3, I omit it and only present details on the second step, the economic part of the model.

Demographics: Households go through several stages $a \in \{1, \ldots, 8\}$ in their lives. A stage a lasts several time periods. After birth, households educate, then enter the labor market and retire. Several stages a cover labor market activity, reflecting different productivity levels (typically hump-shaped). Households face a constant, age-dependent probability of dying $1 - \gamma^a$. They differ in skills, birth date and death date[21]. After they are born, they are randomly assigned one of three skill levels, low, medium or high, $i \in \{l, m, h\}$. Medium and high skills are acquired through further education, which has no monetary cost but delays access to the labor market. Education for medium skills takes place in stage $a = 1$, for high skills in stages $a \in \{1, 2\}$. Retirement is defined exogenously and happens some time during stage $a^R = 5$. Stages $a \in \{6, 7, 8\}$ are full retirement stages but with different probabilities of dying $1 - \gamma^a$, to better replicate the empirical age structure of the population. As in Blanchard (1985), a reverse life insurance allocates assets at death[22].

Labor market: After education, households can enter the labor market. They choose whether to participate or not (at a rate $\delta^{a,i} \in [0, 1]$, which represents the number of time periods of the life-cycle stage with participation). The labor market is imperfect,

[21] In the implementation, households also differ in the the speed at which they go through the stages of the life cycle, which reflects differences in appetite for effort, luck or other unobserved attributes, a generalization of Gertler (1999) used in Jaag et al. (2010). For ease of presentation, I ignore this model feature. Aggregation results compute average values within each household class, which is sufficient for macroeconomic purposes, does not introduce any insurance and deals with numerical complexity (for details, see the technical appendix Davoine, 2020).

[22] I use an implementation where the average durations of stay in each life-cycle stage correspond to ages 15-19, 20-24, 25-39, 40-54, 55-69, 70-79, 80-84 and 85+. I later use the words "*life-cycle stage*" and "*age group*" interchangeably.

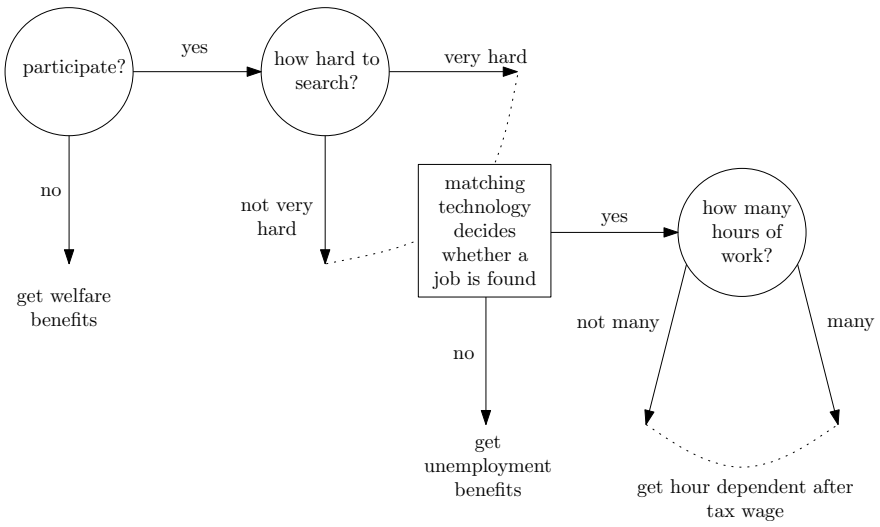

Figure 2: Sequence of households decisions related to the labor market

leading to unemployment. Households who join the labor market start unemployed. Further, households who have a job may be hit by idiosyncratic unemployment shocks with probability $1 - \varepsilon^{a,i}$ in each time period. Consistent with empirical evidence, the probability $1 - \varepsilon^{a,i}$ depends on skill levels, being greater for low-skilled households. Depending on search efforts, a job may or may not be found. If unemployed, households choose job search efforts ($s^{a,i} \geq 0$). If they have a job, they decide how many hours to work ($l^{a,i} \geq 0$). Being spared the unemployment shock leads to rents, which are bargained with firms to define the wage, building on the static search and matching setting of Boone and Bovenberg (2002). As in Jaag et al. (2010), non-participation in life-cycle a^R is interpreted as retirement. The sequence of households' decisions related to the labor market is summarized in figure 2.

Conditional on labor market participation and employment, gross labor income equals

$$y_{lab}^{a,i} = l^{a,i} \cdot \theta^{a,i} \cdot w^{a,i},$$

where $\theta^{a,i}$ is an exogenous age-productivity profile calibrated with micro-data and $w^{a,i}$ is the bargained wage per efficiency unit, assuming separate labor markets for each age and skill class.

