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Monetary Capacity

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January 31, 2025

Abstract

Monetary capacity refers to the maximum level of monetization attainable by a state, given scarcity of commodity money and the need to finance public expenditure by taxing money. We develop a model showing that monetary and fiscal capacity are complements in imperfectly monetized economies. A positive shock to fiscal capacity implies lower expected seignorage and thereby increases monetary capacity. Simultaneously, a positive shock to monetary capacity increases the efficiency of taxation, and hence the incentive to invest in fiscal capacity. We take this model to the data by exploiting an exogenous shock to Europe's monetary capacity: the inflow of precious metals from the Americas (1550-1790). Our causal estimates indicate that increases in monetary capacity led to gradual and persistent increases in fiscal capacity in England, France and Spain. A historical overview of Europe and China from antiquity to the early-modern period confirms that monetary and fiscal capacity co-evolved in the long run.

JEL Codes: E50, E60, H21, N10, O11

Keywords: monetary capacity, fiscal capacity, monetization, inflation, taxation, quantity theory of money, monetary non-neutrality.

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1 Introduction

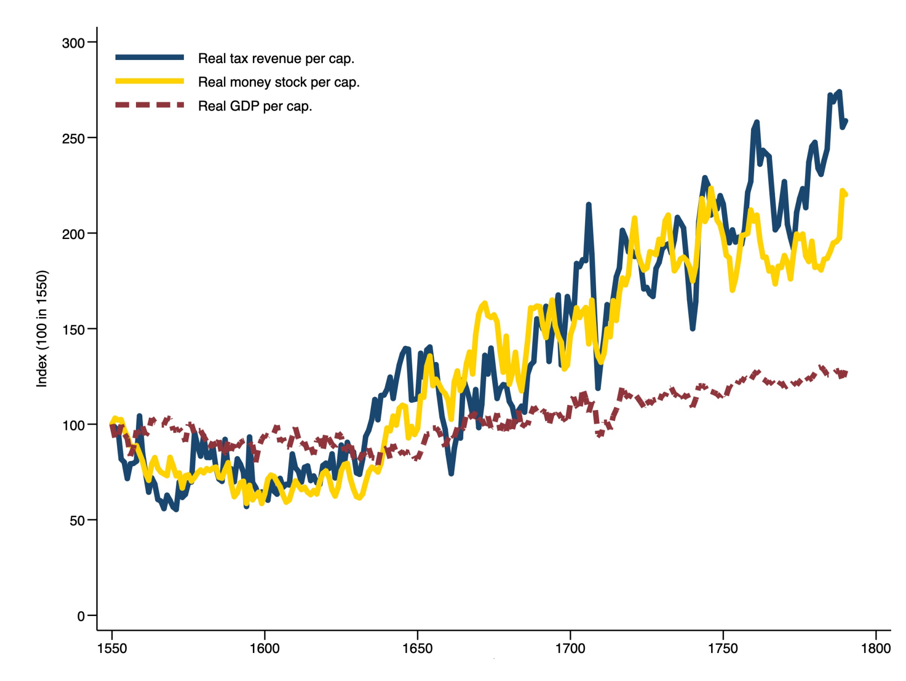
It is well documented that a state's ability to tax its citizens, its *fiscal capacity*, is a key determinant of economic growth (Besley and Persson, 2011; Dincecco and Prado, 2012). A largely separate literature concluded that higher monetization also increases growth, by lowering transaction costs, spurring trade and increasing investment (Boehm and Chaney, 2024; Palma, 2018a, 2020; Rössner, 2023). In this paper, we explore how fiscal capacity and monetization interact and thereby shape the long-run evolution of states. To do so, we define and characterize a new dimension of state capacity: *monetary capacity*.

Monetary capacity refers to the maximum level of monetization attainable by a state. In the commodity money system that dominated much of human history, both supply-side and demand-side factors shaped a state's monetary capacity. Scarcity of precious metals imposed a supply constraint on the capacity to issue widely-held currencies, and hence on monetization. At the same time, limited fiscal capacity created a demand constraint, since it forced governments to resort to seignorage to cope with fiscal shocks, and hence discouraged citizens from holding the currencies. Like other dimensions of state capacity, monetary capacity posed a binding constraint on early modern states. In the words of Pomeranz and Topik (1999, p.14): "[E]ndless books have been written about the dangers of government printing too much money. But for centuries the opposite problem was just as common: governments often couldn't mint enough coins... to meet their subjects' needs". Thus, to understand the process whereby these economies became increasingly monetised over time, one needs to figure out how they developed their monetary capacity, and how this interacted with contemporaneous investments in fiscal capacity.

To understand the link between fiscal and monetary capacity is important for our understanding of the long-run development of countries. Historical evidence shows that rises in monetary capacity and fiscal capacity went hand in hand, and predated modern economic growth by several decades. Figure 1 makes this descriptive point, by showing real per capita tax revenues and money stocks (two proxies for, respectively, fiscal and monetary capacity)[1] and GDP for an

[1] We follow the literature in proxying for fiscal capacity by per capita tax revenues, as states in early stages of development would be taxing at capacity. In a similar vein, we use the per capita money stock (a measure of monetization) as a proxy for monetary capacity (the maximum monetization attainable by a state). This is a valid approach for our time period, since, as suggested by the quote above, monetary capacity was a binding

Figure 1: Monetary and Fiscal Capacity in Western Europe (index, year 1550 = 100)



Note: This figure shows a yearly unweighted average of each of the three variables for England, France, and Spain. The index shown is normalised to 100 for the year 1550 for each variable. The data sources are described in detail in Appendix C.

average of three early modern Western European countries: England, France, and Spain. While monetary and fiscal capacity were stagnant during the 16th century, they both started to grow in a sustained fashion from around 1630 onwards. Economic growth followed, and hence did not cause, these transformations in monetization and taxation. Instead, these changes occurred against the backdrop of the exploitation of silver and gold mines in the Spanish colonies: by the end of the 17th century, the European per capita money stock was six times as high as in 1500, mostly due to inflows of precious metals from the Americas (Chen et al., 2021; Palma, 2022). While Figure 1 is merely descriptive, it provides the motivation for our main goal in this paper, which is to study, both theoretically and empirically, the co-evolution of fiscal and monetary capacity.

In this paper, we argue that it is no coincidence that higher monetary capacity went hand in

constraint in early modern economies. Our theoretical model will provide a formal justification for this approach, by showing that monetization coincides with monetary capacity in equilibrium.

hand with sustained increases in fiscal capacity in early modern Europe. We show that monetary and fiscal capacity are complements, and hence they should be expected to move together in the long-run. On the one hand, greater monetary capacity (as afforded by the inflow of precious metals from the Americas) is an important pre-condition for the rise of strong fiscal states, since a greater monetisation of the economy strengthens the incentives to invest in fiscal capacity. On the other hand, the state's capacity to raise taxes is an essential ingredient in determining the credibility, and hence the success, of a currency. Thus, strong fiscal capacity is, in turn, an important pre-condition for strong monetary capacity. Given the importance of both taxation and monetisation for economic growth (Besley and Persson, 2011; Dincecco and Prado, 2012; Palma, 2020), the implication is that the co-evolution of monetary and fiscal capacity was an important ingredient in the emergence of sustained economic growth in the early-modern period.

We make our central argument using theory, empirics, and historical evidence. In the theoretical part of the paper, we construct a simple model in which agents use a commodity money, "silver" (which could be privately or publicly owned), to reduce the transaction costs associated with barter. Scarcity of silver implies that the economy is imperfectly monetized, that is monetary transactions (those in which silver is exchanged for consumption good) take place alongside barter transactions (where consumption good is exchanged for other consumption good). A government collects public revenues through a seignorage tax on monetary transactions, as well as a transaction tax that is constrained by pre-installed fiscal capacity. Although the transaction tax applies to all transactions, barter transactions are harder to tax, in that part of the resulting revenues are lost before reaching the government. Our model nests a continuum of government "types", from a benevolent planner who entirely allocates public revenues to socially optimal uses, to a rapacious type who entirely embezzles them. We find that the seignorage tax is distortionary, in that it decreases the equilibrium number of monetary transactions, which are more efficient than barter transactions. In turn, the equilibrium seignorage tax rate decreases in the transaction tax rate, since a higher transaction tax rate makes monetary transactions a more valuable source of government revenues, and thus increases the cost of distortions associated with the seignorage tax. . "Monetisation" - that is the share of monetary transactions in total transactions, given the equilibrium seignorage tax - is then increasing in the transaction tax rate.

This implies that the maximum attainable monetisation ("monetary capacity") is constrained not only by the availability of silver, but also by the government's fiscal capacity. Moreover, since it is optimal for the government to fully use its fiscal capacity, in equilibrium monetisation coincides with monetary capacity. It follows that exogenous shocks to fiscal capacity increase monetary capacity and monetisation. Our main result however is that the opposite also holds: exogenous shocks to monetary capacity, such as an exogenous inflow of silver, increase fiscal capacity. This is because greater monetisation makes the economy more valuable and easier to tax, thus strengthening the incentives to invest in fiscal capacity.

In the empirical part of the paper, we bring this last result to the data by studying the consequences of a supply-side shock to monetary capacity: the discovery and exploitation of precious metals in the Americas across the early modern period (1550-1790). As historians have repeatedly pointed out, for silver-starved European economies, these (overwhelmingly privately-owned) inflows meant an increased capacity of governments to issue money, and a dramatic increase in the share of transactions conducted using money. Moreover, as shown by Palma (2022), the discovery and production of precious metals in the Americas was exogenous to the short-term variations of the European economies. We thus study the causal effect of monetary capacity on fiscal capacity in Europe (with monetary and fiscal capacity being proxied by, respectively, per capita real money stocks and per capita real tax revenues), using a Local Projection-Instrumental Variable Approach (Jordà, 2005) in which production of precious metals in the Americas is used to instrument for monetary capacities in Europe. We restrict attention to the years after 1550, when silver from the Americas began to arrive in large quantities, and before 1790, when paper monies increasingly replaced commodity money and weakened the link between precious metals and money stocks. For the sample countries, we investigate England, France and Spain, as these countries were heavily impacted by the precious metals shock, and have detailed historical annual data for both monetization and taxation.[2]

The empirical results identify a significant and substantial causal impact of monetary capacity on fiscal capacity. In the first stage, an increase in the production of precious metals in the Americas significantly increased per capita real money stocks across our sample of European

[2] For details about the precious metals production shock, see Palma (2022).

countries. In the second stage, a 1 percent increase in per capita real money stocks increased per capita real tax revenues by 0.6-1.5 percent over a 20 years interval. Moreover, consistent with a gradual investment in fiscal capacity, the effect built up over a period of 14-17 years in England and France, and persisted over the course of subsequent decades in all countries considered. In contrast, the effect for Spain peaked earlier and was overall smaller, potentially related to the fact that part of the silver went directly to Spanish government coffers. These findings are robust to controlling for income and measures of warfare and the representativeness of political regimes. Likewise, the findings are robust to accounting for potential violations of the exclusion restriction through the adjusted impulse responses methodology of Jordà et al. (2020a).

In the final part of the paper, we put these empirical results into broader historical context by collecting the fragmentary data available for earlier periods and other parts of Europe, as well as for China. The resulting patterns support the notion of a close relationship between precious metals, monetary capacity and fiscal capacity (again proxied by per capita real money stocks and tax revenues). From antiquity to the early modern period, and across European countries, the available evidence shows that peaks and troughs of monetary and fiscal capacity coincided with fluctuations in the availability of precious metals, as well as with one another.[3] The long-run analysis also confirms that the inflow of precious metals from the Americas was a transformative event, resulting in an unprecedented increase in monetization levels and breaking the cycles of monetization and demonetization that occurred before. In the case of China—where scarcity of precious metals led to experimentation with paper money already in the Middle Ages—failure on the fiscal front was a key reason for the failure of paper money from the Ming dynasty and until the twentieth century. This stands in sharp contrast with the experience of Europe, where several countries successfully adopted paper money from the late 18th century onwards, on the back of strong fiscal states.

In summary, the main contribution of the paper is to establish theoretically and empirically that monetary and fiscal capacity, and in more general terms, markets and states are interdependent. Markets and states are often conceptualized as alternative methods of allocating resources

[3]European colonizers, in turn, made great efforts to introduce "modern" money in several parts of the world, even though there was a considerable fixed cost to doing so, as it then made it considerably easier to collect tax revenue (Einzig, 1966, p. 506).

and governing social interactions. This characterization is incomplete, however, as they also depend on each other to function. Markets, and by extension, a monetized and commercialized economy, facilitate state-building, while a strong state fosters monetization. We also document that this interdependence is not merely a theoretical possibility. Rather, the co-movement of monetary and fiscal capacity has been a defining and robust characteristic of the European political economy since antiquity.

Our paper complements, and somewhat qualifies, a large literature that investigates the origins of state capacity from an empirical and theoretical perspective. At least since Tilly (1990), the literature pointed to war pressure as the key driver of fiscal capacity (Besley and Persson, 2011, 2009; Dincecco, 2009). Our paper complements this view by suggesting that sufficient monetary capacity is a necessary condition that needs to be in place for an effective build-up of fiscal capacity. We hereby contribute to an emerging literature that explores alternative key drivers of fiscal capacity. In this vein, Dal Bó et al. (2022)'s examination of excise revenues in early modern Britain show that the taxation of traded goods was more important for the build-up of fiscal capacity than previously thought.

The findings also offer new insights into a central idea in macroeconomics, the long-run neutrality of money. The common wisdom is that money is neutral in the long run: an increase in money supply has no real effects and only leads to a proportional increase in the price level.[4] In contrast, we find that it did have a real long-run effect, in the form of an increase in fiscal capacity. The reason for this positive effect is that historically large segments of economies were not sufficiently monetized. Following a positive monetary shock, money penetrated into these under-monetized segments. Prices increased, but less than proportionally, because now a greater share of the economic activity relied on money. The growing monetization in turn facilitated market transactions and increased tax revenues. Hence, the effects of the increase in money supply were real and had economic as well as political implications.

In the same vein, our findings relate to the literature on the trade-off between monetary expansion and taxation (Mankiw, 1987; Sargent and Wallace, 1981; Sims, 1994). The common wisdom in the literature is that states can raise revenue by either increasing taxes or increasing

[4]See, however, Brzezinski et al. (2024); Jordà et al. (2020b); Palma (2018a, 2022).

money supply, the latter of which in turn increases the price level. Hence, in the short run, increasing taxes and increasing money supply are substitutes. We find in this study that, over the long run, the relationship is more complex. In under-monetized economies, if the money supply expands in a way that provides liquidity to new regions or sectors, it also improves the tax collection, triggering a virtuous cycle of monetary and fiscal capacity building (Capie, 2004; Desan, 2014, p.256). Hence, in the long run, taxation and money supply are complements.

The remainder of the paper is structured as follows. Section 2 sets out our model, giving a precise definition to the notion of monetary capacity and exploring its link to fiscal capacity. Section 3 discusses the new dataset and causal empirical results relating to the effect of increases in monetary capacity on fiscal capacity in early modern Europe. Section 4 puts the evolution of monetary and fiscal capacity in historical context, starting in antiquity and exploring the evolution in Eastern and Western Europe. Section 5 concludes.

2 Model

We first describe the model setup (Section 2.1) and we then identify its equilibrium (2.2). The latter section also contains our definition of monetary capacity. Our main result is stated in Section 2.3.

2.1 Setup

Our model consists of two types of agent: citizens who engage in market transactions, and a government who finances public expenditure through taxes. We will discuss each type of agent in turn.

Citizens. Consider an economy inhabited by a measure of atomistic citizens, with mass one. There are two private goods, a consumption good (c) and silver bullion (b), and public expenditure (g). The utility of citizen i is

$$U_i = c_i + b_i + \tilde{\alpha} g, \tag{1}$$

where $\tilde{\alpha} \geq 0$ is a parameter which captures the relative importance of public expenditure. Each agent is initially endowed with one unit of the consumption good, and $(1-\lambda)\sigma$ units of silver, where $\lambda \in [0,1]$ and $\sigma > 0$. An additional $\lambda\sigma$ units of silver are owned by the government. Thus, the economy's total endowment of silver is represented by σ.

Citizens are part of a market economy where they can exchange their goods with each other. Silver is a homogeneous good, and citizens are indifferent between consuming their own endowment, or the endowment of others. When it comes to the consumption good, however, citizens only obtain utility from the consumption good of others (as in Diamond 1982). They will then want to engage in transactions, to sell their own consumption good. We can distinguish two types of transactions. In the first, citizens sell their own consumption good in exchange for another agent's consumption good. In the second, they sell their own consumption good in exchange for another agent's silver. We call the first type of transactions *barter transactions*, and the second type *monetary transactions*. Barter transactions are subject to search costs: to arrive at the exchange with one unit of own consumption good, an agent must leave home with $\phi > 1$ units. Monetary transactions are instead frictionless (in the absence of taxes).[5]

For sellers of silver to engage in monetary transactions, they must first convert their silver into "coins". Conversely, for buyers of silver to be able to consume the silver, they must first convert the coins back into silver. Both transformations are carried out at the "mint". While the transformation process is itself costless, the government imposes a seignorage tax $s \geq 1$ on silver that transits through the mint. The case of $s = 1$ is therefore one of no seignorage tax, while any $s > 1$ describes a positive tax. Specifically, for each unit of silver that sellers of silver bring to the mint, they obtain coins containing $1/s$ units of silver, while the remaining $(s-1)/s$ units are appropriated by the government. Similarly, for each unit of silver (embedded in coins) that buyers of silver bring to the mint, they obtain $1/s$ units of raw silver.

