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**Keywords:** Inflation Tax, Capital Tax Competition, Currency Union

**JEL Classification Codes:** H21, H77, F15

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# 1 Introduction

Although interregional tax competition has been a widely investigated area of research in public economics since Zodrow and Mieszkowski (1986) and Wilson (1986), research focusing on how different monetary regimes affect interregional tax competition, and how monetary policy itself is affected by the tax competition caught surprisingly little attention.

Governments have two broad sources of revenue: Taxation and seignorage. Seignorage is obtained by simply printing money, which can be an inflationary practice under many circumstances. As a result, seignorage imposes a tax on agents' nominal money balances to the degree that it creates inflation, because inflation erodes the purchasing power of nominal money balances. The idea that inflation is not only a monetary problem, but also an element of government finance, is not a new one. According to the public finance view of inflation, pioneered by Phelps (1973), inflation should actually be derived as part of the public finance problem along with other optimal tax rates. The central question of this paper is: Given that inflation is an integral part of government finance, and that governments can use inflation rate as well as capital tax rate as strategical variables in financing a national public good, how will monetary unification affect inflation rate and capital tax rate?

The fundamental argument of this paper is that governments compete in inflation in a similar fashion as they would compete in other conventional taxes, if agents in each country can keep at least some fraction of their savings in a foreign currency and then use their foreign currency holdings to purchase foreign products. Intuition is easy: Competition in inflation will lead to low inflation levels, because a country with high inflation rate will lose its inflation tax base, which is defined as balances held in that country's currency. Each country will end up with low inflation levels in a non-cooperative Nash equilibrium.

Inflation is an important concern in currency unions. As an example, the monetary authority of the Eurozone, European Central Bank (ECB) adapts very strong anti-inflationary policies and is almost desparate to keep its inflation level below 2% annualy. However, taking a closer look at inflation performance of the Eurozone, one observes that the Eurozone is not doing particularly well

compared to similar economies. This paper provides an explanation for the case that a currency union can actually create a higher inflation rate for its members: Due to creation of a currency union, incentives for inflation tax competition will obviously be absent, and a higher inflation rate will prevail across the union. Moreover, this will affect other taxe rates, such as the capital tax rate, as well.

In a model that allows for international trade in goods markets as well as in money markets, interactions of the capital tax rate and the inflation rate are investigated. It is shown that the capital tax rate set by a national government creates a horizontal externality for the other country's national government, and this effect pushes the equilibrium level of capital tax rates in both countries down. A similar effect is present for the inflation rate of the domestic currency chosen by the national central bank. We will call this phenomenon 'inflation tax competition'. Inflation tax competition pushes equilibrium level of inflation rates in both countries down. However, there is a vertical externality created by the interaction between capital taxe rates and inflation rates, which leads to higher capital tax rates in both countries. Equilibrium levels of capital tax and inflation rates depend on which of these opposing effects will dominate. If the two countries form a currency union, then the inflation rate that prevails across the currency union, as determined optimally by the choice of single currency's growth rate by the central bank will be higher than the inflation rate that would prevail in either country under monetary independence. Although inflation rate will be higher, individual countries will choose a lower capital tax rate than under monetary independence.

Capital taxes also play an important role in international policy decisions. Especially, since the capital account liberalization movements of 1970s and 1980s, free trade in foreign currencies has been made possible through free trade in capital assets. As a result, inflation tax competition as it will be discussed in this paper cannot be thought of as being immune to capital market considerations. In this paper, we have a simple capital market that pays an international real interest rate to those who invest in capital. It will be shown that the vertical externality created by capital taxe rates and inflation rates is actually a direct effect of international real interest rate on households' disposable incomes.

With increasing international integration and financial liberalization, foreign currencies, espe-

cially those which yield a more stable return than the domestic currency, occupy some non-trivial fractions of individuals' portfolios. In such a financially integrated environment, governments will find it profitable to provide a strong currency, that is, a currency subject to a lower inflation, and expand the tax base for inflation tax. This is the way two or more governments with independent currencies engage in 'inflation tax competition'.

There is one important remark we need to make here. Data shows that inflation tax makes up a relatively small proportion of government revenues, especially in most of the developed countries. For example, from 1987 to 1996, inflation tax accounted only for 0.44% of all tax revenues in UK, and 1.74% of all tax revenues in Germany. Although inflation tax revenues don't account for too great shares of government revenues, especially in most of the developed countries, the benefits of a strong and stable currency is not limited to increasing the inflation tax revenue only. The actual competition between different currencies is to determine which one will become a reserve currency, which implies control over the international capital markets in the long run, because international capital markets are mainly under control of the supplier of the reserve currency. Our model is too simple to capture all these scenarios, and it is our ongoing project to explain the creation of a reserve currency in a coalition formation setting. We just need to underline at this point that we are aware of the empirical facts about the inflation tax revenues. Hence the inflation tax competition, as it is defined in this paper, can be understood as an analogy to competition among currencies for gaining the trust of international markets.

The main argument of this paper is that when a monetary union is formed between countries who have been competing in inflation rates, the union-wide inflation rate will be higher than what individual countries would have obtained. This is a direct result of cease of inflation tax competition across members of a monetary union. Capital taxes will have to adjust accordingly.

## 2 Literature Review

Capital tax competition literature first focused on horizontal externalities across jurisdictions discussed by Zodrow and Mieszkowski (1986). If the tax base is mobile, then different regions compete

against each other to capture most of the mobile tax base. In equilibrium, overall tax rate will be low. Moreover, since public good provision is based on government revenues, public goods will be undersupplied. This result simply follows from the fact that competing jurisdictions of the same rank will engage in horizontal competition, and an increase in one jurisdiction's tax rate will increase the tax base that is available to other jurisdictions.