Household maximization: Taking results of the voting into account, households make labor decisions $\left(\delta^{a,i}, s^{a,i}, l^{a,i}\right)$ and consumption decisions $C^{a,i}$ to maximize their expected economic life-time utility $V_t^{0,i}$, where $V_t^{a,i}$ is the expected remaining economic life-time utility of a household in life-cycle stage a with skill level i at time t. Preferences are expressed in recursive fashion and restrict households to being risk neutral with respect to variations in income but allow for an arbitrary intertemporal elasticity of substitution:

$$V_t^{a,i} = \max\left[\left(Q_t^{a,i}\right)^{\rho} + \gamma^a \beta \left(G V_{t+1}^{a,i}\right)^{\rho}\right]^{1/\rho},$$

where ρ defines the elasticity of intertemporal substitution $1/(1-\rho)$, β is a time discounting factor, $Q_t^{a,i}$ is effort-adjusted consumption, $G = 1 + g$ is the gross factor of

long-run growth by which the model is detrended[23].

Labor market activity generates disutility. As in Greenwood et al. (1988) and Jaag et al. (2010), effort-adjusted consumption $Q^{a,i}$ captures the utility cost of labor market activity expressed in goods equivalent terms, with

$$Q^{a,i} = C^{a,i} - \bar{\varphi}^{a,i}\left(\delta^{a,i}, s^{a,i}, l^{a,i}\right),$$

and $\bar{\varphi}^{a,i}$ a convex increasing function in all its arguments. Specifically,

$$\begin{aligned}\bar{\varphi}^{a,i} = {} & \delta^{a,i}\left[\left(1-u^{a,i}\right)\varphi^{L,i}\left(l^{a,i}\right)+\left(1-\varepsilon^{a,i}\right)\varphi^{S,i}\left(s^{a,i}\right)\right] + \\ & \varphi^{P,i}\left(\delta^{a,i}\right) - \left(1-\delta^{a,i}+\delta^{a,i}u^{a,i}\right)h^{a,i},\end{aligned}$$

where $u^{a,i} \in [0,1]$ represents the fraction of time in unemployment, $h^{a,i}$ is the value of home production if the household is not working, $\varphi^{L,i}$ captures the disutility of working, $\varphi^{P,i}$ the disutility of participation and $\varphi^{S,i}$ the disutility of job search efforts.

Given the Blanchard (1985) insurance, the budget constraint of households is:

$$G\gamma^{a,i}A^{a,i}_{t+1} = R_{t+1}\left(A^{a,i}_t + y^{a,i}_t - \left(1+\tau^c\right)C^{a,i}_t\right),$$

where $A^{a,i}$ represent assets, $y^{a,i}$ net income flows, τ^c the consumption tax rate and $R = 1 + r$ the gross interest rate.

Social security: Before retirement, households who do not participate in the labor market receive welfare benefits y^a_{nonpar} while unemployed workers receive unemployment benefits $b^{a,i} = b^i \cdot y^{a,i}_{lab}$, where b^i is the skill-dependent replacement rate.

After retirement, households receive pension benefits $y^{a,i}_{pens} = \nu^a P^{a,i} + P^{a,i}_0$, where $P^{a,i}_0$ is a flat part, $P^{a,i}$ represents acquired pension rights and $\nu^{a,i}$ is a conversion factor between pension rights and pension payments. Pension rights can be accumulated with labor earnings, following $P^{a,i}_{t+1} = \delta^{a,i}_t\left(1-u^{a,i}_t\right)y^{a,i}_{lab,t} + P^{a,i}_t$. Beyond wages, the pay-as-you-go pension system also influences labor supply: the stronger the earnings-related part $\nu^{a,i}P^{a,i}$, the larger the incentive for workers to provide labor supply along all margins, ceteris paribus.

Taking labor income taxes and social security contributions $\tau^{a,i}_t$ into account and assuming that each labor market state (i.e. non-participation, unemployment and employment) is visited in each time period[24], net income amounts to:

$$y^{a,i} = \begin{cases}\left(1-\tau^{a,i}\right)\left[\delta^{a,i}\left(1-u^{a,i}\right)y^{a,i}_{lab} + \delta^{a,i}u^{a,i}b^{a,i} + \left(1-\delta^{a,i}\right)y^a_{nonpar}\right] & \text{if } a < a^R, \\ \left(1-\tau^{a,i}\right)\left[\delta^{a,i}\left(1-u^{a,i}\right)y^{a,i}_{lab} + \delta^{a,i}u^{a,i}b^{a,i} + \left(1-\delta^{a,i}\right)y^{a,i}_{pens}\right] & \text{if } a = a^R, \\ \left(1-\tau^{a,i}\right)\ y^{a,i}_{pens} & \text{if } a > a^R.\end{cases}$$

[23]To match the age profile of consumption during calibration, retired households also make inter-vivo transfers.