[5]The assumption that barter transactions involve more frictions than monetary ones could be micro-founded by explicitly modelling the consumption good as heterogeneous in preferences. A simple example is as follows. Suppose there are three varieties of the consumption good (A, B and C), and three types of consumers. Type A consumers only obtain utility from variety A, type B only from variety B, and so on. Let an agent of type XY be someone who has an endowment of type X and is a consumer of type Y, and imagine agents of the six possible types (AB, AC, BA, BC, CA and CB) have equal masses. In this setting, it would be easy to justify that search costs are higher for barter transactions, since e.g. a type AB would necessarily have to find a type BA. In monetary transactions, instead, it would be enough for them to find either of BA and BC.

To capture a situation in which silver is scarce, as it was in early-modern economies (i.e. there was not enough silver to conduct all transactions with silver coins), we assume that silver can only be exchanged once. This is a stark way to assume that the velocity of money is not high enough for silver to be used in all transactions. In the absence of such an assumption, even a minuscule quantity of silver would always be enough for all transactions to be monetary.

In addition to a seignorage tax, citizens are subject to a transaction tax $t \geq 1$. Both barter transactions and monetary transactions are subject to this transaction tax. Specifically, after each barter transaction, each agent must stop at the "tax man". For every unit of consumption good or silver good that agents arrive with after a transaction, they are left with $1/t$ units, while the remaining $(t-1)/t$ units are appropriated by the tax man.

To summarise, the key difference between barter and silver transactions is that the former is subject a search friction ϕ, while the latter incur no search friction but are subject to a seignorage tax s. Both types of transactions are subject to the transaction tax t. The seignorage and transaction taxes are policy variables set by the government, as we describe next.

Government. The government has three sources of income to finance public goods expenditure g. First, it owns a fraction $\lambda \in [0, 1]$ of total silver σ. Denoting the price of silver in terms of consumption goods by p, this gives the government a wealth of $p\lambda\sigma$. Second, the government receives revenues R_t from the transaction tax t described above, which applies uniformly to all transactions. Finally, the government receives revenues R_s from the seignorage tax s which it receives from monetary transactions, again described above. Part of the silver that the government receives from taxes (the part taxed from buyers of monetary silver) has already been exchanged, while the other part (the part taxed from sellers of silver) has not. This is relevant, since we have assumed a limited velocity of silver, such that the government can only exchange the latter part of silver.[6]

Transaction taxes differ from seignorage in two additional ways. First, to allow for the possibility that barter transactions may be harder to tax than monetary transactions, we assume that, for every unit of revenues generated by the transaction tax on barter transactions, $\delta \in [0, 1]$

[6] In particular, the government's yet-to-be exchanged silver includes the $\lambda\sigma$ units initially owned by it, as well as the $(1-s)/s * (1-\lambda)\sigma$ units that it collects from sellers of silver.

units are lost before reaching the government. Second, following the fiscal capacity literature (Besley and Persson, 2009), we assume that the transaction tax cannot exceed the government's fiscal capacity, $\tau \geq 1$. Fiscal capacity must be developed in advance, and costs $\xi C(\tau)$ units of public expenditure to be developed. The function $C(\cdot)$ is continuous, increasing and convex, and $C'(1) = 0$. The parameter $\xi > 0$ is a cost shifter.

Putting everything together, the government's constrained optimisation problem is given by:

$$\max_{g,\tau,s,t} W = c + b + \alpha g, \tag{2}$$

$$\text{subject to: } g + \xi C(\tau) \leq R_s + R_t + p\lambda\sigma \tag{3}$$

$$t \leq \tau \tag{4}$$

where $c = \int_{i\in[0,1]} c_i di$, $b = \int_{i\in[0,1]} b_i di$, and α is the weight that the government gives to public expenditure g. In other words, the government funds public expenditure, and investment on fiscal capacity[7], by setting taxes in order to maximise the sum of citizens' utilities, but valuing public expenditure at rate α. Comparing this with the utility of citizens given by equation 1, the difference is that the weight that the government gives to public expenditure, α, need not be the same as the value that citizens attach to it, $\tilde{\alpha}$. The government's three sources of income are used to finance public expenditure as well as the initial investment in fiscal capacity.

We make two assumption on α: $\alpha > 1$, and $\alpha \geq \tilde{\alpha}$. The former assumption allows us to focus on the case of interest, namely the one in which tax revenues are important, at least from the government's point of view. The latter assumption nests a continuum of government "types" into the model, with the restriction that the government values public expenditure at least as much as citizens. As $\alpha \to \tilde{\alpha} > 1$, the government type approaches a benevolent utilitarian planner who maximises total citizen utility. At the opposite extreme, that is as $\alpha \to \infty$ and $\tilde{\alpha} \to 0$, the government type approaches one who only cares about public expenditure, despite this being a

[7] That investment in fiscal capacity is financed out of future revenues is only a simplifying assumption. Models of fiscal capacity often have two periods, and investment in period 2's capacity is financed out of period 1 revenues (generated through exogenously-given initial capacity). To extend the model for these purposes would not yield valuable insights in our context: all that would change is that investment would be weighed, not against the opportunity cost of period 2's revenues (α), but against their period 1 cost (say α_{initial}). If the opportunity costs of revenues did not change over time ($\alpha_{\text{initial}} = \alpha$), then the equilibrium of the extended model would look the same as that of the current one.

pure waste from the point of view of the citizenry. For example, this could be a government who entirely embezzles public revenues for personal consumption.[8]

Timeline. The timing of the game is as follows:

1. The government sets fiscal capacity, τ.

2. The government sets the transaction and seigniorage taxes, t and s.

3. Transactions take place, taxes are collected, public expenditure takes place. After this, payoffs realise.

2.2 Equilibrium

We find the equilibrium using backward induction.

Period 3. The share of monetary transactions in total transactions is determined by the equilibrium of the silver market. Unlike the consumption good, silver can be consumed directly by those who own it. Still, agents are willing to sell their silver in monetary transactions if utility from the consumption good received is higher than utility from consuming the silver directly. This supply of silver meets demand for it. The latter is motivated by the fact that, by exchanging consumption good for silver, agents can avoid the cost of barter transactions. The market is in equilibrium when the price of silver in terms of the consumption good, p, equalises supply and demand.

We begin by deriving silver supply. This comes from the government as well as from private agents. For every unit of silver that the government sells in monetary transactions, it obtains p units of consumption good. Since one unit of silver can finance as much public expenditure as one unit of the consumption good, the government sells all its silver if $p > 1$, while it entirely retains it, and directly transforms it into public expenditure, if $p < 1$. For every unit of silver that private agents sell in monetary transactions, they bring home $p/(st)$ units of another agent's

[8]It would be straightforward to make α and $\tilde{\alpha}$ probabilistic, the capture the occurrence of fiscal shocks (e.g. due to war), but this would not change our results qualitatively, nor give important new insights.

consumption good, obtaining an equal amount of utility.[9] Since the alternative is to eat the silver directly, obtaining one unit of utility, private agents sell all their silver if $p > st$, while they entirely retain it, and eat it directly, if $p < st$. Intuitively, the threshold price st increases in the taxes that one needs to pay in order to bring silver to the exchange, since the alternative (to eat the silver directly) is an untaxed activity. In summary, the aggregate supply of silver is

$$B^s = \begin{cases} 0 & \text{if} \quad p < 1 \\ z \in [0, \lambda\sigma] & \text{if} \quad p = 1 \\ \lambda\sigma & \text{if} \quad 1 < p < st \\ z \in [\lambda\sigma, \sigma] & \text{if} \quad p = st \\ \sigma & \text{if} \quad p > st \end{cases} .$$

Silver supply is illustrated in Figure 2.[10]

We next turn to the demand for silver, also illustrated in Figure 2. For every unit of their own consumption good that agents exchange in barter transactions, they bring home $1/(\phi t)$ units of another agent's consumption good. If instead they exchange the unit for silver in monetary transactions, they bring home $1/(pts)$ units of silver.[11] Since another agent's consumption good and silver have equal weights in utility, the aggregate demand for silver is

$$B^d = \begin{cases} \frac{1}{p} & \text{if} \quad p < \frac{\phi}{s} \\ z \in \left[0, \frac{1}{p}\right] & \text{if} \quad p = \frac{\phi}{s} \\ 0 & \text{if} \quad p > \frac{\phi}{s} \end{cases} .$$

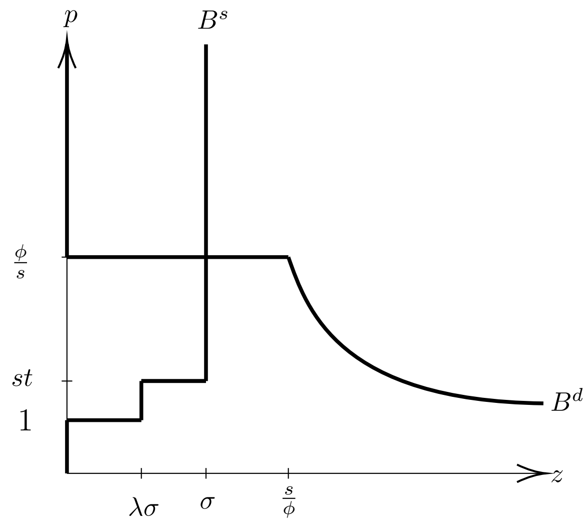
If $p < \phi/s$, an agent's own consumption good yields more utility when exchanged in monetary

[9] Having to stop at the mint, agents arrive at the exchange with $1/s$ units of silver. There, they obtain p/s units of consumption good. Having to stop of the tax man on the way back, they arrive at home with $p/(st)$ units of the consumption good.

[10] Note that supply equals the economy's total endowment of silver if $p > st$, that is $B^s = \sigma$. This is because the government finds it optimal to sell not only its own silver, but also the silver it collects from sellers of silver.

[11] In barter transactions, agents arrive at the exchange with $1/\phi$ units of own consumption good. They receive in exchange $1/\phi$ units of another agent's consumption good, of which only $1/(\phi t)$ are left after stopping at the tax man. In monetary transactions, they they arrive at the exchange with one unit of own consumption good. They receive in exchange $1/p$ units of silver, of which they are left with $1/(pt)$ after stopping at the tax man, and $1/(pts)$ after stopping at the mint.

Figure 2: Silver market equilibrium



transactions, than when exchanged in barter transactions. Thus, agents exchange their entire endowment of the consumption good in monetary transactions, resulting in a demand for $1/p$ units of silver. The opposite is true for $p > \phi/s$. Intuitively, ϕ/s captures the value of silver for those who demand it. It increases in the cost of the search frictions saved by monetary transactions, and it decreases in the seignorage tax which only hits such transactions.

In equilibrium, the price of silver equalises demand and supply. For some parameter values, however, the equilibrium features no "private" monetary transactions (that is monetary transactions in which it is private agents who sell the silver), or indeed only monetary transactions. To rule out these cases, which are of marginal interest in the historical setting that we are considering, we impose

Assumption 1.

$$st < \frac{\phi}{s}. \tag{5}$$

Assumption 2.

$$\sigma < \frac{1}{\phi}. \tag{6}$$

Assumption 1 requires taxes not to be so large as to induce a collapse of the private market for silver. (We are forced to state the assumption in terms of endogenous variables at this stage, but we will later show that it holds in equilibrium.) This is what happens when the assumption is violated, since the tax burden of bringing silver to the exchange for private agents is higher than the value of silver for those who demand it. In terms of Figure 2, the top horizontal portion of the supply curve is below the horizontal portion of the demand curve. Assumption 2 ensures that silver is scarce: even if all of it is used in monetary transactions, some transactions are still conducted through barter. In terms of Figure 2, supply always meets demand in the horizontal portion of the latter curve.

Given scarcity of silver, the equilibrium price of silver equals its value to those who demand it, i.e. $p^* = \phi/s$, implying that all of the surplus from the monetary economy is captured by sellers of silver. We note that, in this model, the equilibrium price is not decreasing in σ, implying that a greater abundance of silver does not result in "inflation" (intended as an increase in the silver price of the consumption good). This is a by-product of the simplifying assumption of homogeneous search costs: we show in Appendix A that a straightforward generalization to heterogeneous search costs would make the model more realistic in this sense.

In equilibrium, all endowments are exchanged. Agents use all of their yet-to-be exchanged silver to purchase consumption good in monetary transactions. This includes both privately owned silver, as well as the silver that is owned or collected by the government. At the same time, agents sell some of their consumption good in exchange for silver in monetary transactions, and barter the rest for other consumption good. Thus, in equilibrium, agents only consume the silver of others, even though this is as good as their own endowment at generating utility. This is because yet-to-be exchanged silver trades at a premium relative to its consumption value, since it can be used to reduce search costs in barter transactions.

A citizen's indirect utility before the transaction tax and public good provision, which we also refer to as "private utility", is

$$\frac{(1-\lambda)\sigma}{s}p^* + \frac{1}{\phi} = \frac{(1-\lambda)\sigma\phi}{s^2} + \frac{1}{\phi}. \tag{7}$$

Expression (7) has an intuitive meaning.[12] If silver was not used as means of exchange, then private utility would be $(1-\lambda)\sigma + 1/\phi$, since all privately-owned silver would be eaten directly by its owners, and all consumption good would be bartered. The ability to use silver as a means of exchange would, absent the seignorage tax, increase private utility to $(1-\lambda)\sigma\phi + 1/\phi$, since each unit of silver, when used in monetary transactions, stops $\phi - 1$ units of the consumption good from being lost to search frictions.[13] There are two ways that the seignorage tax gets in the way, reflected in the quadratic term which enters (7). First, by taxing sellers of silver, it reduces the amount of silver brought to the exchange by private agents. Second, by lowering the demand for silver and thus its equilibrium price, it reduces the amount of consumption good transacted in monetary transactions.

Period 2. At this stage, the government sets the seignorage and transaction taxes to maximise the objective in (2). Since all endowments are exchanged, expression (7) equals the amount of silver and consumption good that agents bring home after transactions, absent the transaction tax. Since all these goods are in fact taxed, however, private utility after the transaction tax is only $1/t$ times expression (7). Since there is a mass one of citizens, such an amount also corresponds to the sum of citizens' private utility after the transaction tax, that is $c + b$ in equation (2). As illustrated by equation (3), total government revenues are made up of revenues from the transaction tax, revenues from the seignorage tax, and income from selling government-owned

[12]To arrive at expression (7), note that private sellers of silver arrive at the exchange with $(1-\lambda)\sigma/s$ units of silver, and bring home $(1-\lambda)\sigma/s * p^*$ units of the consumption good. Buyers of silver bring to the exchange $\sigma p^* < 1$ units of the consumption good (where the inequality follows from Assumption 2), where they obtain σ units of silver (some of which from the government, or its employees). However, after stopping at the mint, they only bring home σ/s units. The $1-\sigma p^*$ units of consumption good which are not exchanged in monetary transactions are then bartered, resulting in a share $1/\phi$ of then being brought home. Summing up all goods brought home by private agents, one obtains expression (7).

[13]To see this, note that, absent the seignorage tax, each unit of silver purchases ϕ units of another agent consumption good, which can be consumed at no further cost. Had those units being bartered, however, $1/\phi$ of them would have been lost to search frictions, resulting in only one unit being consumed.

silver. Replacing (3) into (2), the government's objective can then be written as

$$W(s,t) = \frac{1}{t}\left[\frac{(1-\lambda)\sigma\phi}{s^2} + \frac{1}{\phi}\right] +$$
$$+ \alpha \left\{ \underbrace{\frac{t-1}{t}\left[\frac{(1-\lambda)\sigma\phi}{s^2} + \frac{1}{\phi} - \delta\frac{1}{\phi}\left(1 - \sigma\frac{\phi}{s}\right)\right]}_{R_t} + \underbrace{\frac{s-1}{s}\sigma\left[(1-\lambda)\frac{\phi}{s} + 1\right]}_{R_s} + \lambda\sigma\frac{\phi}{s} - \xi C(\tau) \right\}. \tag{8}$$

The first term in curly brackets represents revenues from the transaction tax, R_t. They are equal to the tax rate, $(t-1)/t$, multiplied by private utility (the taxable base of the transaction tax), minus a positive term consisting of δ times the value of barter transactions. Such term accounts for the fact that a share δ of revenues generated by taxing barter transactions is lost before reaching the government. The second term in curly brackets captures revenues from the seignorage tax, R_s, and is equal to the tax rate, $(s-1)/s$, times the taxable base, $\sigma[(1-\lambda)\phi/s+1]$. The latter expression reflects the fact that the government taxes silver twice. On the one hand, it taxes the $(1-\lambda)\sigma$ privately-owned units that are brought to the mint to be converted into coins. On the other hand, it taxes the σ units that are brought back to the mint to be converted into silver. Only in the first case, however, can the government sell the silver on the exchange (since the silver has not been exchanged yet), increasing its value by a factor $p^* = \phi/s$. Finally, the last-but-one term in curly brackets is the revenues that the government generates by selling its own silver, while the last term captures investment on fiscal capacity.

It is shown in the Appendix that the seignorage tax which maximises $W(s,t)$ is

$$s^* = s(t) = \max\left[1, (1-\lambda)\frac{2\phi(\alpha-1)}{\alpha[t(\phi-1) + (t-1)\delta\phi]}\right]. \tag{9}$$

The key comparative statics of s^* for our purposes is that it is decreasing or constant in the transaction tax, t. Intuitively, the role of the seignorage tax is to finance public expenditure. But this tax is distortionary, since it reduces demand for silver on the exchange, and hence the price of silver and the share of monetary transactions in total transactions. This implies that private utility is decreasing in s, as indicated in expression (7). The transaction tax is an alternative to the seignorage tax, and has two key features. First, its taxable base is private utility. Second, its efficiency is increasing in the share of monetary transactions in total transactions. Both features imply that the higher is the transaction tax, the more distortionary the seignorage tax turns out to be. Consistent with this, the negative relation between t and s^* is particularly strong when barter transactions are particularly hard to tax (δ is high).

The optimal seignorage tax is also decreasing in the share of silver owned by the government, λ. This is also intuitive: the more silver the government owns, the more distortionary it finds a tax which reduces the monetary value of silver.

