Factor Income Taxation, Growth, and Investment Specific Technological Change[*]

Monisankar Bishnu[±] , Chetan Ghate[**] and Pawan Gopalakrishnan[#]

Abstract

We construct a tractable endogenous growth model with production externalities in which the public capital stock augments investment specific technological change. We characterize the first best fiscal policy and show that there exist several labor and capital tax-subsidy combinations that decentralize the planner's growth rate. The optimal factor income tax mix is therefore indeterminate which gives the planner the flexibility to choose policy rules from a large set. Our model explains why many advanced economies experiencing similar growth rates have widely varying factor income tax rates.

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E-mail: *cghate@icrier.res.in* / *cghate@isid.ac.in*

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[±] Economics and Planning Unit, Indian Statistical Institute, New Delhi - 110016, India. Fax: 91-11-41493981. E-mail: mbishnu@isid.ac.in. Tel: 91-11-41493935.

[**]Corresponding author: Economics and Planning Unit, Indian Statistical Institute - Delhi Center, 7 Shaheed Jit Singh Marg, New Delhi, 110016; ICRIER, Core 6A, 4th Floor, India Habitat Center, Lodhi Road, New Delhi. E-mail:cghate@isid.ac.in. Tel: 91-11-41493938. Fax: 91-11-41493981

[#] Economics and Planning Unit, Indian Statistical Institute, New Delhi - 110016, India. Fax: 91-11-41493981. E-mail: pawan9r@isid.ac.in. Tel: 91-11-27568306

1   Introduction

Why do advanced economies with roughly identical growth rates have widely varying factor income tax rates? In this paper, we develop a tractable endogenous growth model to understand this question. Figure (1) plots the average annual real GDP growth rate from 1990 to 2007 against the factor income tax ratio for several advanced economies.[1] Average growth for all countries (excluding Ireland) falls between 0.875% and 2.462%. The standard deviation of the average real GDP growth rates is 0.878 (excluding Ireland, the standard deviation is 0.4756) which indicates low dispersion of growth rates. What is striking however is that the range in the ratios of the average capital income tax rate to the average labor income tax rate in these economies is much more pronounced: 0.3951 to 1.725.[2] In other words, there is more dispersion in factor income tax ratios relative to dispersion in growth.

This is reinforced by Figure (2) which plots the difference between the average factor income tax rates for these economies. Despite having similar growth rates, what is striking is that whereas the difference between factor income taxes is large in some countries, it is quite small in others.[3]

[Insert Figure 1 and 2]

Finally, Figure (3) plots the levels of factor income tax rates across the G7 countries. The incidence of factor income taxation is quite disparate. In the US, UK, Canada, and Japan, the tax on capital income is greater than the tax on labor income. In contrast, for Germany, Italy, and France, the reverse is true.

[Insert Figure 3]

To explain these observations, we construct an endogenous growth model in which public investment, financed by distortionary taxes, augments investment specific technological

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[1] The growth rates are calculated from the OECD (2012) database: see Table ($VXVOB$). The countries are: Austria (AUS), Belgium (BEL), Canada (CAN), Denmark (DEN), Finland (FIN), France (FRA), Germany (GER), Greece (GRE), Ireland (IRE), Italy (ITA), Japan (JPN), Netherlands (NET), Portugal (PRT), Spain (SP), Sweden (SWE), United Kingdom (UK) and United States of America (USA). The base year is 2000

[2] Canada and Japan have data on capital and labor income tax estimates based on the approach used in Mendoza et al. (1994) and Trabandt and Uhlig (2009) from 1965 to 1996. For Germany, United Kingdom and United States of America, data is from 1965 to 2007. For France, the data is from 1970 to 2007. For Italy, the data is from 1980 to 2007. For Austria, Belgium, Denmark, Finland, Netherlands, Portugal and Sweden, the data is from from 1995 to 2007. For Spain and Greece, the data is from 2000 to 2007. Finally, for Ireland, the data is from 2002 to 2007.

[3] The data on factor income taxes are from Mendoza et al. (1994) and Trabandt and Uhlig (2009). The latter have used the approach in Mendoza et al. (1994) to estimate the tax rates for 17 OECD nations till 2007.

change (ISTC). We build on a series of seminal papers by Huffman (2007, 2008) who explicitly models the mechanism by which the real price of capital falls when investment specific technological occurs. A growing literature has attributed the importance of investment specific technological change to long run growth (see Greenwood et al. (1997, 2000); Whelan (2003)). Investment specific technological change refers to technological change which reduces the real price of capital goods. Greenwood et al. (1997, 2000) show that once the falling price of real capital goods is taken into account, this explains most of the observed growth in output in the US, with relatively little being left over to be explained by total factor productivity.[4]

Huffman (2008) builds a neoclassical growth model with investment specific technological change. Labor is used in research activities in order to increase investment specific technological change. In particular, the changing relative price of capital is driven by research activity, undertaken by labor effort. Higher research spending in one period lowers the cost of producing the capital good in the next period.[5] Investment specific technological change is thus endogenous in the model, since employment can either be undertaken in a research sector or a production sector. His model includes capital taxes, labor taxes, and investment subsidies that are used to finance a lump-sum transfer. Huffman (2008) finds that a positive capital tax that is larger than a positive investment subsidy along with zero labor tax can replicate the first best allocation.