[24]The assumption follows Jaag et al. (2010). Alternatively, one can assume income pooling (perfect insurance) within each age and skill class, as used for instance by Andolfatto (1996) in his real business cycle and unemployment theory.

Production: Production is made by a competitive representative firm taking input prices as given, namely wage rates, the interest rate and the price of the output good, which serves as numeraire. Changes in the production process are costly variations in the capital stock, and are subject to convex capital adjustment costs, following Hayashi (1982).

The production function is linear homogeneous:

$$Y_t = TFP_t \cdot F^Y \left(K_t, L_t^{D,i=1}, L_t^{D,i=2}, L_t^{D,i=3} \right).$$

TFP, which denotes total factor productivity, is endogenous and will be presented below. The labor inputs $L_t^{D,i}$ from different skill classes are not perfect substitutes. I assume capital-skill complementarity, a feature which can account for wage inequality variations (Krusell et al., 2000) and which is consistent with empirical evidence (Griliches, 1969).

Firms make investment I_t and hiring decisions to maximize the flow of dividends they can generate. Formally, the firm maximizes its end of period value W, which equals the stream of discounted dividend payments χ:

$$\begin{aligned} W_t = W(K_t) &= \max_{I_t, L_t^{D,i}} \left[\chi_t + \frac{GW(K_{t+1})}{R_{t+1}} \right], \\ s.t. \qquad & \chi_t = Y_t - I_t - J(I_t, K_t) - \sum_i (1 + \tau^{F,a}) w_t^i L_t^{D,i} - T_t^F, \\ & GK_{t+1} = \left(1 - \delta^K\right) K_t + I_t, \end{aligned}$$

where $J(\cdot)$ denotes the adjustment costs, $\tau^{F,a}$ the firms' social security contribution rate and T^F the total tax bill of firms, net of subsidies they receive. Given an interest rate, investment is defined so that the return on financial investments (the interest rate) equals the marginal cost of investment (Tobin's q), which depends on the marginal product of capital, net of capital adjustment costs and depreciation.

Government: Government provides welfare benefits, unemployment insurance, pay-as-you-go pensions and investment subsidies. The state has other expenditures, all bundled as public consumption. These expenditures include investments in public infrastructure, education, long-term care and health expenditures, as well as expenditures for the provision of generic public goods, all defined exogenously in per capita terms and generating no utility.

To finance expenditures, the government collects consumption taxes, labor and capital income taxes, profit taxes, firm and worker social security contributions. The government can borrow on the capital market (without premium on the interest rate) to finance public debt and meet some exogenously defined target (most of the time kept constant in simulations). The resulting government budget constraint is:

$$GD_{t+1}^G = R_{t+1} \left(D_t^G - PB_t \right),$$

where the government primary balance PB subtracts government expenditures from

government revenue, and adds the net transfer received from the EU central fund:

$$PB_t = \tau^C C_t + T_t^L + T_t^F + T_t^S - C_t^G - SS_t + TR_t.$$

C represents aggregate private consumption, T^L the total revenue from labor income taxes, T^S the total revenue from social security contributions, C^G public consumption, and SS all social security payments, made up of welfare benefits, unemployment benefits and public pensions. TR is a net transfer received from the European Union, who operates cross-country transfers in programmes similar to the Structural and Cohesion Funds. A negative value indicates that the country is a net contributing country.

Growth: In steady-state, output grows at the constant rate g, which is exogenously defined. Households, firms and the government however can also influence the output level. Changes in households' labor supply and consumption decisions, as well as changes in firms' hiring and investment decisions, lead to changes in the labor and capital stock used in production, as described above.

As noted by Glomm and Ravikumar (1997), government can support economic growth through investments in public infrastructure (such as roads, airports, harbours, or telecommunication capacity) or the provision of productivity-increasing public goods (such as education or health services). Public investments play an important role not only in domestic policies, but also in foreign aid (Chatterjee et al., 2003), which includes EU transfers (Gaspar and Pereira, 1995).

Following the reduced-form approach used in these papers, all government expenditures represent public investments and accumulate into a public capital stock, which impacts total factor productivity:

$$\begin{aligned} TFP_t &= \xi_0 M_t^{\eta}\,, \\ M_{t+1} &= (1-\delta^G) M_t \,+\, \mu\, C_t^G, \end{aligned}$$

where M denotes the public capital stock, δ^G its depreciation rate and ξ_0 is a scaling factor. The parameter η represents the elasticity of total factor productivity with respect to government expenditures, defining the impact of public investments on growth: the higher the elasticity, the larger the impact of public expenditures on total factor productivity and thus production. The parameter μ captures the efficiency of the process transforming government expenditures into productive public capital stock. Said differently, μ captures the fraction of government expenditures which impact economic growth.