For certain parameter values, e.g. when search costs are high and the government cares little about public expenditure (ϕ large and α small), the optimal seignorage tax is zero ($s^* = 1$) for all $\tau \geq 1$ and $\lambda \in [0, 1]$. To rule out this uninteresting case, we impose

Assumption 3.

$$\frac{2\phi(\alpha - 1)}{\alpha(\phi - 1)} > 1,$$

which ensures that, at least when τ and λ are low enough, the government uses the seignorage tax to collect revenues.

We now introduce the following

Definition 1. *The economy's **monetization**, m is the share of the consumption good that is sold in monetary transactions, when the government selects the seignorage tax which maximises its objective function.*

Since σp^* units of the consumption good are sold in monetary transactions, and there is one unit of them overall, monetization is equal to σp^*, that is

$$m = \sigma \frac{\phi}{s(t)}. \tag{10}$$

It is easy to verify that, under Assumption 2, the economy is not fully monetized, that is $m < 1$.

Equation (10) illustrates that monetization is decreasing in the seignorage tax, $s(t)$. This is because a higher seignorage tax decreases demand for silver, and thus the equilibrium price of silver and the amount of consumption good which can be purchased using it. Because monetisation is decreasing in the seignorage tax, and the seignorage tax is weakly decreasing in the transaction tax, it follows that monetisation is weakly increasing in the transaction tax, $dm/dt \geq 0$. This result implies that choosing the transaction tax is effectively the same as choosing the degree of monetisation of the economy. Intuitively, a government opting for a low level of taxation is also one who must then impose a high seignorage tax, resulting in a low demand for silver and low monetisation of the economy. In contrast, a government choosing to tax the economy heavily is one who will refrain from using the seignorage tax, resulting in a high degree of monetisation.

There is, however, a limit to how much a government can obtain a high level of monetisation by imposing high taxes, since the government cannot possibly raise taxes above its capacity to do so. Thus, a government's fiscal capacity also determines its capacity to obtain a high level of monetisation of the economy. To capture this notion, we introduce the following

Definition 2. *A government's **monetary capacity**, μ, is the maximum degree of monetisation that the government can obtain, that is the one which realises when the government sets taxes as high as allowed by its fiscal capacity:*

$$\mu(\sigma, \tau) = \sigma \frac{\phi}{s(\tau)}. \tag{11}$$

In a partially monetised economy such as the one we are considering, a government's monetary capacity is driven by supply as well as demand factors. The former are captured by σ: a larger endowment increases the supply of silver, thus increasing the maximum amount of consumption good which can possibly be purchased in monetary transactions.[14] Demand factors are captured by $\phi/s(\tau)$. Higher search costs in barter transactions (a higher ϕ) increase the demand for silver, resulting in a higher price of it. Again, this increases the maximum amount of the consumption good which can possibly be purchased in monetary transactions. Crucially, a similar effect has

[14]This result is especially stark in the current model, where an increase in σ does not reduce the equilibrium price of silver. In Appendix A, we show that a similar result also applies in a more general model, in which the price of silver may be decreasing in σ.

past investment in fiscal capacity, which determines the government's capacity to finance public expenditure using taxes rather than seignorage, and hence its capacity to stimulate demand for silver. Thus, higher past investment in fiscal capacity also increase the maximum amount of the consumption good which can possibly be purchased in monetary transactions.

The notion of monetary capacity draws attention to the fact that, besides factors such as the availability of metals or the relative efficiency of money, how much an economy can possibly be monetised also depends on the government's past investment in fiscal capacity. In turn (as shown in greater detail below) this implies that factors that affect investment in fiscal capacity (such as the importance of public revenues, α, or the cost of investment, ξ) will also determine how monetised the economy can possibly be.

Turning to the optimal transaction tax, it is easy to verify that, if δ is low enough, then the government's objective (eq. 8) is monotonically increasing in it, and $t^* = \tau$. Intuitively, the transaction tax is non-distortionary, since it hits all transactions in the same way. At the extreme, if none of the revenues generated by taxing barter is lost before they reach the government (that is if $\delta = 0$), then one additional unit of private utility taken by the tax man results in one additional unit of public expenditure. Since the latter has greater weight than the former in the government's objective, the government's objective is monotonically increasing in t. If δ is large, however, and if the share of barter transactions in total transactions is also large, then it is possible that the government's objective be monotonically decreasing in t, since too large a share of tax revenues are lost before they reach the government. It would then be $t^* = 0$. To rule out this uninteresting case, we impose

Assumption 4. $\delta < \frac{\alpha-1}{\alpha}$.

Assumption 4 ensures that, even in the extreme case in which all transactions are barter, enough tax revenues reach the government to make its objective increasing in t. Thus, the assumption is sufficient to ensure $t^* = \tau$.

In summary, the government's fully uses its fiscal capacity in equilibrium. As a result, monetisation equals the government's monetary capacity:

$$t^* = \tau \tag{12}$$

$$m = \mu(\sigma, \tau). \tag{13}$$

Period 1. In this period, the government selects fiscal capacity, τ, to maximise the objective function, that is

$$\tau^* = \arg\max_{\tau} W[s(\tau), \tau].$$

It is shown in the Appendix that there exists a finite solution $\tau^* > 1$ to this problem, implicitly defined by

$$\tau^* = \arg_{\tau}\left\{\frac{1}{\tau^2}\left\{\left(\frac{\alpha-1}{\alpha}-\delta\right)\frac{1}{\phi}+\left[\frac{\alpha-1}{\alpha}\frac{1-\lambda}{s(\tau)}+\frac{\delta}{\phi}\right]\mu(\sigma,\tau)\right\}=\xi\frac{dC(\tau)}{d\tau}\right\}, \tag{14}$$

a condition which equalises the marginal benefit of investment in fiscal capacity to its marginal cost.

Since $\mu(\sigma, \tau)$ appears in the marginal benefit of investment, condition (14) makes it clear that considerations about monetary capacity matter for investment in fiscal capacity. This is because the government anticipates that, by investing in fiscal capacity, it will also increase its monetary capacity, and hence monetization. These considerations are important for the investment decision, because greater monetisation makes the economy larger and transactions easier to tax, thus increasing the taxable base of the transaction tax and hence the incentive to invest in the capacity to raise it. Indeed, considerations about monetary capacity are important even for a rapacious government who entirely embezzles public revenues for personal consumption (whose behaviour can be captured by setting $\alpha \to \infty$).

Having characterised the equilibrium of the model, it is now easy to show (and is done in the Appendix), that ϕ and α can be chosen high enough, and σ and δ small enough, so that Assumptions 1-4 simultaneously hold.

2.3 Main result

Having characterised the equilibrium of the model, we now turn to our main result, namely that fiscal and monetary capacity are complements. To see this, it is useful to explore the comparative statics of the equilibrium with respect to three parameters, the endowment of silver (σ), the importance of public expenditure in the government's objective (α), and the cost of investing in fiscal capacity (ξ). What is notable about these parameters is that they only affect one of the two capacities directly, and not the other. In particular, changes in σ only have a direct effect on monetary capacity (by eq. 11), while they do not affect fiscal capacity for constant monetary capacity (as is visible from eq. 14). Thus, to study the comparative statics of the equilibrium with respect to this parameter allows us to determine how an exogenous shock to monetary capacity affects fiscal capacity. Conversely, changes in α or ξ only have a direct effect on fiscal capacity, but not on monetary capacity for constant fiscal capacity. Their comparative statics can then shed light on how an exogenous shock to fiscal capacity affects monetary capacity. Such a comparative statics is described in Proposition 1, whose proof can be found in the Appendix.

Proposition 1. *An exogenous positive shock to monetary capacity (an increase in the endowment of silver, σ) strictly increases fiscal capacity. Likewise, an exogenous positive shock to fiscal capacity (an increase in the weight on public expenditure in the government's objective, α, or a decrease in the cost of investing in fiscal capacity, ξ) weakly increases monetary capacity.*

That an exogenous positive shock to fiscal capacity weakly increases monetary capacity will not come as a surprise, given that it has already been established that $\mu(\sigma, \tau)$ is weakly increasing in τ (eq. 11). The main novelty of Proposition 1 is that the opposite also holds: an exogenous shock to monetary capacity, such as due to an increase in the endowment of silver σ, also increases fiscal capacity. The intuition for this result can be grasped by inspecting equation (14), which equalises the marginal benefit of investment in fiscal capacity to its marginal cost. An increase in σ increases monetary capacity, $\mu(\sigma, \tau)$, which in equilibrium coincides with the monetisation of the economy (see eqs. 12-13). This increases the marginal benefit of investment in fiscal capacity for two reasons, captured by the two terms in square brackets in (14). On the one hand, greater monetisation increases the value of the private economy, and thus the taxable base of the transaction tax. This first channel (a "private income channel") is only present if the silver is at least in part privately owned, that is if $\lambda < 1$. Intuitively, if all silver was owned by the government ($\lambda = 1$), then an increase in its endowment would not make citizens any richer, leaving the capacity to tax them no more attractive than it was before. On the other hand, greater monetary capacity and hence monetisation reduces the share of transactions conducted using barter, making the transaction tax more efficient. This second channel (an "efficiency channel") is only present if barter transactions are more inefficient to tax than monetary ones, that is if $\delta > 0$.

The result that an increase in the the endowment of silver increases fiscal capacity may appear surprising, as one might have expected (in line with the fiscal capacity literature) that a greater natural resource endowment, by reducing the need for fiscal revenues, should *reduce* investment in fiscal capacity. Part of this discrepancy originates from the fact that unlike the previous literature, which typically assumes the resource to be owned by the government, we allow for the possibility that the silver be owned by the private sector ($\lambda < 1$). This clearly matters for the result, since, even in our model, to set $\lambda = 1$ entirely eliminates the private income channel through which an increase in σ affects increases fiscal capacity. However, our results do not entirely depend on the assumption that part of the silver be privately owned. As argued above, even if the private income channel is muted by setting $\lambda = 1$, an increase in σ still increases fiscal capacity, through the efficiency channel (provided $\delta > 0$). What's driving this result is that, in our setting, silver is a peculiar natural resource, since it can be used as money. This implies that, independently on who owns the silver, its use as money increases the share of monetary transactions in total transactions, thus making the transaction tax more efficient and hence worth investing in.[15]

Proposition 1 suggests that, for an under-monetized economy such as the one we are studying, the level of taxation and money supply are positively correlated in the long-run. This

[15] It is important to acknowledge that, for simplicity, we have assumed a utility function that is linear in public expenditure. Had it been concave, an increase in the endowment of government-owned silver would have had an additional negative effect on investment in fiscal capacity, by decreasing the marginal utility of public expenditure. In this alternative setting, in the extreme case in which the silver is entirely government-owned and barter transactions are as efficient to tax as monetary ones (that is if $\lambda = 1$ and $\delta = 0$), then an increase in σ would lead to a decrease in fiscal capacity. Even in that alternative setting, however, one could choose λ low enough and δ high enough so that a positive relationship between the two could still be found.

contrasts with the fiscal theory of the price level, according to which increasing taxation and increasing money supply, being alternative tools to raise revenues, tend to be inversely correlated. In essence, the difference between our model and the fiscal theory of the price level is that we endogenise monetary capacity, while the latter takes a high monetary capacity as given. Our reasoning is therefore better suited to study under-monetized economies who cannot take their level of monetization for granted. While we focus on the early modern period, a similar insight may be applicable to modern weak states, whose lack of fiscal capacity inhibits them from sustaining a monetized economy, resulting in a vicious cycle of undermonetization and underprovision of public goods.

3 Empirical analysis

Our framework argues that an exogenous positive shock to monetary capacity should increase fiscal capacity, and a positive shock to fiscal capacity should increase monetary capacity (Proposition 1). This section tests the first of these predictions, that is the causal impact of monetary capacity on fiscal capacity. The reason why we focus on this prediction is that the impact of monetization on fiscal capacity is less well-understood and has received less attention in the empirical literature than the impact of fiscal capacity on monetization.[16] Moreover, the natural experiment associated with the discovery and exploitation of massive amounts of silver in the Americas allows for a unique opportunity to identify the impact of monetary capacity on fiscal capacity.

The first subsection that follows discusses the variables that we employ in the empirical analysis. For sake of brevity, we relegate the detailed discussion of the data sources and methodology for constructing these variables to Appendix C. The second subsection discusses the empirical methodology. The causal effect of monetary capacity on fiscal capacity is estimated through

[16]For the early modern period, empirical support for the argument that fiscal capacity had a positive impact on monetization is provided by Karaman et al. (2020). For 11 European states between 1500 and 1900, this paper finds that a higher fiscal capacity stabilized monetary units, as states no longer depreciated their currencies for seignorage. This impact breaks down only at very low levels of fiscal capacity, because weak states lacked the capacity to circulate currency, and could not generate seignorage revenues in the first place. As for the modern period, empirical support for the impact of fiscal capacity on monetary stability is provided, among others, by Sargent (1982) and Catao and Terrones (2005).

a Local Projection Instrumental Variable (LP-IV) approach, where monetary capacity is instrumented by the discovery and extraction of precious metals from the Americas. The third subsection discusses the results. For all three countries for which detailed data is available (Spain, England and France), monetary capacity has a positive, significant and persistent effect on fiscal capacity. The fourth and last subsection discusses the robustness of the results.

3.1 Variables

We test the impact of monetary capacity on fiscal capacity, instrumenting the former with the silver and gold output in the Americas. These privately-extracted and owned outputs,[17] which peaked in the early 17th and late 18th century respectively for Potosí and Mexican silver, and in the mid 18th century for Brazilian gold, resulted in exogenous variation in European money stocks (see Palma 2022). Because we rely on a natural experiment for identification, we focus on the period in which this experiment was most relevant, between 1550 and 1790.[18] We also restrict the sample to England, France and Spain, the only countries for which detailed monetary and fiscal data is available. These countries were also among the most affected by the inflow of metals from the Americas (Palma, 2022).

According to Definition 11, monetary capacity is the maximum level of monetisation that a government can obtain, given its fiscal capacity. To measure this theoretical concept in the data, we can take advantage of the fact that, according to the model, monetisation coincides with monetary capacity in equilibrium. This result is also consistent with historical evidence according to which monetary capacity posed a binding constraint in early modern economies (Pomeranz and Topik 1999, p.14, p. 14). We thus proxy for monetary capacity using the yearly per capita real money stock, a measure of the economy's monetisation.[19] To calculate this proxy, we first collect the data on the money stocks of different countries. We then convert the money

[17]Among the countries considered, only for Spain was there a direct effect of metal outputs on government revenues, since the industry was taxed by the Spanish Crown. We take this issue into account in Section 3.2.

[18]The year 1550 marks the beginning of the arrival of American precious metals in Europe in large quantities, whereas the year 1790 marks the growing importance of paper money and a weakening relationship between precious metals and money stocks. For France we stop at 1788, before the French Revolution.

[19]We focus on state-issued money because private forms of money rarely circulated at the national level, did not last long without government backing, and complemented, rather than displaced, state-issued money.

stock from local currency into silver, the universal measure of value for the early modern period. We next divide the money stock by the population to get the per capita money stock in grams of silver. Finally, we divide the per capita money stock by the daily cost of a standard consumption basket in grams of silver to arrive at the per capita real money stock.[20]

As standard in the literature, we proxy for fiscal capacity using yearly per capita real tax revenues. This is also consistent with our model, where the tax rate (t) coincides with fiscal capacity (τ) in equilibrium. Per capita real tax revenues are calculated by dividing the central government revenues by the population and the daily cost of a standard consumption basket of each country. Consequently, fiscal capacity is measured in terms of standard consumption baskets, the same unit as monetary capacity.

Figure 3 shows the per capita real money stock and real tax revenue series for the three countries in our sample. The two series appear to be closely related, and both increased significantly through the early modern period. This close relationship, however, does not by itself imply a causal relationship between the two, since monetary and fiscal capacity may both be determined by other variables.

The yearly precious metal production in the Americas is measured as the sum of silver and gold production in metric tons, with the latter translated to silver units. As with other variables, the data sources are discussed in the Appendix C.