Kenn and Kotsogiannis (2002) show that tax competition doesn't have to lead to inefficiently low taxes, and it can lead to high taxes instead, if the competing agents are different layers of the state. That is, the same tax base can be double taxed by two different layers of government (say, by the local government, as well as by the federal government), and in that can equilibrium tax rates will be too high. When vertically connected jurisdictions, such as state and federal governments, compete for a mobile tax base, then each of them will be subject to vertical externalities. That is, an increase in one jurisdiction's tax rate will result in a decrease rather than an increase in the tax base that is available to the other jurisdiction. In most cases horizontal and vertical externalities are found together, and whether the equilibrium tax rates will be too low or too high depends on whether horizontal or vertical externalities dominate. [1]

Another source of vertical externalities is decentralization, as analyzed by Wilson and Janeba (2005). In their model, the mix of horizontal and vertical externalities is determined by the degree of decentralization, and they find that 'in contrast to standard tax competition models, decentralizing the provision of public goods may improve welfare' (p.1211).

Makris (2006) investigates what happens to capital tax rates if countries share a common currency. This paper is close to ours, however we differ in our fundamental assumptions. Makris (2006) assumes that there is only a single composite commodity and there is autarky in money markets. Hence, his model cannot distinguish between the two cases of many countries with many currencies and many countries with a single currency. Our results, as far as effects of single currency on capital tax rates are considered, are in line with Makris (2006), however we allow for trade in money markets, and as a result, we are able to focus on inflation as a strategic variable.

Several papers investigate the strategic interaction of jurisdictional fiscal authorities and mone-

[1] Devereux, Lockwood and Redoano (2007), Lockwood and Makris (2006) provide empirical evidence that support the theory of vertical tax competition, and how it compares to the effects of the horizontal tax competition.

tary authority in a monetary union. They reach different results depending on specific assumptions they make. Cooper and Kempf (2003) consider a two world country in an overlapping generations model, where agents need to accumulate foreign currency in the first period if they want to consume foreign goods in the second period. Such a cash constraint imposed by both countries creates an opportunity for both governments to export their inflation to the other country. When these countries are in a monetary union, no such cash constraints will be available, hence there will optimally be no inflation. Bottazzi and Manasse (2002) show that, when the monetary authority of the monetary union cannot commit to a lump-sum redistribution of seignorage, then excessive inflation will result. Their model, however, doesn't incorporate any trade relations.

It is not trivial to bring in money into the canonical tax competition model of Zodrow and Mieszkowski (1986). Makris (2006) does so by employing a utility function where money is an argument and provides positive marginal utility. Introducing money in the utility function can be justified by the underlying assumption that there exist frictions in the money market. Actually, Feenstra (1986) shows that there exists a functional equivalence between having money as an argument in the utility function and introducing liquidity costs in households' budget constraints. Such frictions, however, don't play a crucial role for our model, which focuses on transactions role of money. The very reason why households hold money constitutes an important factor for understanding how exactly the competition in inflation tax works. As a result, we need to clarify not only what the money demand is, but also why households hold money. As Ostroy and Starr (1990) discuss it in great detail, the transactions role of money cannot be separated from its role as the store of value. For purposes of this study, the demand for money should emerge as a direct result of these two functions of money.

Sibert and Liu (1998) present a model where central banks of home and foreign countries act like providers of differentiated goods in a Bertrand model. They show that when two currencies can be substituted for one another, money growth can either be too high or too low depending on how substitutable they are. In our model, we assume perfect substitutability between currencies, however we also assume that households are perfectly informed about central bank policies, so that we don't obtain a race to the bottom in inflation tax competition.

There is a significant portion of literature on currency unions, claiming that establishment of currency union will lower the optimal inflation rate for its members. Cooper and Kempf (2003), Sibert (1992), Cardarelli and Vidal (1999) are examples of this view. These papers either ignore the vertical externalities created by interactions of inflation and other taxes, or in their models, there are too strong assumptions which ensure that a country will have enough incentive to export its inflation tax. That is, in a cash in advance model, where public good is financed by goverment revenues, inflation tax is a good source of income, because altough it taxes foreigners who are holding domestic currency, its benefits (that is, public good provision) are not shared with foreigners. In our paper, we stress the fact that foreigners may abandon the domestic currency, if it is too costly to hold. To the best of our knowledge, this paper is the first investigation of horizontal and vertical tax externalities that are borne by interactions of capital taxes and inflation rates under a regime of independent but tradable currencies and under a regime of a single currency.

# 3 The Model

There are two countries, country 1 and country 2, and each country is populated by a representative household. Each country has a national government that decides at which rate to tax domestically employed capital. Trade of goods and money takes places at the central exchange of each country. Central exchanges of country 1 and country 2 issue their own national fiat currencies (currency 1 and currency 2, respectively). Seignorage revenue is transferred from the central exchange to the national government. Seignorage revenue and revenue from capital taxation are used in financing a national public good. Both countries impose a local currency constraint: Country specific private consumption goods can be bought only using domestic currency.

## 3.1 Households

Each household is endowed with a mobile factor, capital, and an immobile factor, labor. Amount of capital endowed to a household in either country is $k$. Endowment of labor for either household is one unit, and it is supplied inelastically.

This is a two period model. In the first period, households receive labor and capital income, and decide what proportion of their income they want to keep in currency 1, and what proportion in currency 2. In second period, households use their currency 1 and currency 2 holdings to purchase private consumption goods of country 1 and country 2, respectively.

Firm located in country $i$ will be called firm $i$, and private consumption good produced in country $i$ will be called good $i$, where $i = \{1, 2\}$. Demand for good $i$ by the household in country $j$ is denoted by $x^{i,j}$. National government of country $i$ supplies a national public good $g^i$. Preferences of the household in country $i$ is given by:

$$u^i\left(x^{i,i}, x^{i,j}\right) + v^i\left(g^i\right) \tag{1}$$

Household's utility function has standard properties: $u(0,0) = 0,\ u_1 > 0,\ u_2 > 0,\ u_{11} < 0,\ u_{22} < 0$ (where subscripts denote partial derivatives), and $v(0) = 0,\ v' > 0,\ v'' < 0$.