Single-country equilibrium: In a single-country setting, the gross interest rate $R_{t+1} = 1 + r_{t+1}$ is exogenously defined, as for small open economies. Savings can be invested in firms, government debt and foreign assets. Assuming no arbitrage, the net returns on these three types of assets are the same and equal to the interest rate r_{t+1}. The goods

market then clears because of trade with the rest of the world:

$$Y_t = C_t + I_t + C_t^G + TB_t,$$

where C_t is the aggregate private consumption and TB_t is the trade balance[25]. Holding of foreign assets by domestic households evolves with changes in the trade balance:

$$D_{t+1}^F = R_{t+1}\left(D_t^F + TB_t\right).$$

Private household assets A_t are invested in the domestic representative firm W_t, government debt D_t^G and foreign assets D_t^F, so that the asset market clearing condition is satisfied:

$$A_t = W_t + D_t^G + D_t^F.$$

Differences across countries: As in Boersch-Supan et al. (2006), an extension of the two-country Buiter (1981) procedure to any number of countries and capital adjustment costs, labor is immobile but capital is perfectly mobile. One also assumes that all countries produce the same composite good and that they either belong to the same currency union, or that exchange rates are constant[26]. The interest rate is no longer exogenous, but endogenous.

Multi-country equilibrium: The equilibrium interest rate is the same in all countries. The intuition is as follows. Assume there is an arbitrage opportunity. Investors in the low interest rate country start to invest in the high interest rate country. The capital stock in the first country declines, increasing the marginal product of capital and thus the interest rate in that country. The opposite happens in the second country. This continues until an equilibrium is reached where the two interest rates are identical.

As a whole, the set of countries is a closed economy, where the interest rate adjusts so that the goods market clear. The resulting equilibrium interest rate is thus the unique value such that the goods market clear over all countries. Formally, consider M countries indexed by $j \in \{1, ..., M\}$. Assume that terms of change are fixed and that each variable is normalized so that the numeraire value, after currency-exchange corrections, is the same in all countries. The interest rate is then the unique value such that

$$\sum_{j \in \{1,...,M\}} TB_{j,t} = 0.$$

Rest of the world: I do not consider all countries in the world but restrict policy analysis to a smaller subset of European countries, too small to be isolated from the world

[25] Specifically, $TB_t = Y_t - I_t - J_t - C_t - C_t^G - Vac_t^F + TR_t$, where Vac_t^F represents the costs paid by firm to post open vacancies, which consume a part of output.

[26] The model is calibrated for Austria, Belgium, Czech Republic*, Denmark, Finland, France, Germany, Italy, The Netherlands, Poland*, Slovakia, Spain, Sweden* and the UK*. In this list, stars identify the four countries whose currency is neither the Euro nor pegged to the Euro, and thus do not meet the assumption of fixed exchange rates. These countries appear in the list to have broader diversity and because exchange rate variations vanish over the medium run. Because the UK still obey the EU rules, it also belongs to the list.

capital markets. Consistent with empirical evidence, the goods market, as a whole, will not clear over this subset. I thus consider a large synthetic *Rest-of-the-world* country (or a small group of Rest-of-the-world countries), which will account for trade with the rest of the world. The goods market will clear over all countries which are either part of the subset, or one of the Rest-of-the-world countries. Compared to a case without a Rest-of-the-world country, the adjustment of the equilibrium interest rate is dampened. This reflects access of all countries to the world capital market.

D Online Appendix: large-scale model calibration

The calibration of the large-scale model is standard. Consensual empirical estimates from the literature are taken, when available. For other parameters, household-level datasets are used. The model is calibrated and benchmarked to values averaged between 2010 and 2015, to remove business cycle fluctuations.

The appendix describes the calibration approach first for European countries and then for the two Rest-of-the-world regions. The appendix then describes data sources, followed by a presentation of the main calibration outcomes. Model evaluation information, following the approach of other general equilibrium studies in similar contexts[27], is also provided.

Calibration approach for European countries: Starting with *demographics*, the country-specific skill distribution is derived from the European Union Labour Force Survey (EU-LFS). Country-specific fertility and age-dependent mortality rates are defined so that the age structure in the model replicates the age distribution reported by Eurostat.

Continuing with *production*, the specification of the production function, which exhibits capital-skill complementarity with three types of labor (low, medium and high skills), is an extension of the production function from Krusell et al. (2000), which also exhibits capital-skill complementarity but with two types of labor (low and high skills). Elasticity parameters are derived from Krusell et al. (2000) and the remaining production parameters are defined to match output, the marginal product of capital and income shares by production input. The private capital depreciation rate is set to match the capital/output ratio. Private capital stock estimates are taken from the OECD Structural Analysis (STAN) database. These estimates include tangible assets and new intangible assets but neither residential capital nor military expenditures.