3.2 Empirical strategy

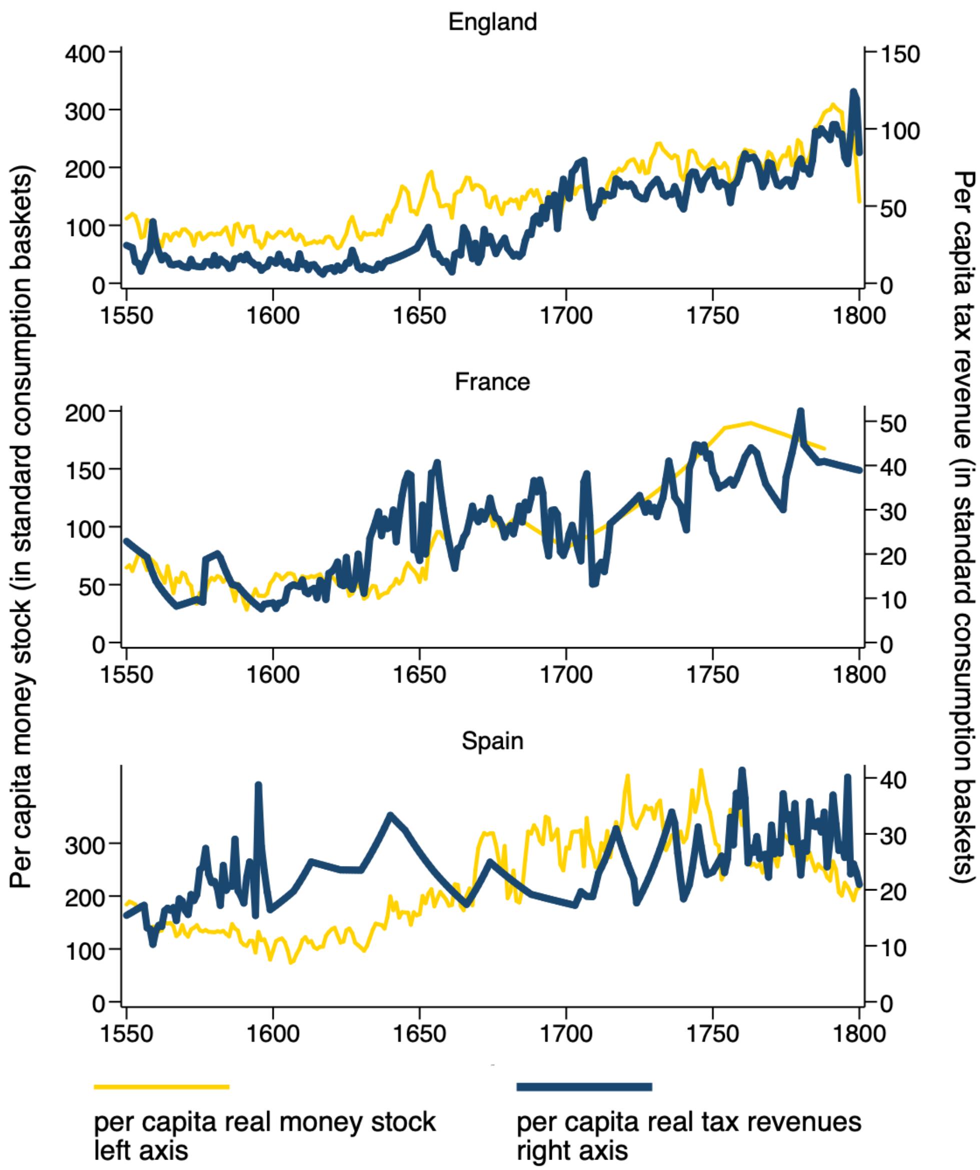
The empirical specification follows the Local Projection-Instrumental Variable (LP-IV) methodology (Jordà, 2005). This methodology uses an excluded instrument to estimate the causal effects for different time horizons. The methodology is well-suited for our aim of estimating long-run effects, as it yields consistent estimates even at long horizons.[21]

Following the LP-IV methodology, we proceed in two stages. In the first stage, we use the

[20]Money stocks (which for premodern Europe were predominantly composed of coin stocks) have been reconstructed using a combination of assumptions. These rely on the annual observation of mint output flows combined with the occasionally observed stock (usually at the moment of total or partial recoinages) and other supporting information, which varies from study to study. For more details on the reconstruction method of money stocks, see Palma (2018b).

[21]See Jordà et al. (2020b) for a general discussion of the methodology and the consistency of the estimates.

Figure 3: Money Stock and Tax Revenues Per Capita (in standard consumption baskets)



Note: See Appendix C for data sources.

production of precious metals in the Americas as an instrument for monetary capacity. In the second stage, we estimate the causal effect of monetary capacity on fiscal capacity, using only the exogenous variation in the former variable that was generated by the production of precious metals.

More in detail, the first-stage equation, estimated separately for each country i, is of the following form:

$$ln(monetary_{i,t}) = \alpha_i + \gamma_i ln(metals_{t-1}) + \boldsymbol{\phi_i} \mathbf{x_{i,t}} + e_{i,t}, \tag{15}$$

where $monetary_{i,t}$ is the per capita real money stock (our proxy for monetary capacity) in country i and year t, and $metals_{t-1}$ is total production of precious metals in the Americas in year $t-1$, expressed in grams of silver.[22]

The second-stage relationship is estimated separately for each country i for each time horizon h:

$$\ln(fiscal_{i,t+h}) - \ln(fiscal_{i,t-1}) = \alpha_{i,h} + \beta_{i,h} ln(\widehat{monetary}_{i,t}) + \boldsymbol{\psi_{i,h}} \mathbf{x_{i,t}} + u_{i,t+h}. \tag{16}$$

The outcome variable on the left-hand side is the cumulative growth of real per capita tax revenues (our proxy for fiscal capacity) in country i, between years $t-1$ and $t+h$. The main explanatory variable on the right-hand side, $ln(\widehat{monetary}_{i,t})$, is the log of the per capita real money stock, instrumented with the production of precious metals in the first stage. The vector $\mathbf{x_{i,t}}$ is a vector of control variables whose components are described below for each local projection result; at baseline, these include lags of the dependent variable, as well as contemporaneous and lagged values of the log of real GDP per capita.[23] The term $u_{i,t+h}$ is a horizon-specific error term. To address the potential serial correlation in the error term (Jordà, 2005), we use HAC-robust standard errors based on Newey and West (1987) throughout.[24]

The main coefficient of interest is $\beta_{i,h}$, estimated for each time horizon h in the second stage.

[22] Note that the excluded instrument has no i-subscript, since it is the same for all countries in the analysis.

[23] As explained in more detail further below, we explicitly control for real GDP per capita to account for a potential effect of the instrument on fiscal capacity via increased economic activity. Our results are unaffected by excluding this control variable.

[24] Montiel Olea and Plagborg-Møller (2021) note that the inclusion of lagged variables in the estimation can eliminate the need to use HAC-robust standard errors. In our specification, we include lagged variables and additionally allow for autocorrelation in the error term.

This coefficient captures the impact of exogenous changes in monetary capacity in year t on the cumulative growth of fiscal capacity in country i, between years $t-1$ and $t+h$. For example, $\beta_{i,0}$ measures the impact of monetary capacity on fiscal capacity between years $t-1$ and t; $\beta_{i,1}$ the impact between years $t-1$ and t; and so on.

One concern with the empirical strategy is whether the proposed instrument, precious metal production in the Americas, satisfies the two requirements of the instrumental variable approach.[25] The first requirement is relevance: the instrument, precious metal production, should be sufficiently correlated with the European money stocks, after controlling for other variables. The existence of a strong correlation between the two is confirmed by both historical and statistical evidence. In the early modern period, the bulk of the European money stock was coins made of silver and gold, and America was by far the most important producer of these two metals (Barrett, 1990). As for the statistical evidence, the first-stage estimation results presented in the next section corroborate the close relationship between precious metal production in the Americas and European money stocks.

The second requirement is the exclusion restriction: after controlling for other covariates, American precious metal production should affect fiscal capacity only through monetary capacity. There are several ways in which this condition could be violated. One potential violation would occur if conditions in Europe, such as the state of the economy, simultaneously affected both American metal production and fiscal capacity in Europe. The historical evidence suggests, however, that the variations in American precious metal production were independent of European conditions. In particular, Palma (2022) shows that both the discovery of the mines and the mining intensity were driven by local conditions and accidents, with a high degree of randomness. A second potential violation is that American metal production might have affected tax revenues through channels other than a stronger incentive to invest in fiscal capacity due to a higher monetisation. They might have increased tax revenues at constant fiscal capacity, by increasing economic activity, the taxability of transactions, or, in the case of Spain, by directly generating additional tax revenues for the government. Alternatively, they might have affected the incentive to invest in fiscal capacity through channels other than higher monetisation, such

[25] For a formal discussion, see Stock and Watson (2018).

as by triggering wars or a deterioration of political institutions. To address these concerns, we include as covariates real per capita GDP and, in robustness, measures of warfare and the representativeness of political regimes (as measured by the occurrence, or not, of parliamentary meetings in a year). In addition, we conduct our second stage over long time horizons of up to 30 years ($h = 30$), based on the logic that increases in tax revenues due to increased economic activity or a greater taxability of transactions should materialise in the short run, whereas those due to the development of fiscal capacity should build up over time. Finally, to further address potential violation of the exclusion restriction, we estimate a modified version of the LP-IV method based on the methodology outlined by Jordà et al. (2020a). The modified method assumes that the exclusion restriction does get violated, and adjusts the estimates for this violation. The results of these exercises, reported in the following sections, support the robustness of the empirical findings.

3.3 Results

Table 1 reports the first-stage results.[26] The F-statistic is above the rule-of-thumb value of ten for all three countries in the sample. Likewise, the elasticity of the per capita real money stock with respect to metal production in the Americas is positive and significant for all three, with a higher point estimate for Spain. In particular, a one percent increase in the production of precious metals in the Americas is estimated to have increased Spanish real per capita money supply by 0.5 percent after one year. This greater impact on Spanish money supply is expected, since the precious metals from the Americas first arrived in Spain, and diffused to England and France only indirectly through capture or trade.

Figure 4 presents the second-stage results. For each country i and horizon h, the vertical axis reports the point estimate of the coefficient $\beta_{i,h}$, together with the confidence intervals. For all three countries in our sample, an exogenous increase in monetary capacity increased fiscal capacity. For the timing of impact, it was fastest in Spain, where the effect of an increase in the real per capita money stock in year t was already visible in the same year, and peaked 5 years

[26] France has two observations fewer, because we end the sample before the French Revolution; doing this across all countries would yield similar results.

Table 1: First-stage results

Dependent variable: real money p. c.	England (1550-1790)	France (1550-1788)	Spain (1550-1790)
lagged metals production	0.189***	0.243***	0.495***
	(0.058)	(0.053)	(0.077)
Observations	241	239	241
First-stage F	10.42	20.76	41.27

Note: The table shows the first-stage results, where the endogenous variable is the log real per capita money stock. Regressions control for two lags of log per capita real tax revenues, as well as contemporaneous and lagged per capita real GDP. The LP-IV approach uses Newey-West standard errors throughout. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

later. In contrast, in England and France, the effect built up more slowly over time, peaking respectively 14 and 17 years after the increase in monetary capacity. For the magnitude of the effect, it was stronger in England and France than in Spain; over the course of 20 years, a one percent increase in the per capita real money stock increased per capita real tax revenues by between 1 and 1.5 percent in England and France, but by only 0.6 percent in Spain. As for the persistence of the effect, in all three countries, the impact was quite persistent over the 20-year time horizon considered in Figure 4. In Appendix Figure B.7, we extend the time horizon to 30 years, and show that the coefficient is remarkably stable even over this longer period of time.

The finding that, in England and France, the effect of greater monetary capacity built up slowly and was persistent over time, is evidence in support of our mechanism: it is what one would expect if the incentives to invest in fiscal capacity had strengthened following an increase in monetary capacity, and states had embarked in a process of capacity building which was both gradual, and with lasting effects. In contrast, alternative channels through which greater monetary capacity may have affected fiscal revenues - such as an increase in economic activity, or the taxability of transactions - should mostly have an immediate effect, or an effect which reduces over time (once prices adjust, and economic activity returns to pre-expansion levels).[27] From this standpoint, it is interesting to note that the baseline effect of greater monetary capacity is most rapid and smallest for Spain. As argued above, an immediate effect is expected for this

[27] Palma (2022) finds a hump-shaped impact of increases in American metal production on real GDP in Europe, with peaks 6-9 years after the injection. To control for several leads of per-capita real GDP leaves our results substantially unchanged.

country, where the government was able to tax the American precious metal industry directly. In terms of the model, it was $\lambda > 0$ for this country (the government directly owned a share of the silver), while it was $\lambda = 0$ for England and France (whose governments could only get the silver indirectly, by taxing monetary transactions): then, you would expect metal inflows to have a quicker effect on tax revenues in Spain, than in England or France. The model also provides an interpretation of the finding that metal inflows had a smaller effect on tax revenues in Spain: whereas England and France needed to develop their fiscal capacity to collect the silver from private citizens (the "private income channel" described in Section 2.3), this channel was less important for Spain. This point is strictly related to the well-known argument that Spain suffered from an "institutional resource curse" following the arrival of the American metals, since the direct inflow of the metals in government coffers made the King less dependent on local elites for tax revenues, and thus more willing to undermine the representative government.[28] We return to this point at the end of the next section.

3.4 Robustness

We next evaluate the robustness of the results. For this purpose, we estimate the impulse responses with different sets of control variables and different time horizons. We also estimate adjusted impulse response functions that take into account potential violations of the exclusion restriction, following the methodology of Jordà et al. (2020a).

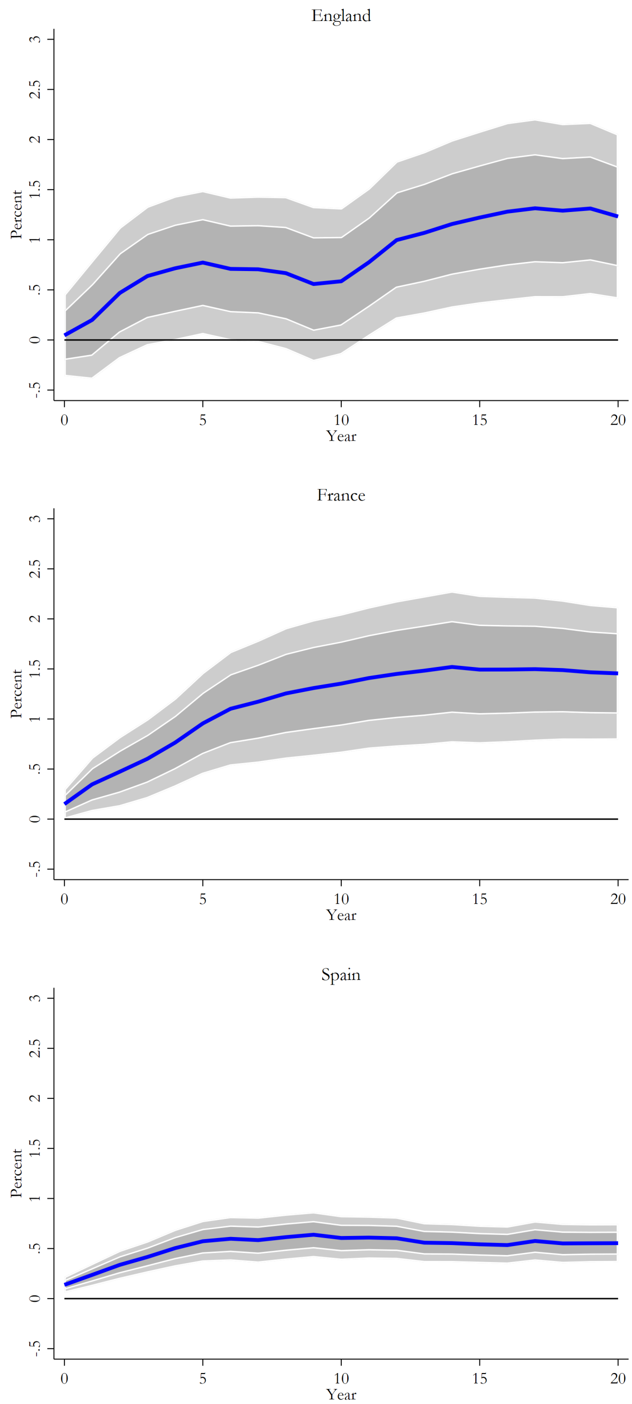
Robustness to control variables

Table 2 presents the estimation results for different sets of control variables. For each specification, the size of the impact and standard errors are reported for horizons $h = 10$ and $h = 20$. The full set of impulse responses are reported in the Appendix B.

Column 1 is the baseline specification, presented earlier in Figure 4. Columns 2 and 3 report the results when the money stock is instrumented with the contemporaneous or the second lag of metals production instead of the first lag. Across both specifications, the estimated coefficients are very similar in size and statistical significance to the baseline results.

[28] For a review of the literature concerned with Spain's resource curse, see Charotti et al. (2022).

Figure 4: % change in per capita real tax revenues due to a 1% exogenous increase in per capita real monetary stock



Note: LP-IV impulse responses showing the cumulative response of per capita real tax revenues to a 1% increase in per capita real money stock, instrumented with the production of precious metals. 90% (light gray) and 1 standard deviation (dark gray) Confidence Intervals shown, based on Newey-West standard errors. The regressions control for two lags of log of per capita real tax revenues, as well as contemporaneous and lagged per capita real GDP. See Appendix C for data sources.

Column 4 modifies the baseline specification by dropping real per capita GDP from the set of control variables. The estimated coefficients increase across all time horizons for England, while they stay similar for France and Spain. Note that in the baseline specification, the estimated coefficient for monetary capacity captures only its direct positive impact on fiscal capacity. When real per capita GDP is omitted from the set of control variables, the estimated coefficient also captures any indirect positive impact that may be transmitted through a higher real per capita GDP, which is consistent with a higher estimate.

Column 5 controls for the impact of warfare. Bellicist theories of state formation argue that wars in early modern Europe set in motion innovations in military and fiscal administration that resulted in ever higher tax revenues and the birth of the modern state (Hoffman and Norberg, 2002; Karaman and Pamuk, 2013; Levi, 1988; North, 1981; O'Brien and Palma, 2023). To account for any bias that the impact of warfare might introduce to the estimation results, we include a proxy for it in the regression equations. To construct the war proxy, we first calculate the total number of wars each state participated in each year, based on Brecke (1999). We then calculate a 3-year moving average of this variable, since the impact of war built up over time, and use this moving average as a control variable. When the proxy for warfare is included in the regressions, the estimates remain close to those in the baseline specification.

Column 6 controls for the level of parliamentary activity. The contract theory of the state argues that parliaments increased tax revenues, by making it easier for the executive and economic elites to settle on a tax-for-public-services deal, solving associated collective action problems, and lending legitimacy to taxation (Hoffman and Norberg, 2002; Levi, 1988; North, 1981). To account for the potential impact of the parliaments, we include in the regressions an indicator variable for parliamentary meetings for each year and state, based on Henriques and Palma (2023) for England and Spain, and De Magalhaes and Giovannoni (2022) for France, which takes the value 1 in years where the parliaments meets, and zero otherwise. For England and France, the estimation results remain similar to the baseline, while for Spain the estimate doubles. This result is consistent with the argument that American silver generated an "institutional resource curse" in Spain (see the discussion in the previous section). If the production of precious metals in the Americas had two separate effects on fiscal capacity, that is a positive effect through higher monetary capacity[29] and a negative one through the collapse of parliaments, then controlling for the latter would only leave the former to be estimated and result in a higher coefficient. Consistent with this interpretation, Figures B.5 and B.6 find that, when parliamentary activity is accounted for, the effect of higher monetary capacity on fiscal capacity builds up more slowly, peaking only about 10 years after the increase in monetary capacity.