Budget constraint of the household in country $i$ for first period is given as:

$$p_i w_i + p_i r_i k = m^{i,i} + e_{ij} m^{i,j} \tag{2}$$

and for second period:

$$x^{i,i} = \frac{m^{i,i}}{p_i'}, \quad x^{i,j} = \frac{m^{i,j}}{p_j'} \tag{3}$$

Price of good $i$ in the first period is denoted by $p_i$, and $p_i'$ is price of good $i$ in the second period. $w_i$ is real wage income earned by household $i$, $r_i$ is the real return to capital when it is sold to firm $i$, $e_{ij}$ is the nominal exchange rate for currency $j$ in terms of currency $i$, and finally, $m^{i,j}$ denotes nominal holdings of currency $j$ by household $i$.

First period budget constraint shows that nominal holdings of money balances in terms of currency $i$ should be equal to household's income expressed in terms of currency $i$. Second period budget constraint shows demand for consumption goods.

### 3.2 Production

Production in both countries is performed by perfectly competitive firms. Capital is perfectly mobile across the two countries, and as a result, whether household $i$ decides to sent its capital to firm 1 or firm 2, capital has to earn the same marginal income in either country. A non-arbitrage condition can be formulated as: $p_i r_i = e_{ij} p_j r_j$. Law of one price holds, and there are no arbitrage opportunities. Thus an international real interest rate of $\rho$ prevails in the international capital market. Capital employed by a firm (capital per labor) will be denoted by $k_i$.

**Definition 1** *Production technology in country $i = \{1, 2\}$ is subject to constant returns to scale, and it is given by a twice differentiable production function $f(k_i)$, which satisfies $f(0) = 0$, $f' > 0$, and $f'' < 0$.*

Firm $i$ produces a total output of $f(k_i)$, and it pays $r_i k_i$ as rent on capital, $w_i$ as labor income, $t_i k_i$ as tax on capital. Thus the first order condition for the profit maximization problem of firm $i$ yields:

$$f'(k_i) = (r_i + t_i) \tag{4}$$

As a result, optimum level of capital employed by a firm through international capital market is a function of real interest rate and domestic capital tax rate:

$$k_i = k(r_i + t_i) \tag{5}$$

Income to immobile factor, namely labor, is given by

$$w_i \equiv w(r_i + t_i) = f(k(r_i + t_i)) - f'(k(r_i + t_i))\, k(r_i + t_i) \tag{6}$$

meaning that labor income is a function of the marginal cost of capital.

Households receive labor and capital income at the end of the first period, and their disposable income will be denoted by $y(r_i, t_i)$. Each household uses its disposable income to purchase currency 1 and currency 2:

$$y\left(r_i, t_i\right) \equiv p_i w\left(r_i + t_i\right) + p_i r_i k = m^{i,i} + e_{i,j} m^{i,j} \tag{7}$$

The basic question a household faces at the end of the first period is, what fraction of disposable income do they want to hold in currency 1, and what fraction in currency 2. Demand for currency 1 and currency 2 are derived demand from demand for good 1 and good 2, respectively. Given its currency 1 and currency 2 stocks, household $i$ will be able to purchase $x^{i,i} = \frac{m^{i,i}}{p_i'}$ and $x^{i,j} = \frac{m^{i,j}}{p_j'}$ units of good $i$ and $j$, respectively.

### 3.3 Monetary Policy

Each country has a central exchange that acts as the market place for domestically produced private good, for currency exchange, and as the sole issuer of national currency. Real revenue from money creation is transferred from the central exchange of a country to the government of that same country. Revenue from money creation is called seignorage[2].

In this model, we will define money as the commodity with the highest 'saleableness', following the definition of Menger (1894), and we will separate the periods of buying and selling in goods markets so that money will have a strictly positive value in equilibrium, which builds on the general equilibrium model introduced by Magill and Quinzii (1992). At the end of the first period, individuals bring their disposable incomes, which is kept in terms of country specific private consumption good, to the central exchanges of country 1 and country 2 in order to acquire currency 1 and currency 2, respectively. In either of the two central exchanges, households exchange their disposable incomes for fiat currency issued by the respective central exchange. Let $m^{i,j}$ denote the amount of country $i$ currency demanded by the household in country $j$. The household in country 1 decides what fraction of its income to keep in country 1 currency, $m^{1,1}$, and sells this fraction to the central bank of country 1 in exchange for country 1 currency. It sells the rest of its disposable income to the central bank of country 2 in exchange for country 2 currency, $m^{1,2}$. Same applies to the household in country 2. Both households use their currency holdings to buy private con-

[2]Since there is no economic growth in this model, there won't be any difference between seignorage and inflation tax.

sumption goods of country 1 and country 2 in the second period. Thus total monetary holdings of household in country $i$ is given by $\left(m^{i,i} + e_{ij}m^{i,j}\right)$, measured in currency $i$.Total stock (across the two countries) of currency $i$ is given by $m^i = m^{i,i} + m^{j,i}$.

In the second period, both households buy country 1 and country 2 private consumption goods from the central exchanges of country 1 and country 2, respectively. Central exchange in either country decide at what rate they want to increase the monetary base, which is simply the money they created during the first period by buying households' disposable incomes. Central exchange of country $i$ decides to expand the monetary base by a ratio of $\sigma_i$. Hence the seignorage revenue of the central bank in country $i$ is given by $\sigma_i \left(m^{i,i} + m^{j,i}\right)$. Central exchange of country $i$ uses the newly printed currencies to purchase some the domestic private consumption good, and transfers it to the local government, as the inflation tax revenue.

Since we will mention some basic characteristics of an equilibrium, we need to define an equilibrium first.

**Definition 2** *Equilibrium is defined for a given set of prices* $(p_1, p_2)$ *as a vector of* $\left(\phi_i, \phi_j, \pi_i, \pi_j, t_i, t_j, e_{ij}\right)$, *where shares of domestic currency holdings in total currency holdings of households* $(\phi)$, *inflation rates* $(\pi)$, *capital tax rates* $(t)$, *and exchange rate between currencies* $(e)$ *clear all markets (2 goods markets, 2 money markets, and an exchange rate market), and no household, no national government, and no central bank can be better off by deviating.*

Both central exchanges determine the growth rate of their national currencies. However, by doing so, in equilibrium, they are determining the domestic inflation rate.