Regarding *growth parameters*, the same value for exogenous productivity growth, a long-run trend computed from Eurostat data, is given to all countries. The baseline value for the public investment elasticity is taken from the survey Bom and Ligthart (2014) and reported in table 1 of the main text. As the survey covers more than 500 estimates produced in 68 empirical studies, the elasticity can be interpreted as the average return of public investment projects.

Switching to *labor markets*, age-dependent productivity profiles are obtained from

[27]For instance, the model evaluation approach is the same as in Braun et al. (2017).

Mincer wage regressions using survey microdata, namely the European Union Statistics on Income and Living Conditions (EU-SILC). Average participation rates, unemployment rates and working hours are computed for each age and skill groups from the EU-LFS and EU-SILC surveys. Labor supply elasticities vary by skill groups and differ for participation and hours decisions, but are identical across countries. Conservative values are taken from the discussion in Immervoll et al. (2007) and reported in table 1 of the main text. Other parameters of labor disutility functions (shift parameters) are set to match the average participation rates, unemployment rates and working hours.

Regarding parameters on *savings*, the interest rate is set at 3%, consistent with the macroeconomic literature. The intertemporal elasticity of substitution is set at 0.4, which lies in the medium range of estimates from the empirical literature. Intervivo transfer parameters are defined to match life-cycle consumption profiles computed from Eurostat data. The trade balance is taken from OECD Annual National Accounts.

Social security parameters are derived as follows. Pensions benefits are set to match the pension replacement rates, provided by the OECD Pensions at a Glance documentation, and the aggregate pension expenditures, provided in the OECD Annual National Accounts. Unemployment insurance replacement rates are computed from the EU-SILC dataset. Social security contributions, and remaining social security benefits, are computed as for income tax rates, presented below. Other parameters related to institutions are taken from the European Commission's Mutual Information System on Social Protection (MISSOC) database.

Finishing with *public finance*, the information on public debt comes from OECD Annual National Accounts. Labor income taxes, social security contributions and selected social security benefits are set to match the averages by age and skill classes computed from the EU-SILC, the OECD Tax-Benefit model and the MISSOC database. The OECD Tax-Benefit model, which provides tax and social security information for representative family circumstances in OECD countries, is used to impute missing tax and benefit data from the EU-SILC.

Calibration approach for Rest-of-the-world regions:[28] To reflect large economic differences between countries without including many single countries, two regions are included in the model, a developed *North Rest-of-the-world* country (NROW) and an emerging *South Rest-of-the-world* country (SROW). NROW is an aggregate of Canada, Japan and the USA while SROW is an aggregate of Brazil, China and India.

Macro-level data is used the same way as for the calibration of European countries, but comes from different sources, including ILO, the UNESCO and the World Bank.

Micro-level data is not available for all of the six countries. To ensure consistency, specific micro-level data is completely ignored. A three steps approach is followed instead. First, for each of the six Rest-of-the-world countries, we identify a twin country (or a set of countries) from the sample of 14 European calibrated countries whose demographic, economic and policy characteristics are the closest. Second, we use the micro-level data inputs for this twin country in the calibration process of NROW and

[28]The approach is taken from Davoine and Molnar (2017).

SROW. Third, we make stylized corrections to the resulting calibration outcome where there are documented differences. As a result, micro-level calibration inputs from the UK are used for NROW and an average of calibration inputs from the Czech Republic, Slovakia and Poland for SROW. The most important stylized corrections are proportional adjustments to the participation and unemployment rates by age and skill classes to match the aggregate participation and unemployment rates.

Data sources: Data sources consist of national statistics, household-level surveys, results from empirical analyses, outcomes of tax-benefit models and standardized descriptions of social security systems. Data is either used for setting parameter values or to evaluate model outcomes, which are not calibrated.

National statistics and macroeconomic aggregates come from the OECD (Annual National Accounts), Eurostat and the Penn World Table (Version 9.0). Information from the ILO, the UNESCO and the World Bank is also used for the NROW and SROW regions of the model.

Household-level surveys include the European Union Labour Force Survey (EU-LFS) and the European Union Statistics on Income and Living Conditions (EU-SILC). The EU-LFS consolidates standardized information on labor market activity for representative households collected by national statistical offices. The EU-SILC does the same but on income, poverty, social exclusion and living conditions.

Results from empirical analyses include econometric estimates of labor supply elasticities (summarized in Immervoll et al., 2007), estimates of the public investment elasticity (summarized in Bom and Ligthart, 2014), estimates of labor income shares (from the OECD Unit Labour Costs database), estimates of capital stocks (from the OECD Structural Analysis database, or STAN), estimates of pension replacement rates (from the OECD Pensions at a Glance publication) and estimates of relative earnings by education group (from the OECD Education at a Glance publication).