The last column of Table 2 controls for the impacts of warfare and parliamentary activity simultaneously. The estimates remain very similar.

Table 2: Robustness checks

	Baseline	No Lag Instrument	Second Lag Instrument	No GDP Control	War	Parliaments	War and Parliaments
England							
$h = 10$	0.586	0.562	0.676	1.325***	0.479	0.633	0.529
	(0.443)	(0.448)	(0.433)	(0.478)	(0.512)	(0.460)	(0.539)
$h = 20$	1.232**	1.140**	1.175**	1.842***	1.293**	1.303**	1.376**
	(0.499)	(0.520)	(0.460)	(0.500)	(0.607)	(0.506)	(0.623)
France							
$h = 10$	1.354***	1.282***	1.462***	1.160***	1.546***	1.359***	1.587***
	(0.421)	(0.393)	(0.463)	(0.271)	(0.594)	(0.418)	(0.611)
$h = 20$	1.456***	1.369***	1.572***	1.299***	1.782***	1.458***	1.810***
	(0.403)	(0.371)	(0.447)	(0.259)	(0.593)	(0.408)	(0.613)
Spain							
$h = 10$	0.606***	0.601***	0.622***	0.601***	0.692***	1.566***	1.728**
	(0.134)	(0.127)	(0.139)	(0.128)	(0.177)	(0.536)	(0.675)
$h = 20$	0.554***	0.541***	0.582***	0.595***	0.595***	1.333***	1.411**
	(0.116)	(0.114)	(0.123)	(0.122)	(0.153)	(0.468)	(0.570)

This table shows second-stage results for horizons $h = 10$ and $h = 20$ for alternative specifications, with Newey-West standard errors in parentheses. The first column shows the baseline specification. The second and third column show alternative specifications where the contemporaneous value or the second lag of the metals production variable are used in the first stage, respectively. The fourth column shows the baseline specification without any GDP controls. The fifth, sixth and seventh column show results when adding war controls, parliament controls, and both of these controls to the baseline, respectively.

We also consider the validity of our results for longer time horizons of up to 30 years. Note that, the further we extend our horizon, the smaller the sample becomes, and thus the less reliable and precisely estimated the results are. Nevertheless, Appendix Figure B.7 clearly shows

[29] Recall that, in the model, even if silver is entirely owned by the government ($\lambda = 1$), an increase in monetisation still increases fiscal capacity through the efficiency channel, that is by making transactions easier to tax.

that the estimated effects remain strong and significant even over these longer time horizons.

Robustness to violations of the exclusion restriction

Thus far we have shown that our results are robust to the addition of controls, including variables that capture economic growth and political regimes. Nevertheless, violations of the exclusion restriction may still arise if precious metals increase fiscal capacity through a mechanism other than increased monetary capacity, whenever such a mechanism is not captured through our control variables. To further address this issue, we adopt the approach of Jordà et al. (2020a) to construct impulse responses which take into account violations of the exclusion. The approach proceeds by calculating impulse responses for a set of different plausible assumptions about the size of effects that violate the exclusion restriction. The results are presented in detail in Appendix Section D. The main takeaway is that, for the results to be significantly different from our baseline, the violation of the exclusion restriction would have to be large relative to our main proposed mechanism.

4 Long-run patterns

This section puts the theoretical model and empirical analysis in the preceding sections into a broader historical context by reviewing the comparative evidence since antiquity. The long-run evidence supports the notion that precious metal production, monetary capacity and fiscal capacity had a mutually reinforcing relationship and moved together through several cycles of ups and downs from antiquity to the Middle Ages. It also indicates that, in Western Europe, the American silver shock ended these cycles and had a substantial, asymmetric but transformative impact on the economy and politics. Finally, the comparative evidence of Europe and China suggests that the link between monetary and fiscal capacity becomes even stronger when paper money replaces commodity money.

4.1 Monetary and fiscal capacity from antiquity to the early modern period: the case of Europe

Evidence for the close connection between monetary and fiscal capacity is available since antiquity, though data for that period is scarce. The first well-documented historical peak in monetization and taxation was in the mid-5th century BC Athenian Empire. In this period, the estimated money stock per capita reached a level of around 200 grams of silver, and tax revenues per capita a level of around 10-15 grams. These levels were made possible, in part, by the Laurion silver mines located nearby the city of Athens, which had an estimated annual peak output of about 80 tons (Ober, 2015; Patterson, 1972).

After the decline of Athens, the second peak was reached during the Pax Romana. In the first two centuries AD, money stocks per capita rose to 50-100 grams of silver, and tax revenues per capita to 10-15 grams. Roman monetization was supported by the Iberian mines, which had an estimated annual output of 200 tons of silver (Duncan-Jones, 1998; Goldsmith, 1987; Hopkins et al., 2009; Patterson, 1972).

The Roman peak was in turn followed by a collapse in the third century AD. The precise line of causation is difficult to unravel. In terms of precious metal availability, the exhaustion of the Iberian mines and the resulting decline in annual silver output to about 30 tons arguably played a role (Patterson, 1972). Fiscally, the growing spending on war triggered depreciation of silver coinage and inflation, which in turn induced demonetization of the economy (Bransbourg, 2015; Harris, 2008; Kohn, 2005).[30]

The early Middle Ages marked the nadir of both monetary and fiscal capacity. On the monetary front, annual silver output in Europe is estimated to have decreased to a few tens of tons, and money stocks per capita to about 15 grams of silver (Patterson, 1972). On the fiscal front, centralized taxation collapsed, leaving little historical record of treasury revenues. These two processes were inherently related. Demonetization necessitated breaking up the armies into smaller units that could be supported by the local produce, and central governments ceded de

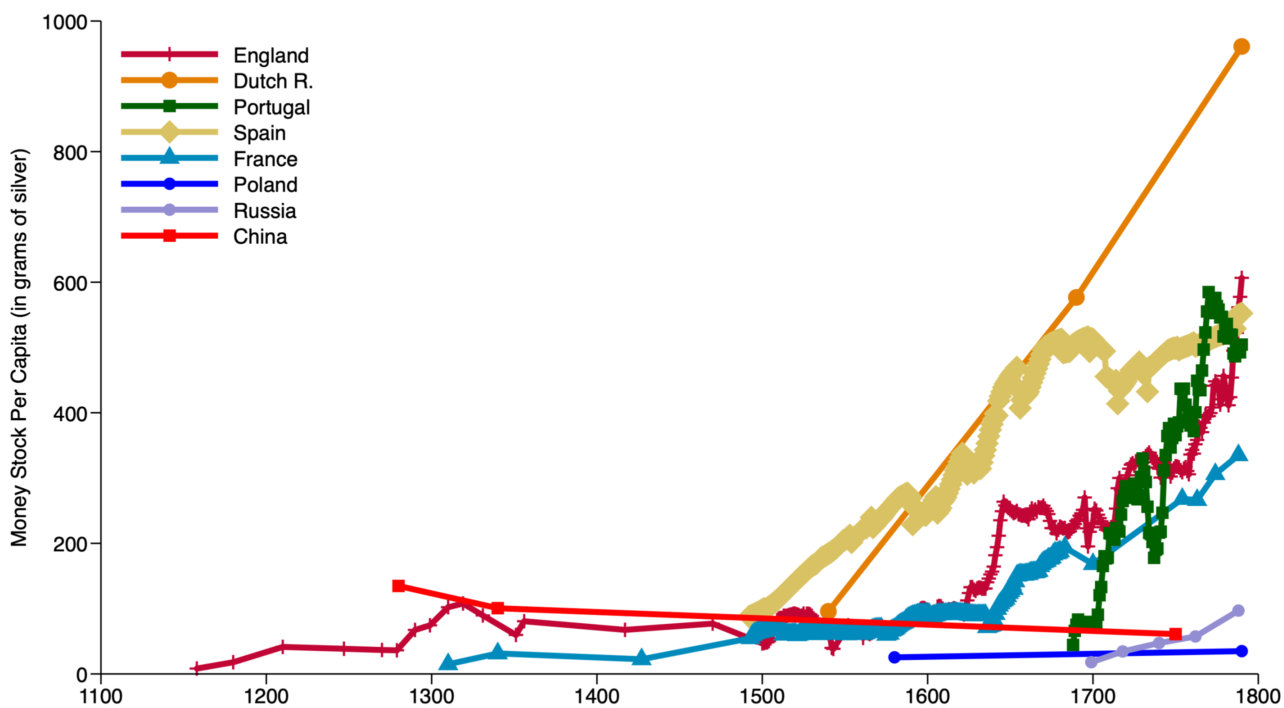
[30] During the Late Roman Empire, gold increasingly replaced silver, and perhaps constituted more than half of the money stock in value, but whether it was a perfect substitute for silver is debatable. Gold had a much slower velocity, and was only convenient for very large transactions (Goldsmith, 1987). Gold production itself declined after the fourth century and largely disappeared by the 8th century (Spufford, 1988, p. 18-21).

facto control over the countryside (Kohn, 2005; Spufford, 1988). The collapse of central governments in turn undermined monetization, as mining and minting required large-scale investments and centralized coordination.

Another cycle of expansion and contraction of silver output occurred from the 11th to the 15th centuries. With the discovery of new mines in northern and central Europe, annual silver output gradually increased to about 50 tons by around 1300. However, as soon as what could be extracted from these mines with the technology of the day was exhausted, the output began to decline, and collapsed back to around 15 tons by 1450s (Velde and Weber, 2000).

Estimates of the English money stock are available for this period, allowing us to track how its trajectory mimicked that of the medieval silver production cycle. Figure 5 presents these estimates, expressed in grams of silver. The English per capita money stock increased from 10 grams to 150 grams from 1150 to 1300, but fell back to around 70 grams by 1450, in line with the silver production estimates.

Figure 5: Money Stock Per Capita (in grams of silver)



Note: See Appendix C for data sources.

The 16th century marked a dramatic increase in the availability of precious metals, driven by massive silver and gold production in the Americas: annual production (in silver-equivalent units) varied between 200 and 800 metric tons over most of the early modern period (Palma, 2022, p.1599). The silver arrived in Europe in two waves, with Potosí silver peaking in the early 17th and Mexican silver in the late 18th century. Gold production, mainly located in Brazil, peaked around the mid-18th century (Barrett, 1990; Palma, 2020).

This drastic increase in precious metals availability marked the end of the cycles of monetization and demonetization and the beginning of a dramatic upsurge in money stocks in Western Europe. Figure 5 plots the available fragmentary evidence on the per capita money stocks of the Dutch Republic, Portugal, Poland-Lithuania and Russia, in addition to the more detailed estimates for England, Spain and France discussed earlier. It also includes data for China, a country to which we return in Section 4.2 below.

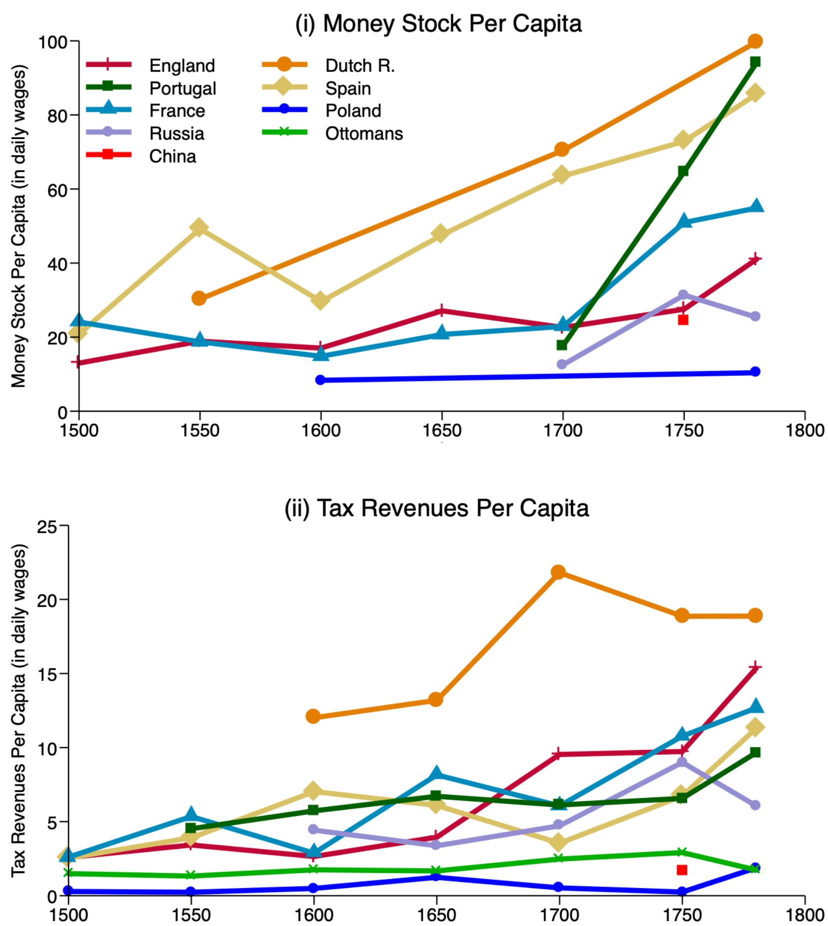
Three patterns stand out. First, the per capita money stocks of Western European countries surged following the inflow of precious metals from the Americas, from 50-100 grams in 1500 to 300-1000 grams in 1800. Second, the trajectory of money stocks once again mimicked that of precious metal production. For Spain, England and France, there were two local peaks, in the mid-17th and late 18th centuries, coinciding with the peaks in silver output. For Portugal and England, the main beneficiaries of the Brazilian gold, per capita money stocks increased rapidly over the 18th century. Finally, Figure 5 also makes it clear that American precious metals had an asymmetric impact across Western and Eastern Europe. The precious metals first arrived in Western Europe. They then diffused to Eastern Europe through trade, but only to a limited extent, leading to a divergence in monetization levels. As the figure illustrates, monetization levels in Poland and Russia remained low.[31]

One limitation of the per capita monetary stock series presented in Figure 5 is that they are in nominal terms, and are not measured relative to GDP. Establishing a real impact requires showing that the per capita money stocks increased in real terms, and also as a share of per capita GDP. The top panel of Figure 6 addresses these issues by plotting, for the eight countries

[31] Russia received limited American silver, and continued to rely on barter and furs in addition to foreign coins (Bonney, 1995; LeDonne, 1991; Seljak; Spasskii, 1970). Monetization levels only picked up in the 18th century, after opening of local silver mines (Danila, 2006; Kahan and Hellie, 1985; Kotilaine, 2005).

considered thus far plus the Ottoman empire, the ratio of per capita money stocks to the nominal wages of unskilled workers, a commonly used proxy for per capita GDP in historical studies. The results are consistent with a real impact. For Western European states, per capita money stocks increased from 15 to 20 days worth of unskilled workers' wages in 1500 to around 45 to 100 days by 1800, while in Eastern Europe they remained stagnant.

Figure 6: Money Stock and Tax Revenues Per Capita (in daily wages)



Note: See Appendix C for data sources.

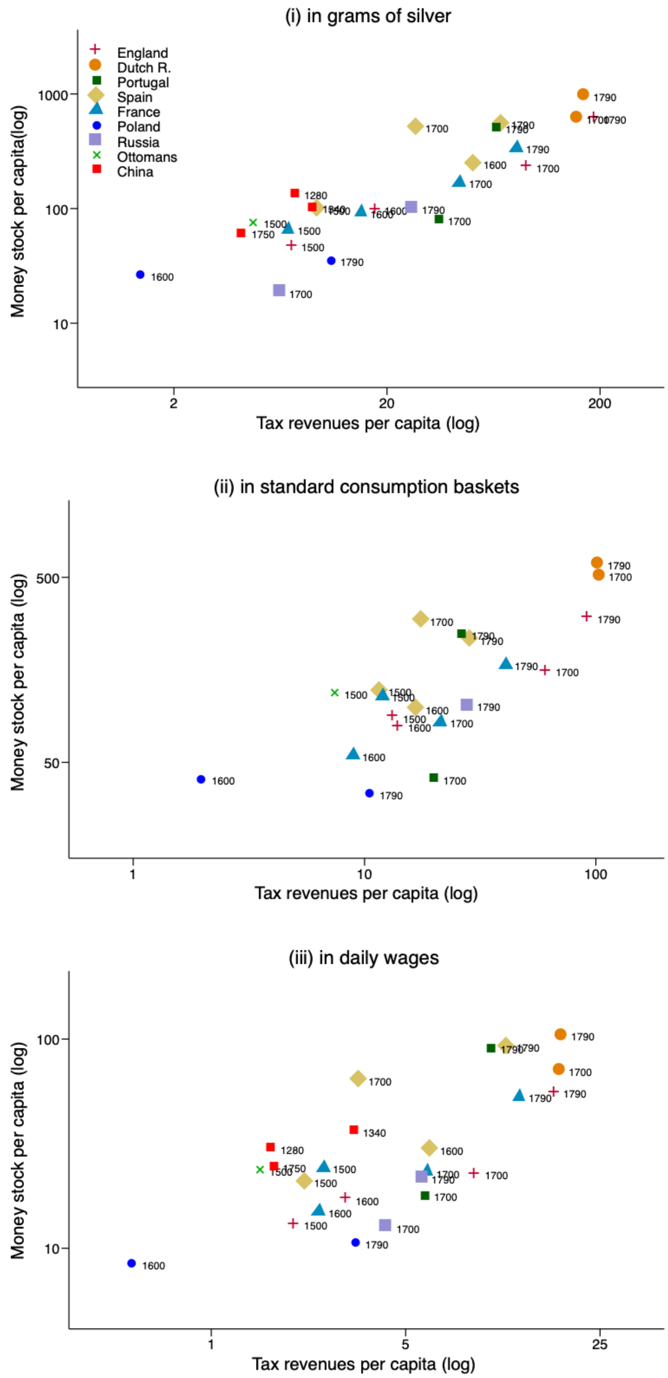
To explore the fiscal counterpart to this increase in monetisation, the bottom panel in Figure 6 plots the ratio of per capita tax revenues to nominal wages, for the same countries. The figure confirms a corresponding real increase in fiscal capacity. In Western Europe, per capita tax revenues increased from about 3 days worth of unskilled workers' wages in 1500 to about 10-15 days by 1800, while they lingered at lower levels in the East.