**Lemma 1** *In both countries, choosing the growth rate of national currencies, denoted by* $\sigma_i$ *for* $i = \{1, 2\}$, *is equivalent to choosing the domestic inflation rate,* $\pi_i$, *in equilibrium.*

**Proof.** Ratio of currency $i$ in the second period to currency $i$ in the first period is given by

$$\frac{\left(m^{i,i} + m^{j,i}\right) + \sigma_i \left(m^{i,i} + m^{j,i}\right)}{\left(m^{i,i} + m^{j,i}\right)} = (1 + \sigma_i)$$

At the end of first period, we have

$$p_i \left( f\left(k_i\right) - t_i k_i \right) = m^{i,i} + m^{j,i}$$

At the beginning of the second period, we have

$$p_i' \left( f\left(k_i\right) - t_i k_i \right) = \left(1 + \sigma_i\right) \left( m^{i,i} + m^{j,i} \right)$$

Hence,

$$\frac{\left(1 + \sigma_i\right) \left( m^{i,i} + m^{j,i} \right)}{p_i'} = \frac{m^{i,i} + m^{j,i}}{p_i}$$

Using the definition of inflation rate $\pi_i = \frac{p_i' - p_i}{p_i}$, we conclude that $\pi_i = \sigma_i$. ■

It is crucial to realize that growth of money will necessarily become inflation, because there is no economic growth in this model. Although monetary policy tool is the growth rate of money, no real growth implies that money growth will turn into inflation, hence central bank sets the domestic inflation rate when it chooses the growth rate domestic money supply.

In both countries, the second period money creation by the central exchange is nothing but a tax on households' wealth, because money creation in second period erodes households' currencies' purchasing power.

When central exchanges transfer the real revenue from second period money creation to their national governments, national governments use the inflation tax revenue together with capital tax revenue in financing a national public good. National public good supply in country $i$ is given by: $g_i = t_i k_i + \pi_i \left( m^{i,i} + m^{j,i} \right)$, where $\pi_i$ denotes the inflation rate in country $i$, and it is defined by $\pi_i = \frac{p_i' - p_i}{p_i}$, where $p_i'$ denoted price level in country $i$ in the second period. For simplicity, and without loss of generality, we can assume that the central exchange in country $i$ decides to issue one unit of its national currency in order to buy households' disposible income.

As it has widely been studied in international economics literature, once individuals' monetary holdings are determined, central banks have every incentive to use inflation tax excessively. As Hamada (1976) has shown, monetary expansion can take on the nature of public bad, and lead to

high inflation rates in both countries. At this point it is useful for purposes of this paper to assume that central exchanges can credibly commit to a money growth rate. That is, both households are well informed about what the growth rate of money (hence inflation) is going to be in the second period, and they adjust their currency holdings accordingly. Once households sold their disposable income, central exchanges do not alter their pre-announced money growth rates.

At the beginning of the second period, the central exchange of country $i$ issues a total stock of new currencies that has $\sigma_i \left(m^{i,i} + m^{j,i}\right)$ in nominal value. Since $\sigma_i = \pi_i$ real currency holdings of households in both countries will depreciate by $(1 + \pi_i)$. The real revenue from second period money creation, $\pi_i \left(m^{i,i} + m^{j,i}\right)$ is then transferred to the national government.

### 3.4 National Welfare

National policies consist of capital tax rate and money growth rate. As explained above, we will simply refer to inflation rate instead of the money growth rate in what follows. Government chooses the capital tax rate which must be paid by the national firm to the national government, at a constant rate per capital it employs. Central exchange chooses the inflation rate, and transfers the inflation tax revenue to the national government. National government supplies the nation with a public good that is produced by a linear technology using capital tax and inflation tax revenues. In both countries, the government as well as the central exchange are benevolent, that is, their objective is to maximize their citizens' welfare.

Capital market equilibrium is given by $\sum_{i=1}^{2} k\left(r + t_i\right) = 2\Omega$. Total capital endowment of home and foreign countries is given by $2\Omega$, and total demand for capital by firms has to be equal to total capital endowment so that the international capital market is in equilibrium. Capital market equilibrium makes it easy to see that real interest rate is necessarily a function of home and foreign capital tax rates, $r = r\left(t_1, t_2\right)$. Moreover, in a symmetric equilibrium we have $t = t_1 = t_2$, and as a result, we have $r = r\left(t\right)$, with $\frac{dr}{dt} = r' = -\frac{1}{2}$.

Considering the equilibrium in currency $i$ market, total supply of currency $i$ in first period is determined by what fraction of their disposable both households want to keep in currency $i$. Let $\phi_i$ denote the fraction of country $i$ household's disposable income exchanged for currency $i$ at the

central exchange of country $i$, and fraction of country $j$ household's disposable income exchanged for currency $i$ is denoted by $\left(1-\phi_j\right)$, so that we have

$$\phi_i y\left(r\left(t_i,t_j\right),t_i\right)+\left(1-\phi_j\right)y\left(r\left(t_i,t_j\right),t_j\right)=m^{i,i}+m^{j,i} \tag{8}$$

At the end of money creation process in the first period, the two central exchanges swap their holdings foreign currency which has been delivered by household in pursue of exchanging some fraction of their currency holdings.