Finally, the Mutual Information System on Social Protection (MISSOC) is a database which is co-administrated by the European Commission and which consolidates information on social protection in the European Union.

Calibration outcomes and model evaluation: Tables 6 and 7 provide calibration values for the main parameters as well as calibration outcomes. The value for some variables is not calibrated but an outcome of the calibration process. These variables are indicated with a star. When compared to benchmark values, they allow for an evaluation of the model and the calibration performance. Table 8 provides the sources for the calibrated variables and for the benchmarking information.

All in all, model outcomes are close to the benchmark values, taking data availability, data comparability and the simplification process inherent to model building into account. The main gaps concern the labor revenue share and the capital depreciation rate.

Gaps for labor revenue shares come from the fact that the model does not include transition phenomenon in eastern European countries. To some extent however, such

phenomenon is still on-going (e.g. Sachs, 2018). The lack of a consensual way to measure capital stocks accurately creates measurement noise which can carry to capital depreciation rates (e.g. O'Mahony and Timmer, 2009). Catch-up phenomenon due to technological transfer, which are not included in the model, can explain the large gap for the SROW region, which is representative of countries similar to Brazil, China or India. Unusual data classification can explain the few large gaps which appear for other model outcomes, namely the tax/GDP ratio for Spain and the private consumption/output ratio for Denmark and Italy.

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Table 6: Model parameter values, outcomes and benchmark data, part 1

	AT		BE		CZ		DE		DK		ES		FI		FR	
	Mod	Data	Mod	Data	Mod	Data	Mod	Data	Mod	Data	Mod	Data	Mod	Data	Mod	Data
Demographics																
Low skills share (%)	16.2		29.4		8.6		22.9		23.7		48.5		18.0		29.6	
Med skills share (%)	65.6		37.2		75.9		55.7		42.0		21.8		44.7		41.7	
High skills share (%)	18.2		33.4		15.5		21.4		34.3		29.7		37.3		28.7	
*Old age dependency ratio (%)	28.2	27.0	29.0	27.1	27.1	25.1	35.3	31.8	28.8	27.9	28.9	26.8	31.2	29.6	30.1	27.9
Production																
Exo. productivity growth (%)	1.21		1.21		1.21		1.21		1.21		1.21		1.21		1.21	
Capital/Output	3.7		3.0		3.7		3.5		3.4		4.4		3.0		3.2	
*Capital depreciation rate (%)	5.5	4.4	6.7	4.5	7.1	4.1	4.5	3.9	5.8	4.4	5.9	3.7	6.7	4.2	5.7	3.9
*Labor revenue share (%)	67.6	67.5	72.6	68.5	61.7	59.1	72.3	67.8	69.1	64.6	55.3	63.7	70.1	67.3	67.8	68.6
Labor Markets																
Average participation rate (%)	64.7		60.8		66.3		64.3		68.9		65.5		66.3		64.4	
Average unemployment rate (%)	5.5		8.4		7.0		6.2		4.6		10.8		7.3		9.8	
Average retirement age	59.4		59.6		61.2		60.6		62.7		61.1		62.4		60.2	
*Net earnings low vs med skills	0.72	0.78	0.91	0.94	0.75	0.77	0.71	0.82	0.84	0.91	0.86	0.86	0.94	0.95	0.78	0.92
*Net earnings high vs med skills	1.45	1.39	1.21	1.26	1.52	1.44	1.51	1.38	1.17	1.14	1.28	1.30	1.31	1.38	1.51	1.41
Savings																
Annual interest rate (%)	3.0		3.0		3.0		3.0		3.0		3.0		3.0		3.0	
Intertemp. elasticity of substitution	0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40	
Trade balance/GDP (%)	0.70		2.67		-0.05		2.77		1.92		-1.91		3.01		0.01	
*Consumption/Output (%)	54.7	53.0	46.6	51.0	49.4	49.0	55.4	55.0	41.5	47.0	51.6	57.0	50.3	50.0	55.0	55.0
Social Security																
Net pension replac. rate - low skills	0.88	0.91	0.59	0.81	0.92	0.98	0.45	0.55	1.17	1.17	0.95	0.80	0.71	0.71	0.89	0.76
Net pension replac. rate - med skills	0.82	0.90	0.56	0.62	0.69	0.64	0.46	0.57	1.04	0.77	0.88	0.80	0.69	0.63	0.92	0.71
Net pension replac. rate - high skills	0.64	0.69	0.41	0.41	0.52	0.45	0.42	0.46	0.90	0.62	0.78	0.67	0.63	0.63	0.83	0.56
Net UI replacement rate - low skills	0.48		0.41		0.34		0.46		0.53		0.24		0.49		0.41	
Net UI replacement rate - med skills	0.39		0.37		0.34		0.36		0.50		0.21		0.46		0.42	
Net UI replacement rate - high skills	0.31		0.27		0.24		0.34		0.40		0.17		0.33		0.35	
Pension expenditure/GDP (%)	13.9		11.8		9.0		10.0		14.9		11.8		12.9		14.9	
Health and LTC expenditure/GDP (%)	8.3		8.1		6.4		9.1		10.4		6.7		10.2		9.6	
Public Finance																
Public debt/GDP (%)	78.7		100.4		46.7		87.6		55.1		64.5		57.5		93.3	
Avg labor tax rate - low skills (%)	10.1		17.1		4.5		9.2		30.3		11.4		18.9		12.8	
Avg labor tax rate - med skills (%)	17.0		21.7		6.7		13.5		33.6		15.0		20.7		13.9	
Avg labor tax rate - high skills (%)	23.8		28.5		10.1		19.0		38.2		20.6		27.5		16.0	
Average SSC employee rate (%)	15.6		9.5		10.0		14.6		8.9		6.5		5.7		13.6	
Average SSC firm rate (%)	26.0		21.7		30.9		14.5		12.0		30.5		19.8		35.9	
Average SSC retiree rate (%)	4.7		2.8		0.0		7.6		0.0		0.0		1.4		1.0	
*Average consumption tax rate (%)	19.1	20.2	23.1	19.4	19.8	20.8	18.4	17.8	33.5	29.2	17.2	13.6	24.5	23.7	19.1	18.2
*Tax ratio/GDP (%)	41.2	42.0	40.8	43.5	32.2	34.2	38.0	36.1	49.8	47.6	38.7	32.3	41.3	42.5	48.1	42.9