Additional evidence of the close relationship between monetary and fiscal capacity in early-modern Europe is provided in Figure 7. For all countries except for China, we plot per capita monetary stocks against per capita tax revenues at four points in time: 1500, 1600, 1700 and 1790. For China, we include all the available data (for 1280, 1340 and 1750) and further discuss this evidence below. The three panels present, respectively, nominal values, real values, and real values as a share of per capita GDP (as proxied by the wages of unskilled workers). All three panels find a clear, positive relationship between per capita money stocks and tax revenues.

The virtuous cycle of monetary and fiscal capacity building in early modern Western Europe ultimately altered the nature of money, but not the close relationship between the two. The money stock series presented in this section keep track of the levels of commodity silver and gold money over time. Increasingly, however, public banks began to experiment with paper money convertible to silver and gold. These experiments culminated in the successful paper note issue by the Bank of England in 1694—a model which later spread across Europe—following which banknotes gradually became an important means of exchange (Palma, 2018a,b). The growing adoption of convertible and later fiat paper money in turn weakened the historical dependence of the money supply on precious metals production. The value of paper money, however, still depended on the fiscal capacity of the state, perhaps even more so than commodity money. Hence, while the relationship between precious metals and monetary capacity weakened, the relationship between monetary and fiscal capacity persisted.

All in all, the long-run historical evidence identifies large contemporaneous swings in monetary and fiscal capacity, which continued until the massive liquidity shock of American silver and gold. This shock transformed the European economy by increasing monetization levels in Western Europe, and ultimately undermining the dependence on precious metals for the money supply itself. There is also overwhelming evidence that the shock triggered a virtuous cycle of monetary and fiscal capacity building, consistent with the theoretical and empirical analysis presented in earlier sections.

Figure 7: Monetary and Fiscal capacity



Note: See Appendix C for data sources.

4.2 The case of premodern China in Europe's mirror

It is informative to compare the European experience with that of China. Already in the Middle Ages, faced with the scarcity of precious metals which plagued China prior to direct contact with the Europeans from the sixteenth century (Palma and Silva, 2024), the Song dynasty (960–1279) was able to successfully introduce paper money in the Sichuan region. Paper money was used for both commerce and tax collection, the latter being a key motivation for the state's involvement with monetary affairs (von Glahn, 1996).

The Song's successors, the Yuan (1271–1368), inherited a favorable level of fiscal capacity and were then able to introduce paper money which circulated widely in all of China (von Glahn, 2024). Fiscal capacity was high by the standards of the time: according to Figure 7, per capita tax revenues in 1340 stood at a higher level than those of many European countries as late as 1600. Monetary capacity was also comparatively high: despite China's scarcity of precious metals, its 1280 and 1340 per capita money stocks—as measured by Figure 7, most likely an underestimate of the true value—were higher than most observations in 1500-1790 Europe.[32] There were in this period occasional episodes of high inflation due to war pressure, but they were only transitory.[33]

Paper money only collapsed for good during the early Ming dynasty (1368–1644), due to the fiscally weak nature of the state (von Glahn, 2020, 2024). Zhu Yuanzhang, a son of poor peasants who commanded the Red Turban Rebellions, eventually toppled the Yuan and became the first Ming emperor, Hongwu. The Hongwu Emperor rejected the market economy and steered China towards a new fiscal model, based on a collection of almost autarkic self-sufficient farming communities (von Glahn, 2016, 2020). Due to scarcity of precious metals, paper money's existence had relied strongly on the credibility of the state. Given that fiscal foundations, in turn, matter for credibility and expectations formation, the Ming's destruction of the fiscal foundations of the state carried with it the seeds of destruction of paper money. The Ming (1368–1644)

[32]The data only includes paper money, however commodity-based money was also in circulation (Guan et al., 2024).

[33]For example, in the mid fourteenth century, the annual inflation rate was close to 13 per cent, and this was then followed by a brief period of hyperinflation (Guan et al., 2024, p.12). A contemporary scholar called Wang Yun wrote that unrestrained printing of paper money made it into nothing but empty script (von Glahn, 1996, pp.61-3)

and Qing (1644–1911) dynasties remained anchored on low levels of taxation levied on land, commerce, industry, and consumption (von Glahn, 2020, p.22). By the late fifteenth century, paper money no longer circulated (von Glahn, 1996). As shown by Figure 7, by 1750, China's per capita tax revenues were one of the lowest in the sample, and its per capita money stock was much lower than that of, for example, that of England, Dutch Republic, Portugal and Spain. China continued to have low state capacity until the second half of the twentieth century (Brandt et al., 2014; Ma, 2013).

The comparative experience of Europe and China is informative to understand why China eventually failed, while Europe succeeded. England's eighteenth century experience was the first successful, sustained experience with paper money since medieval China. Although the bank did suspend convertibility in 1797-1821, its holding of government debt as reserves during this period implied that the credibility of money (i.e. the likelihood of price stability) implicitly relied on the credibility of the government's fiscal position. The survival of paper money thus bears testimony to the solidity of England's fiscal position. At the same time, the converse was also true: the Bank of England's success in circulating the notes contributed to war victories and the financial stability of the state, and made it easier for the government to collect taxes (O'Brien and Palma, 2020, 2023; Palma, 2018a). In the case of China, were the state issued money directly, it was even more evident that people could trust paper money to the same extent that they could trust public finance. Failure on the fiscal front was a key reason why China went permanently off paper money from the Ming dynasty until the twentieth century. But conversely, this monetary limitation bounded tax collection efforts.

5 Conclusion

Monetary and fiscal capacity are jointly determined. This fact has implications for both macroeconomics and development.[34] In macroeconomics, higher taxes and monetary expansions are generally modeled as substitutes (Mankiw, 1987; Sargent and Wallace, 1981; Sims, 1994). In contrast, we argue that, in the long run, they are complements: monetization is a precondition

[34]It was previously known that more advanced economies tend to have more advanced monetary and financial systems, but the direction of causality has been a matter of debate (Levine, 2005).

for the building of fiscal capacity, and, in turn, countries with high fiscal capacity are capable of building more efficient monetary systems. This co-dependence also suggests that, in the context of under-monetized economies, money is not neutral, even in the long run.

The descriptive and theoretical arguments of our paper are supported by causal estimates of the effects of monetary capacity on fiscal capacity. For this purpose, we rely on what was arguably the most significant exogenous shock to monetary capacity in history: the inflow of silver and gold from the Americas. Our rich data for England, France and Spain allows us to pursue an instrumental variable approach, where we instrument money supply through the production of silver and gold in American mines. We find that a one percent increase in the real per capita money stock led to a 0.6-1.5% increase in fiscal capacity over a decade. Importantly, this effect did not diminish over the course of subsequent decades. Thus, the level of monetization significantly affected the real economy in the long run. Our historical discussion suggests that the cases of England, France and Spain are far from exceptional: complementarity between monetary and fiscal capacity has been the rule across the ancient, medieval and early modern world.

For economic development, our results relate to the growing emphasis on the role of state capacity, both as a force which historically allowed Western European countries to surge ahead, and as a constraint in developing countries today. We highlight one neglected cost imposed on societies where the state is too weak: the inadequate provision of a liquid means of exchange, which hinders the collection of taxes. For the empirical evidence, we rely on the premodern period, as it allows identifying long-run trends, and provides a natural experiment for establishing the causal effects. The argument, however, is more general, and relevant for under-monetized economies both historical and modern.

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Appendix

to *"Monetary Capacity"*

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A Theory Appendix

Sketch of a general model with heterogeneous transaction costs. Suppose that agents are heterogeneous in terms of their search costs, and ordered on the $[0, 1]$ interval in order of decreasing search costs. In particular, agent $i \in [0, 1]$ faces search costs equal to $\phi - \theta i$ (where we assume $\theta \geq 0$ and $\phi - \theta > 1$). For $\theta = 0$, this model is identical to the baseline model.

Supply of silver is the same as in the baseline model. To derive demand for silver, note that for every unit of own consumption good that agent i exchanges in barter transactions, they bring home $1/[(\phi - \theta i)t]$ units of another agent's consumption good. If instead they exchange the unit for silver in monetary transactions, they bring home $1/(pts)$ units of silver. Since another agent's consumption good and silver have equal weights in utility, agent i opt for monetary transactions if and only if

$$\begin{aligned} ps &< \phi - \theta i \\ p &< \frac{\phi - \theta i}{s}. \end{aligned}$$

If follows that, if $p < (\phi - \theta)/s$, all agents opt for monetary transactions, whereas if $p > \phi/s$, no one does. For intermediate values of p, all and only the agents located to the left of agent $i(p)$ opt for monetary transactions, where

$$\begin{aligned} i(p) &= \arg\left[ps = \phi - \theta i(p)\right] \\ &= \frac{\phi - ps}{\theta}. \end{aligned}$$

Aggregate demand for silver is then

$$B^d = \begin{cases} \frac{1}{p} & \text{if} \quad p < \frac{\phi - \theta}{s} \\ \frac{1}{p}\frac{\phi - ps}{\theta} & \text{if} \quad p \in \left[\frac{\phi-\theta}{s}, \frac{\phi}{s}\right] \\ 0 & \text{if} \quad p > \frac{\phi}{s} \end{cases} .$$

Under Assumption 1 and a weaker version of Assumption 2—that is $\sigma < 1/(\phi - \theta)$—supply meets demand at a price comprised between $(\phi - \theta)/s$ and ϕ/s. Then, the equilibrium price is found by equating demand and supply, i.e.

$$\frac{1}{p}\frac{\phi - ps}{\theta} = \sigma$$
$$p = \frac{\phi}{\theta\sigma + s}.$$

As can be seen, the equilibrium price is decreasing in the endowment of silver, σ.

Monetisation is now

$$m = \sigma\frac{\phi}{\theta\sigma + s},$$

It is easy to verify that the comparative statics of monetisation in the general model is qualitatively the same as in the baseline case ($\theta = 0$).

Derivation of optimal seignorage tax. Let

$$\Gamma(t) \equiv \frac{1}{t} + \alpha\frac{t-1}{t}.$$

Indirect utility can be rewritten as

$$W(s,t) = \Gamma(t)\left[\frac{(1-\lambda)\sigma}{s}p + \frac{1}{\phi}\right] - \alpha\frac{t-1}{t}\delta\frac{1}{\phi}(1-\sigma p) + \alpha\left\{\frac{s-1}{s}\sigma\left[(1-\lambda)p + 1\right] + \lambda\sigma p\right\} - \alpha\xi C(\tau) \tag{17}$$

$$= \frac{\Gamma(t)}{\phi} - \alpha\frac{t-1}{t}\delta - \alpha\xi C(\tau) + \frac{\Gamma(t) + \alpha(s-1)}{s}(1-\lambda)\sigma p + \alpha\frac{t-1}{t}\delta\sigma p + \alpha\lambda\sigma p + \alpha\frac{s-1}{s}\sigma$$
$$= \frac{\Gamma(t)}{\phi} - \alpha\frac{t-1}{t}\delta - \alpha\xi C(\tau) + \frac{\Gamma(t) + \alpha(s-1)}{s}(1-\lambda)\sigma p + \left(\alpha\frac{t-1}{t}\delta + \alpha\lambda\right)\sigma p + \alpha\frac{s-1}{s}\sigma \tag{18}$$

The first three terms in (18) do not depend on s. The fourth term is the part of indirect utility which depends on the seignorage tax on sellers of silver: note that $\Gamma(t) = 1$ for $t = 1$, and $\Gamma(t) \to \alpha$ as $t \to \infty$. The last two terms are the part of indirect utility which depends on the seignorage tax on buyers of silver.

$$
\begin{aligned}
\frac{dW(s,t)}{ds} &= \frac{\alpha s - [\Gamma(t) + \alpha(s-1)]}{s^2}(1-\lambda)\sigma p + \left[\frac{\Gamma(t)+\alpha(s-1)}{s}(1-\lambda)\sigma + \alpha\frac{t-1}{t}\delta\sigma + \alpha\lambda\sigma\right]\frac{dp}{ds} + \\
&\quad + \alpha\frac{s-(s-1)}{s^2}\sigma \qquad (19) \\
&= \frac{\alpha - \Gamma(t)}{s^2}(1-\lambda)\sigma\frac{\phi}{s} - \left[\frac{\Gamma(t)+\alpha(s-1)}{s}(1-\lambda)\sigma + \alpha\frac{t-1}{t}\delta\sigma + \alpha\lambda\sigma\right]\frac{\phi}{s^2} + \alpha\frac{1}{s^2}\sigma \\
&= \frac{\sigma\phi}{s^3}\left\{[\alpha - \Gamma(t)](1-\lambda) - [\Gamma(t)+\alpha(s-1)](1-\lambda) - \alpha\frac{t-1}{t}\delta s - \alpha\lambda s + \frac{\alpha s}{\phi}\right\} \\
&= \frac{\sigma\phi}{s^3}\left\{2\left[\alpha - \frac{1}{t} - \alpha\frac{t-1}{t}\right](1-\lambda) - \alpha s(1-\lambda) - \alpha\frac{t-1}{t}\delta s - \alpha\lambda s + \frac{\alpha s}{\phi}\right\} \\
&= \frac{\sigma\phi}{ts^3}\left\{2(\alpha-1)(1-\lambda) - \alpha s\frac{(1-\lambda)\phi t + (t-1)\delta\phi + \lambda\phi t - t}{\phi}\right\} \\
&= \frac{\sigma\phi}{ts^3}\left\{2(\alpha-1)(1-\lambda) - \alpha s\frac{t(\phi-1)+(t-1)\delta\phi}{\phi}\right\}. \qquad (20)
\end{aligned}
$$

Note that if the seignorage tax on buyers of silver was zero, then the last two terms in (19) would disappear (it would be $dp/ds = 0$ in this case), and $W(s,t)$ would be monotonically increasing in s. Thus, the distortionary effect of the seignorage tax entirely originates from the fact that it reduces demand for silver.

The government maximises (18) w.r.t. s, subject to the constraint $s \geq 1$. Consider the unconstrained problem first. From (20), the FOC is

$$
s = (1-\lambda)\frac{2\phi(\alpha-1)}{\alpha[t(\phi-1)+(t-1)\delta\phi]} = \tilde{s}.
$$

From (20), it is clear that $d^2W(s,t)/ds^2 < 0$ when $s = \tilde{s}$. Then, the FOC is both necessary and sufficient for a maximum.

If $\tilde{s} \geq 1$, the constrained optimum coincides with the unconstrained one. If $\tilde{s} < 1$, since $dW(s,t)/ds < 0$ for $s \geq 1$, it is $s = 1$ at the constrained optimum. □

Derivation of optimal transaction tax. Indirect utility can be re-written as in (17).

Then,

$$\frac{dW(s,t)}{dt} = \frac{d\Gamma(t)}{dt}\left[\frac{(1-\lambda)\sigma}{s}p + \frac{1}{\phi}\right] - \alpha\frac{1}{t^2}\delta\frac{1}{\phi}\left(1-\sigma p\right) \tag{21}$$

$$= \frac{\alpha-1}{t^2}\left[\frac{(1-\lambda)\sigma}{s}\frac{\phi}{s} + \frac{1}{\phi}\right] - \alpha\frac{1}{t^2}\delta\frac{1}{\phi}\left(1-\sigma\frac{\phi}{s}\right) \tag{22}$$

$$= \frac{\alpha}{t^2}\left\{\left(\frac{\alpha-1}{\alpha}-\delta\right)\frac{1}{\phi} + \left[\frac{\alpha-1}{\alpha}\frac{1-\lambda}{s(t)} + \frac{\delta}{\phi}\right]\mu(\sigma,t)\right\} \tag{23}$$

Clearly, a sufficient condition for $dW(s,t)/dt > 0$ is

$$\frac{\alpha-1}{\phi} - \alpha\delta\frac{1}{\phi} > 0 \tag{24}$$

$$\delta < \frac{\alpha-1}{\alpha}. \tag{25}$$

□

Identification of optimal fiscal capacity. Indirect utility given optimal policy can be rewritten as

$$W[s(\tau),\tau] = \frac{1+\alpha(\tau-1)}{\tau}\left[\frac{(1-\lambda)}{s(\tau)}\frac{\phi}{s(\tau)} + \frac{1}{\phi}\right] - \alpha\frac{\tau-1}{\tau}\delta\frac{1}{\phi}\left[1-\sigma\frac{\phi}{s(\tau)}\right] +$$
$$+\alpha\left\{\frac{s(\tau)-1}{s(\tau)}\sigma\left[(1-\lambda)\frac{\phi}{s(\tau)}+1\right] + \lambda\sigma\frac{\phi}{s(\tau)}\right\} - \alpha\xi C(\tau)$$

$$\frac{dW[s(\tau),\tau]}{d\tau} = \frac{\partial W[s(\tau),\tau]}{\partial\tau} + \frac{\partial W[s(\tau),\tau]}{\partial s(\tau)}\frac{ds(\tau)}{d\tau}$$
$$= \frac{\partial W[s(\tau),\tau]}{\partial\tau}$$
$$= \frac{\alpha}{\tau^2}\left\{\left(\frac{\alpha-1}{\alpha}-\delta\right)\frac{1}{\phi} + \left[\frac{\alpha-1}{\alpha}\frac{1-\lambda}{s(\tau)} + \frac{\delta}{\phi}\right]\mu(\sigma,\tau)\right\} - \alpha\xi\frac{dC(\tau)}{d\tau} \tag{26}$$

where the second line follows from the fact that, if $s(\tau)=1$, then $ds(\tau)/d\tau = 0$, and if $s(\tau) > 1$, then by the optimal choice of $s(\tau)$, $\partial W[s(\tau),\tau]/\partial s(\tau) = 0$. By Assumption 4, the first term in curly brackets is positive. Then, by the properties of $C(\tau)$, $dW[s(\tau),\tau]/d\tau > 0$ for $\tau = 1$.