In our model, we embed production externalities into a model of growth and endogenous investment specific technological change. In particular, we assume that the public capital stock has a direct effect on investment specific technological change (ISTC) *as a positive externality*.[6] We assume that public investment is financed by distortionary taxes thereby allowing a role for factor income taxes to generate growth endogenously in the presence of investment specific technological change. The link between factor income taxation and investment specific technological change is therefore explicit in our model.

In addition, we assume that the presence of labor and aggregate private capital externalities also affect investment specific technological change. This assumption is motivated by Greenwood et al. (1997), who show that the real price of capital equipment in the US – since

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[4]Other authors, such as Gort et al. (1999) distinguish between equipment specific technological change and structure specific technological change. These authors show that 15% of US economic growth rate can be attributed to structure specific technological change in the post war period, while equipment-specific technological progress accounts for 37% of US growth. This implies 52% of US economic growth can be attributed to technological progress in new capital goods.

[5]Krusell (1998) also builds a model in which the decline in the relative price of equipment capital is a result of R&D decisions at the level of private firms.

[6]Our setup *also* allows investment specific technological change to enhance the accumulation of public capital. For instance, providing better infrastructure today reduces the cost of providing public capital in the future.

1950 - has fallen alongside a rise in the investment-GNP ratio, we assume that the aggregate stock of capital also exhibits a positive externality in investment specific technological change through the aggregate capital output ratio. Greenwood et al. (1997, p. 342) say: "The negative co-movement between price and quantity.....can be interpreted as evidence that there has been significant technological change in the production of new equipment. Technological advances have made equipment less expensive, triggering increases in the accumulation of equipment both in the short and long run." Finally, we assume that the specialized labor input in the research sector exerts an externality in the production of the first sector, the final good. Our main result is that the differences in factor income taxes that we observe empirically can be explained well when we account for the above externalities in a model of endogenous investment specific technological change.

In our model, a final good sector produces a final good, using private capital, and labor. Labor supply is composite in the sense that one type of labor activity is devoted to final good production, and the other to research which directly reduces the real price of capital goods in the next period.[7] The agent optimally chooses each labor activity. The second sector captures the effect of public capital and the private capital stocks and research activity on reducing the real price of capital goods. In the planner's problem, we assume that public investment is financed by a proportional income tax. We characterize the balanced growth path (BGP) and show that the growth maximizing tax rate is determined by the relative importance of the public capital output ratio vis-a-vis the private capital output ratio in the investment specific technological change function. This characterizes the first best fiscal policy in the model. The implication of this is that if a planner was to choose the tax rate, he could maximize long run growth as long as the tax rate equals the relative contribution of public capital to investment specific technological change.

We then decentralize the planner's allocations. We assume that public investment is financed by distortionary factor income taxes on capital and labor income. We show that there is an indeterminate combination of capital tax rates and the labor tax rates that can replicate the first-best allocation. This result is not surprising since we confine ourselves to the first best fiscal policy that implements the planner's allocations. What is novel is that we show how the magnitudes of the externalities have a bearing on the optimal tax mix. Our main results can be summarized as follows:

- When there are no production externalities, equal factor incomes *always* yield the first

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[7] A real life example that motivates this assumption is the skill required for advanced manufacturing jobs. Skilled factory workers today are typically "hybrid-workers": they are both machinists as well as computer programmers. For instance, in the US metal-fabricating sector, workers not only use cutting tools to shape a raw piece of metal, but they also write the computer code that instructs the machine to increase the speed of such operations. See Davidson (2012).

best fiscal policy.

- When there are no production externalities, under a simple parametric restriction, *both* equal factor income taxes and unequal factor income taxes yield the first best fiscal policy.

- In the presence of production externalities, different combinations of unequal factor income taxes restore the first best. In the limit, as the effect of externalities diminishes, then the optimal tax rates converge.

Intuitively, the *higher* is the externality associated with the specialized labor input in the research sector (which exerts an externality in the production of the first sector, the final good), the *lower* is the optimal tax on capital for a *given* tax on labor income. This is because agents - by taking this externality as given - under-fund capital accumulation. A lower tax on capital income incentivizes capital accumulation and restores the planner's growth rate. The difference between both factor income taxes declines as the effect of the externality is reduced. Similarly, when the externality effects from the aggregate stocks (public and private) increase, these stocks increase the level of investment specific technological change. However, because agents do not internalize these spillovers from the aggregate stocks, they under-fund capital accumulation relative to the efficient growth rate. To incentivize capital accumulation, the planner sets a low optimal tax on capital income. In the limiting case (when there are no externalities) we show that *equal* factor income taxes always restore the planner's growth rates.