**Lemma 2** *In equilibrium, there will be a unique exchange rate. Indeterminacy of exchange rate will only be the case, when currency $i$ is held only in country $i$, for $i \in \{1,2\}$.*

**Proof.** At the end of first period, central exchange of country $i$ owns private consumption good of country $j$, sold to it by the household from country $j$. The private consumption good produced by country $j$ and owned by the central exchange of country $i$ is equivalent to $\left(1-\phi_j\right)y\left(r\left(t_i,t_j\right),t_j\right)$ in real value. When the two central exchanges swap those foreign private consumption good holdings, they establish an equilibrium exchange rate as:

$$e_{i,j}=\frac{\left(1-\phi_i\right)y\left(r\left(t_i,t_j\right),t_i\right)}{\left(1-\phi_j\right)y\left(r\left(t_i,t_j\right),t_j\right)} \tag{9}$$

which has a strictly positive and unique value for $y\left(r\left(t_i,t_j\right),t_1\right)>0$, $y\left(r\left(t_i,t_j\right),t_2\right)>0$, $\phi_1\in(0,1)$, and $\phi_2\in(0,1)$. It is important to note that however that if $(\phi_1,\phi_2)=(1,1)$, then exchange is undeterminate, in the sense of Kareken and Wallace (1981). ■

Although money growth rates, and thus inflation rates don't play a role in the above statement, we need to alter money demand to include the perfect information of second period's inflation rate. This doesn't change the fundamental lesson of the above lemma, however money demand becomes equivalent to demand for country specific consumption goods. Since we will deal with symmetric equilibria, the following lemma will be useful:

**Lemma 3** *In a symmetric equilibrium, when both central exchanges set the nominal price of their national output at 1 unit of local currency, then we have $e_{ij}=1$.*

In a symmetric equilibrium, the household in country $i$ will hold some fraction $\phi_i$ of its disposable income in currency $i$, and some fraction, namely $(1-\phi_i)$ in currency $j$, so that we have:

$$x^{i,i} = \frac{\phi_i y\left(r\left(t_i,t_j\right),t_i\right)}{1+\pi_i}, \quad x^{i,j} = \frac{\left(1-\phi_i\right) y\left(r\left(t_i,t_j\right),t_i\right)}{1+\pi_j} \tag{10}$$

Since the household in country $i$ will use its currency $i$ and currency $j$ balances, denoted by $m^{i,i}$ and $m^{i,j}$, to purchase country $i$ and country $j$ private consumption goods $x^{i,i}$ and $x^{i,j}$, respectively, and since there is perfect foresight (or central bank's perfect commitment to announced money growth rate) this necessarily leads to:

$$\frac{m^{i,i}}{p_i'} = x^{i,i} = \frac{\phi_i y\left(r\left(t_i,t_j\right),t_i\right)}{1+\pi_i}, \quad \frac{m^{i,j}}{p_j'} = x^{i,j} = \frac{\left(1-\phi_i\right) y\left(r\left(t_i,t_j\right),t_i\right)}{1+\pi_j} \tag{11}$$

The optimization problem of household $i$ is:

$$\phi_i = \arg\max \; u\left(\frac{\phi_i y\left(r\left(t_i,t_j\right),t_i\right)}{1+\pi_i}, \frac{\left(1-\phi_i\right) y\left(r\left(t_i,t_j\right),t_i\right)}{1+\pi_j}\right) \tag{12}$$

First order condition of household's optimal choice of $\phi_i$ yields in a symmetric equilibrium:

$$u_1\left(x^{i,i},x^{i,j}\right) = \frac{1+\pi_i}{1+\pi_j} u_2\left(x^{i,i},x^{i,j}\right) \tag{13}$$

By the envelope theorem,

$$\phi_i = \phi_i\left(\pi_i,\pi_j\right), \quad and \quad \frac{\partial \phi_i}{\partial \pi_i} < 0, \frac{\partial \phi_i}{\partial \pi_j} > 0 \tag{14}$$

This leads to the following total demand function for currency $i$, denoted by $m^i$:

$$m^{i,i} + m^{j,i} = \phi_i y\left(r\left(t_i,t_j\right),t_i\right) + \left(1-\phi_j\right) y\left(r\left(t_i,t_j\right),t_j\right) = m^i\left(\pi_1,\pi_2,t_1,t_2\right) \tag{15}$$

The following lemma will be useful in analyzing the effects of marginal changes in capital tax rates and inflation rates in either or both countries. The lemma's proof is provided in the appendix.

**Lemma 4** *Demand for currency $i$ is given by $m^i = m^i(\pi_i, \pi_j, t_i, t_j)$, for which we have:*

$$\frac{\partial m^i}{\partial \pi_i} < 0, \frac{\partial m^i}{\partial \pi_j} > 0, \frac{\partial m^i}{\partial t_i} < 0, \frac{\partial m^i}{\partial t_j} < 0 \tag{16}$$

**Proof.** Recall that $m^i = m^i(\pi_i, \pi_j, t_i, t_j) = m^i(\phi_i(\pi_i, \pi_j), y(r(t_i, t_j), t_i))$, and observe that $\frac{\partial m^i}{\partial \phi_i} > 0$, $\frac{\partial \phi_i}{\partial \pi_i} < 0$, $\frac{\partial \phi_i}{\partial \pi_i} > 0$, $\frac{\partial m^i}{\partial y} > 0$, $\frac{\partial y}{\partial r} > 0$, $\frac{\partial y}{\partial t_i} < 0$, $\frac{\partial r}{\partial t_i} < 0$, $\frac{\partial r}{\partial t_j} < 0$ Using the envelope theorem, we obtain: $\frac{\partial m^i}{\partial \pi_i} = \frac{\partial m^i}{\partial \phi_i}\frac{\partial \phi_i}{\partial \pi_i} < 0$, $\frac{\partial m^i}{\partial \pi_j} = \frac{\partial m^i}{\partial \phi_i}\frac{\partial \phi_i}{\partial \pi_j} > 0$, $\frac{\partial m^i}{\partial t_i} = \frac{\partial m^i}{\partial y}\frac{\partial y}{\partial r}\frac{\partial r}{\partial t_i} + \frac{\partial m^i}{\partial y}\frac{\partial y}{\partial t_i} < 0$, $\frac{\partial m^i}{\partial t_j} = \frac{\partial m^i}{\partial y}\frac{\partial y}{\partial r}\frac{\partial r}{\partial t_1} < 0$. ■