From (9) there exists $\overline{\tau} \geq 1$ such that, for $\tau > \overline{\tau}$, $s(\tau) = 1$. To see this, note that

$$(1-\lambda)\frac{2\phi(\alpha-1)}{\alpha[\tau(\phi-1)+(\tau-1)\delta\phi]}$$

is decreasing in λ and δ, and increasing in α and ϕ. Setting $\lambda = \delta = 0$, and letting $\alpha \to \infty$ and $\phi \to \infty$, this expression becomes

$$\frac{2}{\tau}$$

which decreases to zero as $\tau \to \infty$.

Replacing $s(\tau) = 1$ in (26), it is then easy to verify that there exists a finite $\hat{\tau}$, with either $\hat{\tau} \geq \overline{\tau} > 1$ or $\hat{\tau} > \overline{\tau} = 1$, such that $dW[s(\tau), \tau]/d\tau < 0$ for $\tau > \hat{\tau}$. Since $dW[s(\tau), \tau]/d\tau > 0$ for $\tau = 1$ and $dW[s(\tau), \tau]/d\tau < 0$ for $\tau > \hat{\tau}$, and $dW[s(\tau), \tau]/d\tau$ is a continuous function, $dW[s(\tau), \tau]/d\tau$ must cross the zero line from above at least once in the interval $[0, \hat{\tau}]$. Each such point is a local maximum, and one of them is a global maximum. At each such point, condition (14) holds. $\square$

Verification that Assumptions 1-4 can simultaneously hold in equilibrium. Given $\tau = \tau^*$ (where τ^* is implicitly defined by 14), $t^* = \tau^*$ and $s^* = s(\tau^*)$, Assumption 1 can be written as

$$s(\tau^*)\tau^* < \frac{\phi}{s(\tau^*)} \qquad \text{(Assumption 1)}$$

$$[s(\tau^*)]^2\tau^* < \phi$$

$$\left\{\max\left[1, (1-\lambda)\frac{2\phi(\alpha-1)}{\alpha[\tau^*(\phi-1)+(\tau^*-1)\delta\phi]}\right]\right\}^2 \tau^* < \phi \tag{27}$$

For convenience, report Assumptions 2-4 here:

$$\sigma < \frac{1}{\phi} \quad \text{(Assumption 2)}$$

$$\frac{2\phi(\alpha-1)}{\alpha(\phi-1)} > 1 \quad \text{(Assumption 3)}$$

$$\delta < \frac{\alpha-1}{\alpha}. \quad \text{(Assumption 4)}$$

It is always possible to choose ϕ high enough so that Assumption (1) is satisfied. To see this, note that, as $\phi \to \infty$, the LHS of condition (27) converges to

$$\left\{ \max \left[1, (1-\lambda) \frac{2(\alpha-1)}{\alpha[\tau^* + (\tau^*-1)\delta]} \right] \right\}^2 \tau^*$$

which is a finite for any $\lambda \in [0,1]$, $\alpha > 1$ and $\delta \in [0,1]$, given that τ^* is finite. Next, it is always possible to make σ small enough, so that Assumption 2 holds. Finally, for any $\phi > 1$, it is possible to choose α so that Assumption 3 holds and, given such α, δ low enough so that Assumption 4 holds.

Proof to Proposition 1. Totally differentiating $dW[s(\tau^*), \tau^*]/d\tau^* = 0$ w.r.t. τ^* and any other parameter x, we obtain

$$\frac{d^2W[s(\tau^*), \tau^*]}{d(\tau^*)^2} d\tau + \frac{d^2W[s(\tau^*), \tau^*]}{d\tau^* dx} dx = 0$$

$$\frac{d\tau^*}{dx} = -\frac{\frac{d^2W[s(\tau^*), \tau^*]}{d\tau^* dx}}{\frac{d^2W[s(\tau^*), \tau^*]}{d(\tau^*)^2}}$$

From the discussion following equation (26), it is clear that $d^2W[s(\tau^*), \tau^*]/d(\tau^*)^2 < 0$ for $\tau = \tau^*$. Then, $d\tau^*/dx$ has the same sign as $d^2W[s(\tau^*), \tau^*]/d\tau^* dx$. From equation (26), it is easy to see that

$$\frac{d\tau^*}{d\sigma} > 0$$
$$\frac{d\tau^*}{d\alpha} > 0$$
$$\frac{d\tau^*}{d\xi} > 0$$

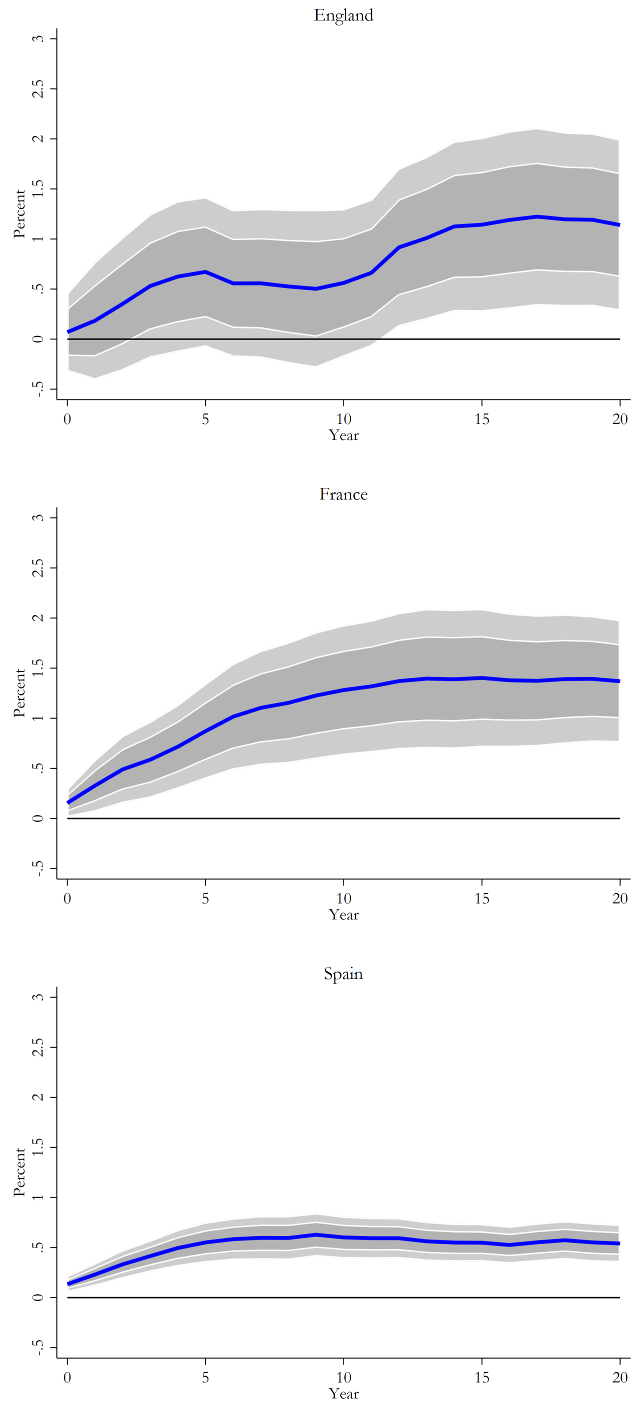
By equation (11), it is then

$$\frac{d\mu(\sigma, \tau)}{d\sigma} \geq 0$$
$$\frac{d\mu(\sigma, \tau)}{d\alpha} \geq 0$$
$$\frac{d\mu(\sigma, \tau)}{d\xi} \geq 0.$$

□

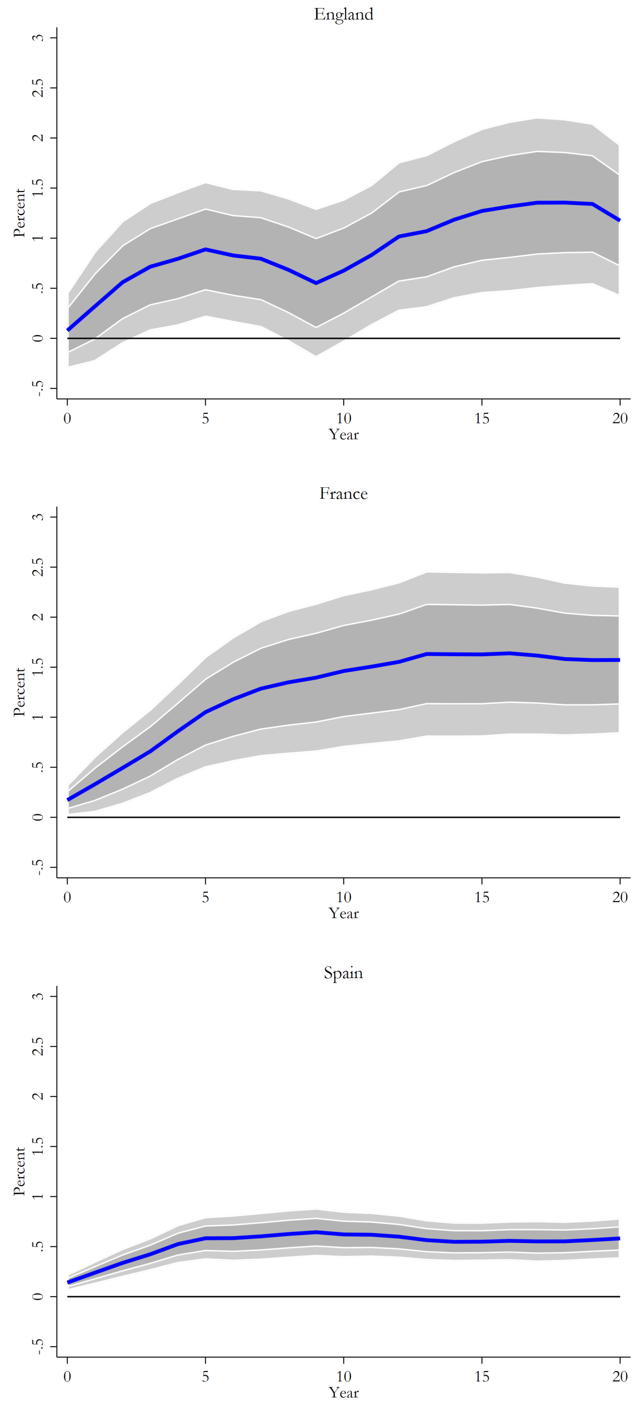
B Additional Figures and Robustness

Figure B.1: Robustness: contemporaneous lag of metals production



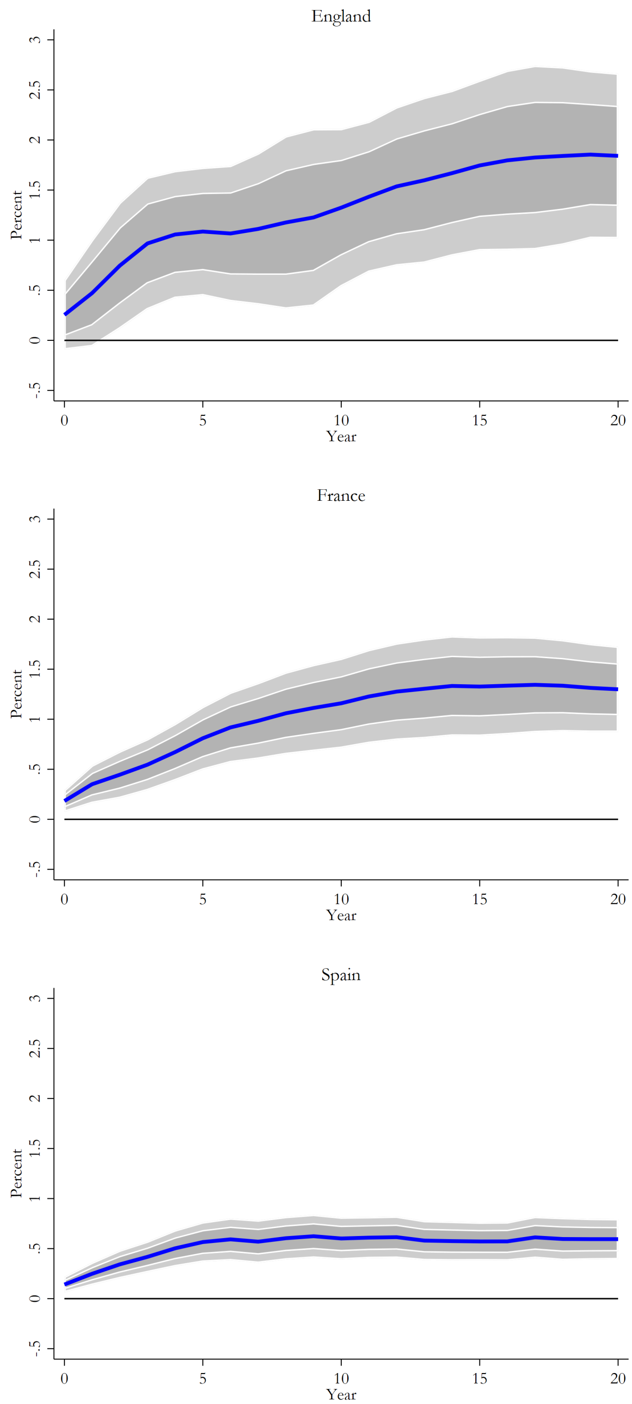
Note: LP-IV impulse responses, with contemporenous metals production (Column 2 of table 2).

Figure B.2: Robustness: second lag of metals production



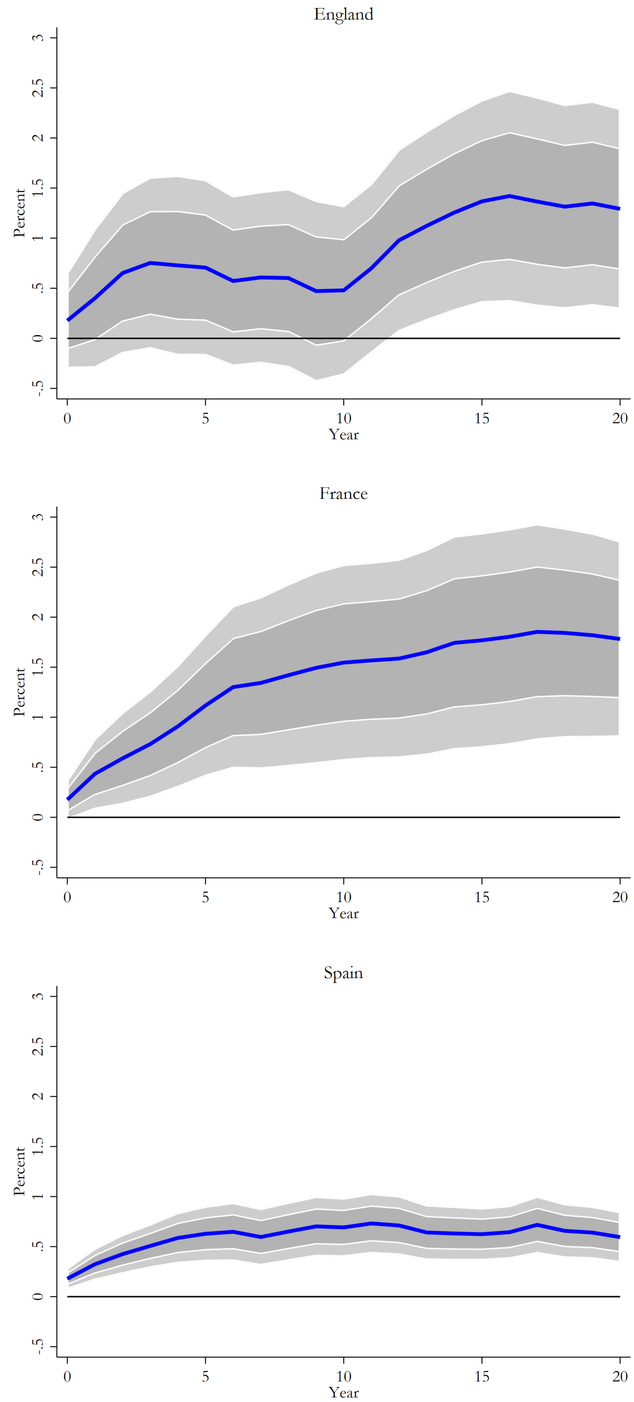
Note: LP-IV impulse responses, with second lag of metals production (Column 3 of table 2).