Table 7: Model parameter values, outcomes and benchmark data, part 2

	IT		NL		PL		SE		SK		UK		NROW		SROW	
	Mod	Data	Mod	Data	Mod	Data	Mod	Data	Mod	Data	Mod	Data	Mod	Data	Mod	Data
Demographics																
Low skills share (%)	45.7		26.6		12.0		19.3		9.1		25.4		8.0		63.2	
Med skills share (%)	39.8		40.6		66.8		47.6		75.2		41.2		48.0		28.6	
High skills share (%)	14.5		32.8		21.2		33.0		15.8		33.4		44.0		8.2	
*Old age dependency ratio (%)	33.9	32.8	27.9	25.9	24.4	20.5	30.7	30.2	21.9	18.7	27.7	26.6	28.6	26.7	12.8	10.7
Production																
Exo. productivity growth (%)	1.21		1.21		1.21		1.21		1.21		1.21		1.21		1.21	
Capital/Output	3.5		3.5		3.0		2.6		4.5		2.5		3.0		2.0	
*Capital depreciation rate (%)	5.5	3.9	5.2	3.9	6.7	4.8	6.8	4.6	5.4	5.2	6.3	3.8	6.4	4.4	21.0	5.0
*Labor revenue share (%)	68.1	68.6	69.6	68.8	69.8	54.6	74.3	65.1	61.0	52.5	74.1	69.6	68.5	62.2	48.9	?
Labor Markets																
Average participation rate (%)	59.5		66.7		60.5		71.5		64.7		66.3		70.0		68.0	
Average unemployment rate (%)	7.7		4.0		13.8		6.5		14.4		5.0		5.6		4.4	
Average retirement age	59.8		61.6		59.4		64.1		58.0		62.1		62.7		58.5	
*Net earnings low vs med skills	0.85	0.85	0.83	0.86	0.73	0.74	0.89	0.92	0.75	0.76	0.81	0.81	0.81	0.77	0.74	?
*Net earnings high vs med skills	1.17	1.39	1.33	1.41	1.80	1.67	1.20	1.22	1.37	1.30	1.36	1.39	1.36	1.47	1.60	?
Savings																
Annual interest rate (%)	3.0		3.0		3.0		3.0		3.0		3.0		3.0		3.0	
Intertemp. elasticity of substitution	0.40		0.40		0.40		0.40		0.40		0.40		0.40		0.40	
Trade balance/GDP (%)	0.53		4.48		-2.54		3.81		-3.43		-0.94		-0.19		0.04	
*Consumption/Output (%)	53.4	60.0	49.9	46.0	59.5	62.0	44.5	45.0	57.5	57.0	61.9	65.0	62.6	61.7	42.7	50.3
Social Security																
Net pension replac. rate - low skills	0.76	0.84	0.63	1.05	0.66	0.61	0.76	0.69	0.49	0.88	0.58	0.67	0.59	?	0.36	?
Net pension replac. rate - med skills	0.79	0.82	0.62	1.01	0.59	0.59	0.75	0.55	0.48	0.85	0.41	0.42	0.45	?	0.34	?
Net pension replac. rate - high skills	0.76	0.83	0.61	0.95	0.51	0.59	0.73	0.78	0.45	0.82	0.26	0.25	0.24	?	0.27	?
Net UI replacement rate - low skills	0.11		0.57		0.09		0.37		0.18		0.12		0.24		0.02	
Net UI replacement rate - med skills	0.10		0.64		0.09		0.38		0.21		0.09		0.18		0.02	
Net UI replacement rate - high skills	0.09		0.45		0.05		0.29		0.22		0.06		0.11		0.01	
Pension expenditure/GDP (%)	15.7		12.3		11.3		11.7		8.1		7.7		7.3		3.3	
Health and LTC expenditure/GDP (%)	7.9		11.2		4.9		10.6		5.9		8.9		9.5		3.5	
Public Finance																
Public debt/GDP (%)	126.4		70.9		61.4		49.5		44.1		81.8		149.7		55.0	
Avg labor tax rate - low skills (%)	13.0		4.5		11.5		19.4		4.3		11.9		13.4		1.0	
Avg labor tax rate - med skills (%)	18.7		9.0		13.3		21.7		6.1		15.1		16.6		2.9	
Avg labor tax rate - high skills (%)	24.7		20.5		15.4		26.6		9.5		19.8		21.4		5.8	
Average SSC employee rate (%)	7.5		14.9		8.4		6.1		8.9		6.0		2.9		3.4	
Average SSC firm rate (%)	25.3		23.3		11.3		32.7		23.4		7.9		3.9		7.9	
Average SSC retiree rate (%)	0.0		10.8		0.0		0.0		0.0		0.0		0.0		1.3	
*Average consumption tax rate (%)	18.7	16.2	22.7	21.8	21.3	19.3	24.9	26.3	18.6	16.1	15.6	14.7	9.6	8.3	18.5	?
*Tax ratio/GDP (%)	40.9	42.9	41.9	38.7	33.5	31.7	48.0	45.5	28.4	28.3	37.4	34.9	31.1	32.4	20.0	22.2