Simplifying, national welfare of country $i$ depends on capital taxes and inflation rates of both countries:

$$W_i(t_i, t_j, \pi_i, \pi_j) = u\left[\frac{\phi_i(\pi_i, \pi_j)\, y(r(t_i, t_j), t_i)}{1+\pi_i}, \frac{(1-\phi_i(\pi_i, \pi_j))\, y(r(t_i, t_j), t_i)}{1+\pi_j}\right] + v[g_i] \tag{17}$$

where public good in country $i$ is given by:

$$\begin{aligned} g_i &= t_i k(r(t_i, t_j) + t_i) + \\ &\quad +\pi_i\left(m^{i,i}(\phi_i(\pi_i, \pi_j), y(r(t_i, t_j), t_i)) + m^{j,i}\left(\left(1-\phi_j(\pi_i, \pi_j)\right), y(r(t_i, t_j), t_j)\right)\right) \end{aligned} \tag{18}$$

In the above equation, it is clearly shown that the public good is financed by two sources: capital tax revenue and inflation tax revenue. National government of country $i$ has a capital tax revenue of:

$$t_i k(r(t_i, t_j) + t_i) \tag{19}$$

and the central bank of country 1 transfers its inflation tax revenue to the national government, which is given by:

$$\pi_i\left(m^{i,i}(\phi_i(\pi_i, \pi_j), y(r(t_i, t_j), t_i)) + m^{j,i}\left(\left(1-\phi_j(\pi_i, \pi_j)\right), y(r(t_i, t_j), t_j)\right)\right) \tag{20}$$

# 4 Seignorage and Capital Taxation

How inflation and capital taxes interact under different monetary regimes will be discussed in this section.

There are two monetary regimes: Either a country has its own national currency, or it forms a currency union with the other country. Independent national currency is governed by the national central bank. Real revenue from money creation is transferred to national government where it is used for financing a national public good. This regime will be called "monetary independence". When country 1 and country 2 form a currency union, there will be a single central bank of the currency union. Central bank of the currency union is also benevolent, and real revenue from money creation will be equally distributed between the two national governments. This regime will be called "currency union".

Competition in inflation tax exists only under the regime of monetary independence, and it is lost with the creation of a currency union. Although vertical externalities between the capital tax rate and the inflation tax rate, or equivalently, the inflation rate, don't change their nature from one regime to the other, the horizontal externalities are affected directly by the creation of a currency union. It is due to the horizontal externalities between the two countries that keeps the inflation rates in both countries down. However, with creation of a currency union, there will be no competition in inflation, hence the central bank of the currency union will be able to internalize the horizontal externalities, and create a higher level of inflation. Hence, lack of competition in inflation tax is not necessarily an adverse affect. This result is pretty intuitive, because otherwise, the two countries wouldn't create a currency union.

Although central banks are benevolent and they transfer their real revenues to national governments, this doesn't necessarily mean that central banks are under control of national governments. We will assume in this section that central banks, whether national or currency union wide, are independent in the sense that money growth rate and capital tax rate are chosen non-cooperatively by different authorities. Policy vector that consists of money growth rate (or equivalently, inflation rate) and capital tax rate, is the Nash equilibrium of non-cooperative game between central bank

and government.

### 4.1 Seignorage and Capital Tax Revenue under National Currencies

Welfare of household in country $i$ under monetary independence is given by (16). National government as well as the central exchange of country $i$ are benevolent, hence they aim to maximize the welfare of the representative household living in country $i$. For this purpose, central exchange in country $i$ solves $\frac{\partial W_i}{\partial \pi_i} = 0$ for given policy variables of countries 1 and 2 $(t_1, \pi_2, t_2)$, and the government solves $\frac{\partial W}{\partial t_i} = 0$ for given policy variables of countries 1 and 2 $(\pi_1, \pi_2, t_2)$.

Aim of this paper is to compare small changes in domestic inflation rate and capital tax rate to their non-cooperative equilibrium levels, for this purpose, we will focus on marginal changes in the welfare function of country $i$ with respect to inflation rate and capital tax rate. In this section we will investigate how a small change in inflation rate and capital tax rate affect the national welfare, and in the next section where we focus on the case of a currency union, we will take our findings under monetary independence as a benchmark, and compare our findings under currency union to those under monetary independence.

The central exchange of country $i$ takes foreign policy variables which are inflation rate and capital tax rate of country $j$, $(\pi_j, t_j)$, as well as the capital tax rate set by the national government of country $i$, $t_i$, as given, and maximizes national welfare of country $i$ by solving the following first order condition:

$$\begin{aligned} \frac{\partial W_i}{\partial \pi_i} &= \left(\frac{y_i}{1+\pi_i}\frac{\partial \phi_i}{\partial \pi_i} - \frac{\phi_i y_i}{(1+\pi_i)^2}\right) u_1 - \left(\frac{y_i}{1+\pi_j}\frac{\partial \phi_i}{\partial \pi_i}\right) u_2 + \\ &\quad + v'\left(m^i + \pi_i\left(\frac{\partial \phi_i}{\partial \pi_i} y_i - \frac{\partial \phi_j}{\partial \pi_i} y_j\right)\right) \end{aligned} \tag{21}$$

Solving for $\frac{\partial W_i}{\partial \pi_i} = 0$ yields the Nash inflation tax level for country $i$, and rearranging, we obtain

$$MRS^i_{g,x} = \frac{1}{(1+\pi_i)\left(\frac{1}{\phi_i} + \varepsilon^i_{\pi_i} - \varepsilon^j_{\pi_i}\right)} \tag{22}$$

where $MRS^i_{g,x}$ is the marginal rate of substitution of public for private good in country $i$. $\varepsilon^i_{\pi_i}$ and $\varepsilon^j_{\pi_i}$ are country $i$ inflation elasticities of demand for currency $i$ and demand for currency $j$, respectively.

Horizontal externality of domestic inflation is evident in the above equation. As the inflation rate associated with currency $i$ increases, this will affect not only currency holdings of the representative household in country $i$, but also currency holding decision of the household in country $j$ is affected. As a result, inflation tax revenue of central exchange in country $i$ erodes faster than it would erode in case of autarky. This is the horizontal externality associated with domestic inflation rates that leads to lower inflation rates in both countries. Hence the very idea of the "inflation tax competition" is embodied in this response as described above.