Figure B.3: Robustness: no GDP control



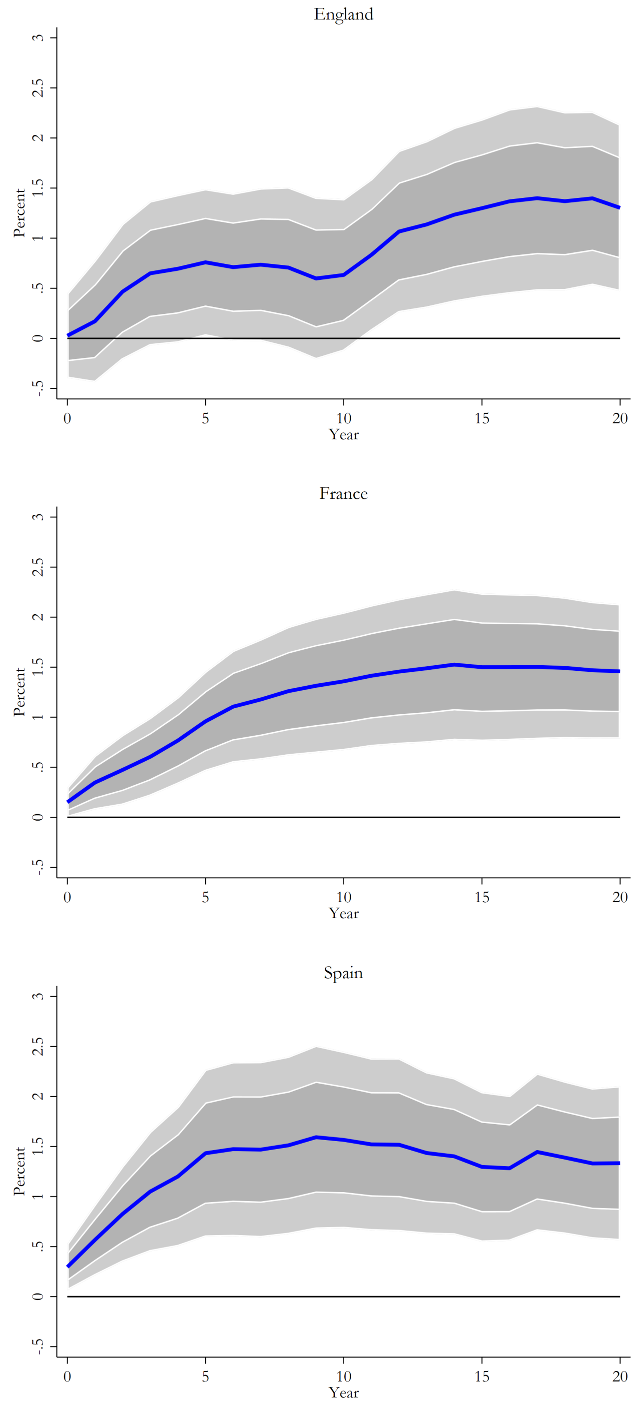
Note: LP-IV impulse responses, with no GDP control (Column 4 of table 2).

Figure B.4: Robustness: war control



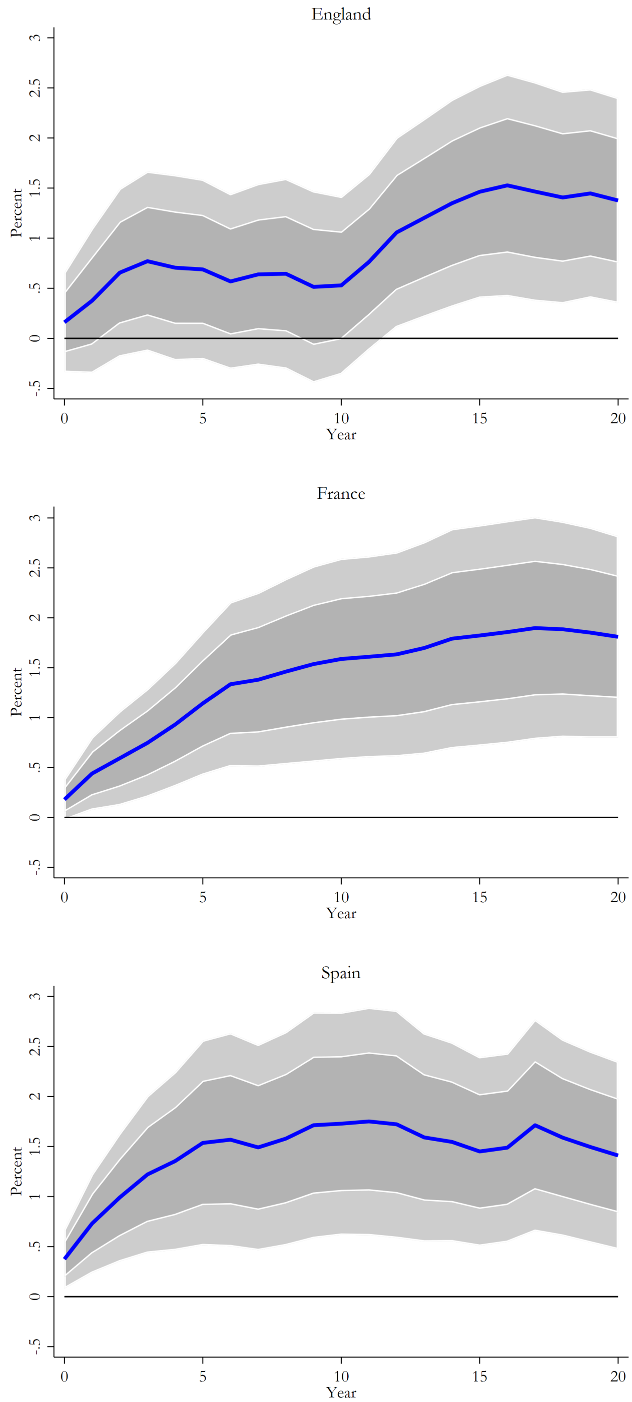
Note: LP-IV impulse responses, with additional war control (Column 5 of table 2).

Figure B.5: Robustness: parliament control



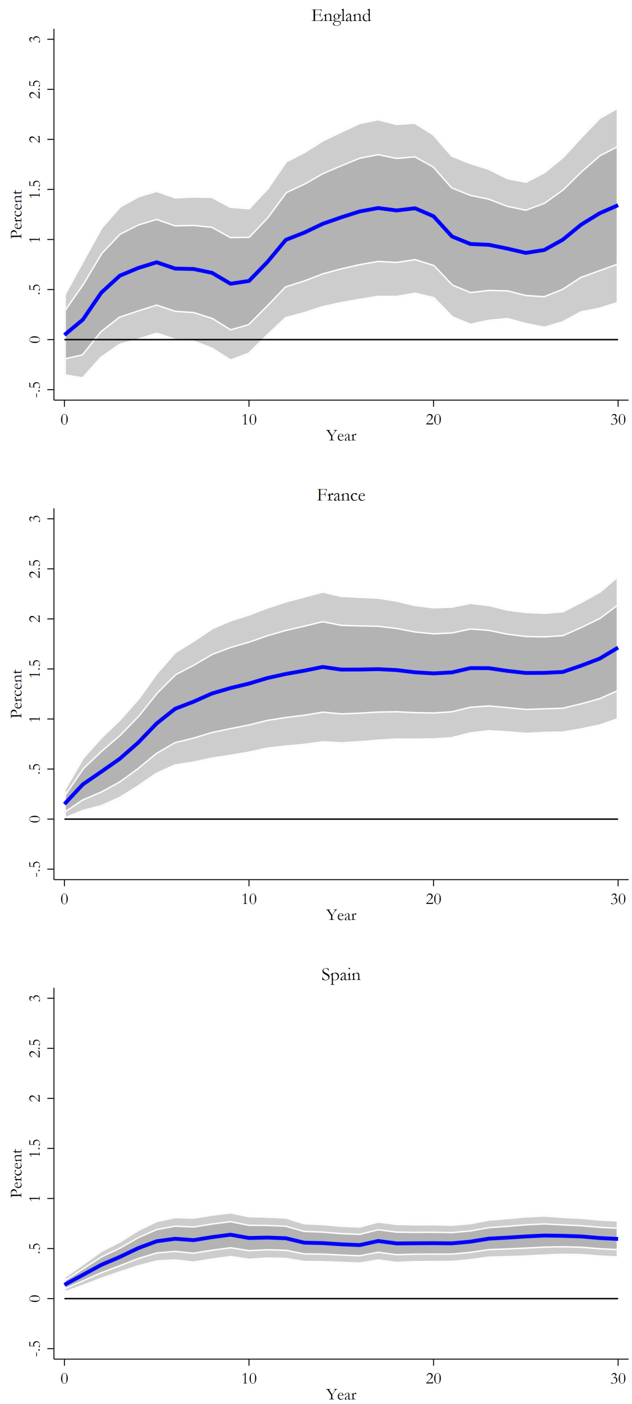
Note: LP-IV impulse responses, with additional parliament control (Column 6 of table 2).

Figure B.6: Robustness: war and parliament control



Note: LP-IV impulse responses, with additional war and parliament controls (Column 7 of table 2).

Figure B.7: Robustness: horizon up to 30



Note: Baseline LP-IV impulse responses, but with horizon up to $h = 30$.

C Data Sources

The money stock series for England is based on Allen (2001a) for 1158-1247, Mayhew (2013) for 1270-1470 and Palma (2018) afterwards. The pre-1500 French money stock series is based on Spufford (1988). Annual estimates for 1493-1680 are based on Glassman and Redish (1985). Between 1680-1788, the series are interpolated based on the six benchmark estimates by Riley and McCusker (1983). The estimates include silver and gold commodity money, but not other types of fiat and paper monies, which were typically marginal until the 19th century. Spanish money stock estimates are based on Chen et al. (2021). For Dutch Republic, De Vries and Van der Woude (1997) and Weber (2000), for Portugal Sousa (2006), for Poland-Lithuania Wojtowicz et al. (2005) and for Russia Blanchard (1989) and Kahan and Hellie (1985) money stock series are used. For Europe the value of monetary units in terms of silver is based on Karaman et al. (2020) and the sources cited therein. For China, money stock for 1280 and 1350 is based on Guan et al. (2024) and for 1750 based on Liu (2015).

The tax revenue data is based on Costa et al. (2024) for Portugal and Karaman and Pamuk (2010), Karaman and Pamuk (2013) and the sources therein for other countries. English revenue data is available annually with few gaps. There are gaps for French revenue data in the 16th and Spanish revenue data in the 17th century, which are interpolated. These revenues are converted to silver, once again based on the rates in Karaman et al. (2020). For China, tax revenue estimates are based on von Glahn (2016) for 1292 and 1329, and Brandt et al. (2014) for 1750.

Price level data is based on Allen (2001b).The price series tracks the daily cost of a standard consumption basket that includes food items totaling 1941 calories per day, fuel and clothing, and reflects the consumption patterns of an adult male for the early modern period. Population data is based on Broadberry et al. (2015), who in turn rely on Wrigley et al. (1997), for England, McEvedy and Jones (1978) for France, and Prados de la Escosura et al. (2022) for Spain. GDP per capita series is based on Broadberry et al. (2015) for England, Ridolfi and Nuvolari (2021) for France and Prados de la Escosura et al. (2022) for Spain. Chinese wage data for 1272 and 1342 is based on Li (2014) and for 1750 based on Liu (2024). European wage data is from Allen (2001b). The yearly precious metal production in the Americas is measured as the sum of silver and gold production in metric tons, with the latter translated to silver units. The production series is based on Palma (2022), which in turn largely relies on TePaske (2010). War data is based on Guan et al. (2024) for Medieval China and Brecke (1999) for other periods and countries. The parliamentary meeting data is based on Henriques and Palma (2023) and De Magalhaes and Giovannoni (2022).

D Robustness to violations of the exclusion restriction

To further address concerns about the exclusion restriction, we adopt the procedure proposed by Jordà et al. (2020). To see how this approach works, suppose that the excluded instrument has a direct effect on fiscal capacity that does not operate through monetary capacity and other control variables. In that case, the true two-stage relationship for each country i changes to the following system of equations:

$$y_{i,t+h} = \alpha_{i,h} + \beta_{i,h} ln(\widehat{monetary}_{i,t}) + \delta_{i,h} ln(metals_{t-1}) + \boldsymbol{\psi_{i,h}} \mathbf{x_{i,t}} + u_{i,t+h} \tag{28}$$

$$ln(monetary_{i,t}) = \alpha_i + \gamma_i ln(metals_{t-1}) + \boldsymbol{\phi_i} \mathbf{x_{i,t}} + e_{i,t}, \tag{29}$$

where $y_{i,t+h} \equiv \ln(fiscal_{i,t+h}) - \ln(fiscal_{i,t-1})$. The only difference to equations 15-16 is that the term $ln(metals_{t-1})$ now enters the second-stage equation 28 directly, violating the exclusion restriction.

Jordà et al. (2020) offer a potential way to test the robustness of the results to such violations of the exclusion restriction. In particular, suppose that $\beta_{i,h} = \lambda_{i,h} * \delta_{i,h}$. In our setup, $\beta_{i,h}$ is the impact of monetary capacity on fiscal capacity, whereas $\delta_{i,h}$ is the impact of American precious metal production on fiscal capacity that does not go through an increase in monetary capacity. Hence, a higher $\lambda_{i,h}$ corresponds to a greater relative impact for monetary capacity.

With $\lambda_{i,h}$ in hand, one can adjust the left-hand-side variable such that the exclusion restriction is satisfied (Jordà et al., 2020, Appendix B). In particular, define $y^{adj}_{i,t+h}$ as:

$$y_{i,t+h}^{adj} = y_{i,t+h} - ln(metals_{t-1}) * \frac{\widehat{\delta}_{i,h} + \widehat{\gamma} \times \widehat{\beta}_{i,h}}{1 + \lambda_{i,h} \times \widehat{\gamma}} \tag{30}$$

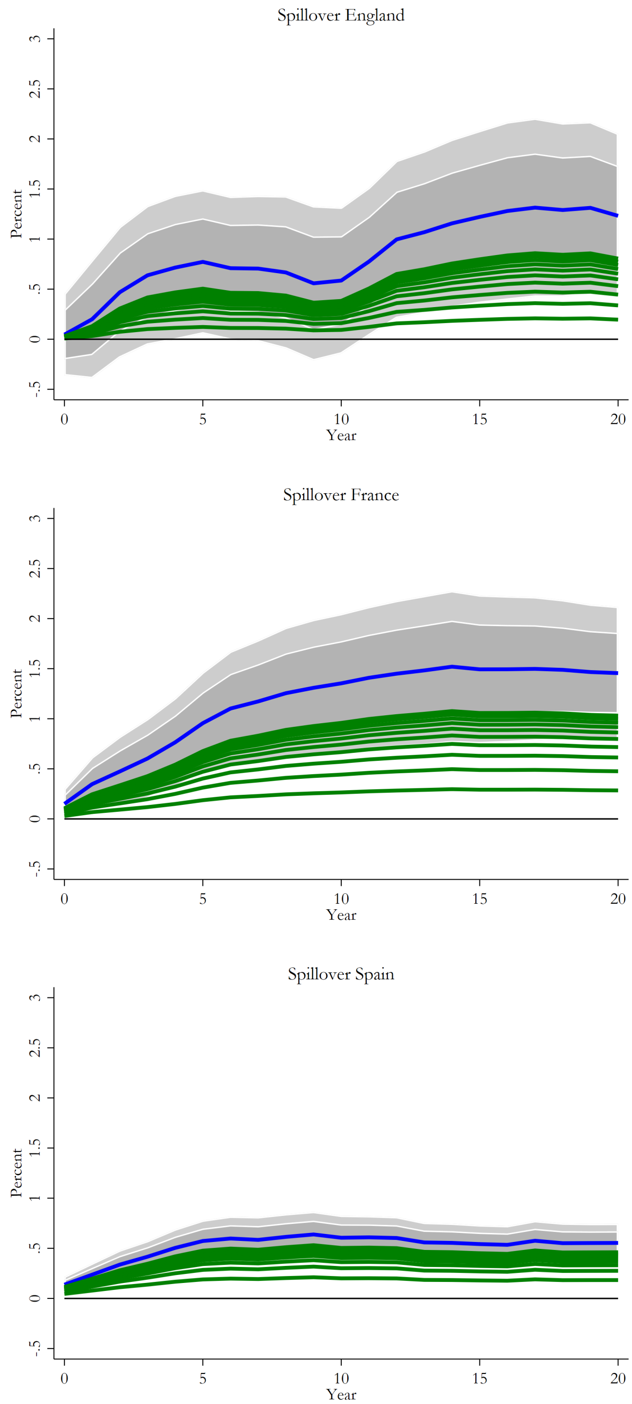
where the "$\widehat{\ }$"-symbol stands for OLS estimates from equations 28-29. After replacing the left-hand-side variable with the adjusted variable from equation 30, the LP-IV procedure will yield valid results.

The difficulty in implementing this procedure is that the true value of $\lambda_{i,h}$ is not known and cannot be determined from the data. Hence, Jordà et al. (2020) advocate performing the adjustments for various reasonable levels of $\lambda_{i,h}$. These levels can be viewed as the bounds on the true impulse responses that would have arisen if the exclusion restriction did not hold.

In our case, we estimate the model for $\lambda_{i,h}$ values between 1 and 10. Lower values of $\lambda_{i,h}$ are unlikely, as it would imply a large direct effect effect of precious metals on tax revenues which goes through channels other than changing monetization. However, for Spain, the main beneficiary of American silver, the revenues from taxation of the domestic economy greatly outweighed the revenues associated with the colonies and silver (Coman and Yun-Casalilla, 2012); as for England and France, if American silver did have any impact on fiscal capacity other than by affecting monetization, it must have been much less important than for Spain. A $\lambda_{i,h}$ value of greater than 10 is plausible, but as $\lambda_{i,h}$ increases, the estimation results converge to the baseline estimates, and so having very high values does not add additional insights to the robustness exercise.

Figure B.8 presents the estimation results for $\lambda_{i,h} = 1, 2, ...10$, alongside the original baseline impulse response and confidence interval. For each country in our analysis, the spillover-adjusted responses are similar in shape to the baseline results. At horizons $t = 10$ and $t = 20$, the results are robust for all $\lambda > 3$ for the case of England; $\lambda > 4$ for Spain; and $\lambda > 5$ for France. For the more realistic larger values of $\lambda_{i,h}$, the effect sizes are within the confidence bounds of the baseline results presented in Figure 4. Thus, violations of the exclusion restriction would have to be large in order to produce results that are statistically distinguishable from the baseline.

Figure B.8: Spillover-adjusted Impulse Responses



Note: This figure shows the baseline impulse responses (blue line and confidence interval) and spillover-adjusted impulse responses (green lines) (Jordà et al., 2020). Spillover terms are $\lambda_{i,h} = 1, 2, ...10$. Lower green lines correspond to lower values of $\lambda_{i,h}$. Specifications follow the baseline LP-IV approach.For data sources, see Appendix C.

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