	Data Sources
Demographics	
Low skills share (%)	EU-LFS
Med skills share (%)	EU-LFS
High skills share (%)	EU-LFS
Old age dependency ratio (%)	Eurostat
Production	
Exo. productivity growth (%)	Eurostat
Capital/Output	OECD STAN
Capital depreciation rate (%)	PWT 9.0
Labor revenue share (%)	OECD Unit Labour Costs
Labor Markets	
Average participation rate (%)	EU-LFS
Average unemployment rate (%)	EU-LFS
Average retirement age	EU-LFS
Net earnings low vs med skills	OECD Education
Net earnings high vs med skills	OECD Education
Savings	
Annual interest rate (%)	Own literature analysis
Intertemp. elasticity of substitution	Own literature analysis
Trade balance/GDP (%)	OECD Nat Accounts
Consumption/Output (%)	OECD Nat Accounts
Social Security	
Net pension replac. rate - low skills	OECD Pensions
Net pension replac. rate - med skills	OECD Pensions
Net pension replac. rate - high skills	OECD Pensions
Net UI replacement rate - low skills	EU-SILC
Net UI replacement rate - med skills	EU-SILC
Net UI replacement rate - high skills	EU-SILC
Pension expenditure/GDP (%)	OECD Nat Accounts
Health and LTC expenditure/GDP (%)	OECD Nat Accounts
Public Finance	
Public debt/GDP (%)	OECD Nat Accounts
Avg labor tax rate - low skills (%)	EU-SILC, MISSOC, OECD TaxBen
Avg labor tax rate - med skills (%)	EU-SILC, MISSOC, OECD TaxBen
Avg labor tax rate - high skills (%)	EU-SILC, MISSOC, OECD TaxBen
Average SSC employee rate (%)	EU-SILC, MISSOC, OECD TaxBen
Average SSC firm rate (%)	EU-SILC, MISSOC, OECD TaxBen
Average SSC retiree rate (%)	EU-SILC, MISSOC, OECD TaxBen
Average consumption tax rate (%)	OECD Consumption Tax Trends
Tax ratio/GDP (%)	OECD Nat Accounts

Legend: *EU-LFS* = European Union Labour Force Survey; *EU-SILC* = European Union Statistics on Income and Living Conditions; *MISSOC* = Mutual Information System on Social Protection; *OECD Education* = OECD Education at a Glance; *OECD Pensions* = OECD Pensions at a Glance; *OECD TaxBen* = OECD Tax-Benefit model; *PWT 9.0* = Penn World Table version 9.0.

Table 8: Data sources for model parameter values and benchmark data