National government of country $i$ takes foreign policy variables as well as the inflation rate set by the central exchange of country $i$ as given, and maximizes national welfare by choosing a capital tax rate. The first order condition for the of national government's optimization problem country $i$ yields:

$$\begin{aligned}\frac{\partial W_i}{\partial t_i} &= \phi_i\left(\frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial r}\frac{\partial r}{\partial t_i}+\frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial t_i}\right)u_1+\\ &+\left(1-\phi_i\right)\left(\frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial r}\frac{\partial r}{\partial t_i}+\frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial t_i}\right)u_2+\\ &+\left(\left(\frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial r}\frac{\partial r}{\partial t_i}+\frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial t_i}\right)+\frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial r}\frac{\partial r}{\partial t_i}\right)\frac{\partial m^{i,i}}{\partial y}v'\end{aligned} \tag{23}$$

Solving for $\frac{\partial W_i}{\partial t_i}=0$ yields the Nash capital tax level for country $i$, and rearranging we obtain

$$\frac{v'}{u_1}=MRS^i_{g,x}=\frac{1}{\left(1+\pi_i\right)\left(1+\frac{1}{2}\varepsilon^i_k+\pi_i\phi_i\right)} \tag{24}$$

where $\varepsilon^i_k$ is the capital tax elasticity of demand for capital in country $i$.

Horizontal externality created by non-cooperative choice of the capital tax rate in country $i$ manifests itself in its effect on international real interest rate, $r$. We have shown in previous section that in a symmetrical equilibrium for capital tax rates, an increase in the capital tax rate of country

$i$ will decrease international real interest rate by $\left(-\frac{1}{2}\right)$. As a result, an increase in the capital tax rate of country $i$ not only decreases representative household's disposable income in country $i$, it also decreases the real value of the disposable income of household in country $j$. This is the very link that gives rise to a vertical externality between capital tax rate and inflation rate, captured by the term $\left(\frac{\partial m^{i,i}}{\partial y}\right)$ in (21).

The optimal choice of the capital tax rate of country $i$ can be separated in two: Horizontal externality due to capital tax competition between the two countries, and the vertical externality created by the existance of the inflation tax. Horizontal externality is represented by the following term:

$$\phi_i \left( \frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial r}\frac{\partial r}{\partial t_i} + \frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial t_i} \right) u_1 + (1-\phi_i) \left( \frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial r}\frac{\partial r}{\partial t_i} + \frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial t_i} \right) \tag{25}$$

Vertical externality created by the existance of the inflation tax is represented by:

$$\left( \left( \frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial r}\frac{\partial r}{\partial t_i} + \frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial t_i} \right) + \frac{\partial y\left(r\left(t_i,t_j\right),t_i\right)}{\partial r}\frac{\partial r}{\partial t_i} \right) \frac{\partial m^{i,i}}{\partial y} v' \tag{26}$$

As the capital tax rate of country $i$ increases , country $i$ household's demand for currency decreases. This is a direct result of the decrease in household's disposable income.

### 4.2 Seignorage and Capital Tax Revenue under a Single Currency

In this subsection, we will investigate how the case of a currency union differs from that of monetary independence. When country 1 and country 2 form a currency union, they abandon their national currencies as well as their national central banks, and there will be only one central bank that issues the common currency of the currency union.

There will be a single central exchange when a currency union is formed, and it will serve in the same manner just like national central exchanges did under monetary independence. The two households in both countries sell their disposable income to the central exchange of the currency union in exchange for common currency, and in the second period they purchase private consump-

tion goods using the common currency. Central exchange of the currency union chooses a money growth rate (necessarily same as the inflation rate) for the common currency in order to maximize the joint welfare of both countries, and it distributes real revenue from currency creation equally to the national governments of country 1 and country 2.

National governments still retain their authority of choosing a capital tax rate for the domestic use of capital. National governments' objective is to maximize the welfare of their citizen household. National governments' objective function is given by

$$W_i^C = u\left(x^{i,i}\left(t_i, t_j, \pi^c\right),\ x^{i,j}\left(t_i, t_j, \pi^c\right)\right) + v\left[t_i k\left(r\left(t_i, t_j\right) + t_i\right) + \frac{1}{2}\pi^c m^c\right] \tag{27}$$

where $m^c = y\left(r\left(t_i, t_j\right), t_i\right) + y\left(r\left(t_i, t_j\right), t_j\right)$

The first order condition of national government's optimization problem in country $i$ is not very different from the case of monetary independence, and it is given by:

$$\begin{aligned}\frac{\partial W_i^c}{\partial t_i} &= \left(\frac{\partial y\left(r\left(t_i, t_j\right), t_i\right)}{\partial r}\frac{\partial r}{\partial t_i} + \frac{\partial y\left(r\left(t_i, t_j\right), t_i\right)}{\partial t_i}\right)\left(u_1 + u_2\right) + \\ &+\frac{1}{2}\left(\left(\frac{\partial y\left(r\left(t_i, t_j\right), t_i\right)}{\partial r}\frac{\partial r}{\partial t_i} + \frac{\partial y\left(r\left(t_i, t_j\right), t_i\right)}{\partial t_i}\right) + \frac{\partial y\left(r\left(t_i, t_j\right), t_i\right)}{\partial r}\frac{\partial r}{\partial t_i}\right)\frac{\partial m^c}{\partial y}v'\end{aligned} \tag{28}$$

where $W_i^c$ denotes the welfare of country $i$ under currency union, and $m^c$ denoted the aggregate demand for the common currency in both countries, and equilibrium tax rate is found by solving $\frac{\partial W_i^c}{\partial t_i} = 0$. Rearranging, we obtain the marginal rate of substitution of public for private good in country $i$ as follows

$$MRS_{g,x}^i = \frac{1}{\left(1 + \pi^c\right)\left(1 + \varepsilon_k^i + \pi^c\right)} \tag{29}$$

The only difference between (23) and (28) is that in (28) vertical externality between domestic tax rate and inflation rate has greater effect on country 2, because the common inflation rate is affected through the term $\left(\frac{\partial m^c}{\partial y}\right)$.