Our framework allows also us to Pareto rank the first best fiscal policy. We show numerically that the departure of the welfare maximizing tax rate from the first best tax policy can be decomposed into 1) the effect because of externalities, and 2) the effect because due to n_2. We show that both production externalities and endogenous ISTC imply departures from the first best policy.

Our paper is related to two strands of the literature on fiscal policy and long run growth in the neoclassical framework. The first literature - started by Barro (1990) and Futagami, Morita, and Shibata (1993) – incorporate a public input – such as public infrastructure – that directly augments production. In Barro (1990), public services are a flow; while in Futagami, Morita, and Shibata (1993), public capital accumulates. However, in the large literature on public capital and its impact on growth spawned by these papers, the public input, whether it is modeled as a flow or a stock, doesn't directly influence the real price of capital goods.[8] Because public capital affects the real price of capital explicitly,

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[8]For instance, in Ott and Turnovsky (2006) - who use the flow of public services to model the public

this means that the public input affects future output through its effect on both future investment specific technological change, as well as future private capital accumulation. Our main methodological contribution is that we merge the public capital/endogenous growth literature with the endogenous investment specific technological change literature. To the best of knowledge, whereas distortionary taxes have been exogenously imposed to correct for externalities in the literature, our model is the first attempt to explain how differences in factor income taxes across countries can be explained by the existence of production externalities.

The rest of the paper proceeds as follows. Section 2 develops the basic model structure followed by characterizing the planner's model, the competitive equilibrium and some numerical experiment under unequal factor income taxes that shows how the magnitude of externalities in the model is crucial to the optimal tax mix. Section 3 concludes.

2   The Model

Consider an economy that is populated by identical representative agents, who at each period t, derive utility from consumption of the final good C_t and leisure $(1 - n_t)$. The term n_t represents the fraction of time spent at time t in employment. The discounted life-time utility, U, of an infinitely lived representative agent is given by

$$U = \sum_{t=0}^{\infty} \beta^t [\log C_t + \log(1 - n_t)]. \tag{1}$$

where $\beta \in (0, 1)$ denotes the period-wise discount factor. There is no population growth in the economy and the total supply of labor for the representative agent at any time t is given by n_t such that

$$n_t \equiv n_{1t} + n_{2t}, \tag{2}$$

where n_{1t} is labor allocated for final goods production and n_{2t} is labor allocated for enhancing investment specific technological change. The representative agent however is not aware that his allocation of labor towards n_{2t} also influences productivity of final goods production.

The final good is therefore produced by a standard production function with capital K_t, n_{1t}, and aggregate n_{2t} entering as an externality, which we denote by $\overline{n}_{2t}$. The key difference is that the planner internalizes the externality from n_2 in direct production, while agents do

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input - and Chen (2006), Fischer and Turnovsky (1998) - who use stock of public capital - the shadow price of private capital is a function of public and private capital.

not. The production function is given by

$$Y_t = \underline{A} K_t^{\alpha} n_{1t}^{1-\alpha} \underbrace{\left(n_{2t}^{1-\alpha}\right)^{\xi}}_{\text{Externality}} \tag{3}$$

where $\underline{A} > 0$ is a scalar that denotes the exogenous level of productivity, $\alpha \in (0,1)$ is the share of output paid to capital, and $\xi > 0$ is the externality parameter capturing the effect that n_2 has on direct production. When $\xi > 0$, the planner internalizes the effect that n_2 has on direct production. When $\xi = 0$, there is no externality from n_2 on the production of the final good. Note, in this framework, as in Huffman (2008) the two labor activities n_{1t} and n_{2t} are assumed to be equally skilled, but are optimally allocated across different activities by households.[9]

Private capital accumulation grows according to the standard law of motion augmented by investment specific technological change,

$$K_{t+1} = (1 - \delta) K_t + I_t Z_t, \tag{4}$$

where $\delta \in [0,1]$ denotes the rate of depreciation of capital and I_t represents the amount of total output allocated towards private investment at time period t. Z_t represents investment-specific technological change. The higher the value of Z_t, the lower is the cost of accumulating capital in the future. Hence Z_t also can be viewed as the inverse of the price of per-unit private capital at time period t. Thus at every period t, Z_t augments investment I_t. $I_t Z_t$ thus represents the effective amount of investment driving capital accumulation in time period $t + 1$.

In addition to labor time deployed by the representative firm towards R&D, the public capital stock, G, plays a crucial role in lowering the price of capital accumulation. Typically, the public input is seen as directly affecting final production – either as a stock or a flow (e.g., see Futagami, Morita, and Shibata (1993), Chen (2006), Fischer and Turnovsky (1997, 1998), and Eicher and Turnovsky (2000)). Instead, we assume that the public input facilitates investment specific technological change. This means that the public input affects future output through future private capital accumulation directly. In the above literature, the public input affects current output directly.

We assume that in every period, public investment is funded by total tax revenue. Public

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[9]Other papers in the literature - such as Reis (2011) - also assume two types of labor affecting production. In Reis (2011), one form of labor is the standard labor input, while the other labor input is entrepreneurial labor.