Central bank of currency union maximizes the joint welfare of both countries, and solves the following first order condition:

$$\sum_{j\in\{1,2\}} \frac{\partial W_j^c}{\partial \pi^c} = 2\left(u_1+u_2\right)\frac{\partial m^c}{\partial \pi^c} + \left(m^c + \pi^c \frac{\partial m^c}{\partial \pi^c}\right) v' = 0 \tag{30}$$

which yields

$$MRS_{g,x}^i = \frac{1}{(1+\pi^c)} \tag{31}$$

Comparing (21) to (30), one observes that non-cooperative inflation rate under currency union has to be higher than that under monetary independence. Intuition is simple: Central bank of the currency union doesn't face an as severe threat of losing its tax base, which is demand for its monetary base, as a national central bank faces, when it increases the inflation rate associated with its currency. Hence this is inflation tax competition, and this very simple model demonstrates how inflation tax competition can yield lower inflation rates in line with the arguments of Hayek (1976) favoring monetary competition.

**Theorem 1** *Under currency union, public good provision will be sub-optimally high.*

Efficient provision of public good will be satisfied when $MRS_{g,x}^i = 1$. This is only true when $\pi^c = 0$, which cannot be the case. Hence, we have $MRS_{g,x}^i < 1$, and the level of public good provision under a currency union is sub-optimally high.

Moreover, under currency union we have: $-\varepsilon_k^i = \pi^c$

**Theorem 2** *Inflation rate associated with the common currency of the currency union will be higher than inflation rates that exist under monetary independence.*

**Proof.** Suppose that in a symmetric equilibrium, for any given capital tax rate in country 1 and country 2, the optimal inflation rate under monetary independence is higher than that under common currency, namely $\pi_i^* \geq \pi^{c*}$ for $i \in \{1,2\}$. Substituting these inflation rates into the first order conditions of the optimization problem of central exchange in country $i$ under monetary

independence, and into that of central exchange of the currency union, the following must be true under any capital tax rates: $\frac{1}{2}\left(m^c + \pi^{c*}\frac{\partial m^c}{\partial \pi^c}\right) > \left(\left(m^{i,i} + m^{j,i}\right) + \pi_i^*\left(\frac{\partial m^{i,i}}{\partial \pi_i} + \frac{\partial m^{j,i}}{\partial \pi_i}\right)\right)$

This requires the following to hold: $v'\left(g_i\left(t_i^c, t_j^c, \pi^{c*}\right)\right) < v'\left(g_i\left(t_i, t_j, \pi_i^*, \pi_j^*\right)\right)$, and hence $g_i\left(t_i^c, t_j^c, \pi^{c*}\right) > g_i\left(t_i, t_j, \pi_i^*, \pi_j^*\right)$. This, however implies that $t_i < t_i^c$ which is a contradiction. Hence $\pi_i^* < \pi^{c*}$ for $i \in \{1, 2\}$. ■

**Theorem 3** *Inflation elasticities of national currencies determine whether capital taxes will be higher or lower under currency union.*

**Proof.** First order conditions obtained from optimization problems of government and central exchange under monetary independence yield:

$MRS_{g,x}^i = \frac{1}{(1+\pi_i)\left(1+\frac{1}{2}\varepsilon_k^i + \pi_i\phi_i\right)}$ and $MRS_{g,x}^i = \frac{1}{(1+\pi_i)\left(\frac{1}{\phi_i} + \varepsilon_{\pi_i}^i - \varepsilon_{\pi_i}^j\right)}$

This yields: $\frac{1}{2}\varepsilon_k^i\left(t_i^*\right) = \frac{1-\phi_i}{\phi_i} + \varepsilon_{\pi_i}^i - \varepsilon_{\pi_i}^j - \pi_i^*\phi_i$

Suppose we increase $\pi_i$ to $\pi^c$. Then we have:

$\Delta\varepsilon_k^i\left(t_i^*\right) = \Delta\left(\varepsilon_{\pi_i}^i - \varepsilon_{\pi_i}^j\right) - \phi_i\Delta\pi_i^*$

Since the elasticity of capital is monotonic in $t_i$, i.e. $\frac{\partial\varepsilon_k^i}{\partial t_i} < 0$, we have:

$\Delta t_i^* < 0$ if $\Delta\left(\varepsilon_{\pi_i}^i - \varepsilon_{\pi_i}^j\right) > \phi_i\Delta\pi_i^*$

$\Delta t_i^* > 0$ if $\Delta\left(\varepsilon_{\pi_i}^i - \varepsilon_{\pi_i}^j\right) < \phi_i\Delta\pi_i^*$ ■

# 5 Conclusion

Interactions between the capital tax rate and the inflation rate have been investigated under two possible scenarios: First, when countries have their own currencies, namely 'monetary independence', and second, when countries form a currency union and introduce a common currency for the union.

Capital tax rates and inflation rates interact in three different ways: The capital tax rate set by the national government of a country creates a horizontal externality for the other country's national government, and this effect pushes the equilibrium level of capital tax rates in both countries down. A similar effect is present for the choice of the inflation rate associated with the domestic currency.

Inflation tax competition pushes the equilibrium level of inflation rates in both countries down. However, there is a vertical externality created by the interaction of capital taxes and inflation, which may lead to higher capital tax rates in both countries.

If the two countries form a currency union, then inflation rate that prevails across the currency union will be higher than the inflation that would prevail in individual countries under monetary independence. Although inflation rate will be higher, individual countries may choose a lower or a higher capital tax rate than what they would choose under monetary independence. The decision of whether the optimal capital tax rate in a given country will increase or decrease due to creation of a currency union depends on the inflation elasticities of the demand for each country's national currency.

Possible extensions of this research will be inclusion of n-countries, asymmetrical countries, considering a labor income tax, and introducing different processes for the central bank to conduct its monetary policy.

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