The University of Manchester

Economics Discussion Paper Series EDP-2305

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July 2023

Economics

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Spending a Windfall*

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Abstract

We study the effect of the discovery of precious metals in America from 1500 to 1810 on international trade. Around 1500, there was a simultaneous discovery of precious metals and new trading routes. We construct a counterfactual of new routes but no precious metals. The discovery of precious metals increased the stock of precious metals more than tenfold. We show that Euro-Asian trade at its peak increased up to 20 times compared with the counterfactual. Our simulations match the observed price dynamics. We find that precious metals were at least as important as the new routes.

JEL codes: E40, F40, N10

Keywords: monetary injections, international trade, early modern trade, Euro-Asian trade, real effects of money

Forthcoming, *International Economic Review*

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1 Introduction

The large and persistent current account deficit of Western countries relative to Asia is not new. During the early modern period (c. 1500–1800), Europe ran a significant current account deficit with Asia. We use a dynamic general equilibrium model to show that the discoveries of precious metals in America explain the volume of international trade between Europe and Asia during that time. The discoveries of precious metals in America implied flows of precious metals to Europe from 1500 to 1810 equal to more than ten times the initial stock. It was a large windfall to Europe. We show that the discoveries of precious metals were fundamental for the increase in imports by European consumers of Asian goods.[1]

We find that consumption of Asian goods in Europe was up to twenty times as large as the value without the new trading routes and without precious metals. This increase is due to a change in transportation costs and endowments rather than different preferences between consumers in Asia and Europe. Our results reject the literature which attributes the observed trade patterns to either the hoarding propensity of Asian consumers or mainly to the decrease in trading costs after the discoveries of new trading routes. Moreover, while the literature has established that the price level, measured in silver, was higher in Europe than in Asia, the reasons why this was the case have not been clear (Allen 2005). Our simulations match the observed price dynamics in Europe and Asia after the discoveries of precious metals, and explain why the silver price level was higher in Europe than in Asia.

We use new data on American production and the flows of precious metals from America to simulate paths for the historical and counterfactual scenarios. With the discoveries of precious metals, European purchases of Asian goods are several times those of the baseline counterfactual scenario. This effect is about the same size (and, at times, larger) than the effect that can be attributed to the discovery of new overseas trade routes between Europe and Asia. Our conclusions support the idea that American precious metals are key to understanding Euro-Asian early modern trade (de Vries 2003).[2]

The new opportunities initiated with the age of discoveries have been emphasized by recent

[1] Much of American silver production was sent to Asia (Desaulty and Albarede, 2013). According to Harley (2004), "European demand for eastern goods was certainly high, but Asian demand for bullion and coin was so great that the rise of European trade with the east should be seen primarily as a consequence not of trade routes to the east but of the discovery of America." Our findings are in accordance with this view.

[2] Our dataset is based on annual production, compiled by Palma (2022).

research to explain the rise of Europe. Allen (2009), for example, stresses the importance of London's trade-driven growth to increase English real wages. Pomeranz (2001) and Frank (1998) argue that precious metals from America contributed to modern economic growth in Western Europe.[3] We focus on evaluating the role of American precious metals on trade between Europe and Asia.

Europe and its colonies paid around 90 percent of the value of their imports from China during the early modern period using silver (Pomeranz 2001, p. 159), a pattern not different from that of trade with India (Steensgaard 1990, Chaudhuri 1968). It would have not been possible for European traders to position themselves in Asia without access to American precious metals. While European consumers were interested in purchasing Asian luxuries, the reciprocal demand did not exist. As we discuss below, most historians assume that Asian consumers were not interested in European goods. In our model, even though European and Asian consumers have the same preferences, the observed trade pattern emerges endogenously. In a counterfactual scenario in which Europe did not have access to precious metals from America, there was no substitute that could have been used. Payment by debt of long maturity was not possible, as no credible enforcement mechanism was available, and no predictable horizon existed for the reversal of equilibrium trade flows (Chaudhuri 1963, p. 29).[4]

Contemporaries were aware that Asia absorbed much of the precious metals brought from America. For instance, a merchant in 1621 wrote that the world's silver flew to China as if it were its natural center (de Vries 2003). The demand for gold and silver in China and India seemed insatiable. While Asia did not show much interest in purchasing European goods, the opposite was true for Europe. Euro-Asian trade during the period brought to Europe goods such as pepper, spices, silk, tea, lacquered furniture, and porcelain. These goods induced market activity and specialization, and were increasingly consumed by people from all social classes (McCants 2007, 2008; Pomeranz 2001, p. 273; de Vries 2008; Hersh and Voth 2022.) Trade of Asian goods such as Chinese porcelain and Indian textiles shaped European tastes and were a prerequisite to the subsequent British industrialization.[5]

[3] See also Palma (2020), Palma (2018a), and Chen et al. (2022).

[4] The value of imports and exports during this period matches for any given year. When we refer to a current account deficit for this period, we define precious metals as money as opposed to goods. The trade deficit ended largely by force: in the case of India, with the takeover of the Mughal empire by Britain, and in the case of China, with the Opium wars of the nineteenth century.

[5] The technique for the production of porcelain was eventually learned in Europe, though the method was

The traditional explanation for the imbalance of Euro-Asian trade during this period relies on cultural factors. Hamilton (1929) states that "for some inexplicable reason Orientals have always had a penchant for hoarding treasure." In turn, Keynes (2013) states about India that "the oriental habit of hoarding or transforming into jewelry vast amounts of precious metals appears to be a chronic one." This viewpoint is still dominant (Kindleberger 1989; Maddison 2007, p. 312). In contrast, our explanation for the patterns of Euro-Asian trade for the period does not rely on different preferences for Asia and Europe. Our explanation emerges as a natural consequence of agents taking optimal decisions in a general equilibrium context.[6]

We first show evidence on the size and effects of the monetary injections caused by the larger availability of precious metals. To understand early modern trade flows as an equilibrium phenomenon, we review the relative size and development of Asia versus Europe. The production of specie is a good proxy to estimate the magnitude of the monetary injections, as bullion was the main input in the production of money. We estimate the stock of precious metals in Europe using the initial stock measured in tonnes of silver and data on the discoveries of precious metals in America. We then simulate a model with international trade and money which makes transparent that monetary flows were an equilibrium phenomenon.

There are two frictions in our model. The first is that money is necessary to conduct transactions. The second is that there are transaction costs to international trade, which represent both transportation and agency costs. The aim is to reproduce how Euro-Asian trade responded to the discovery of the new trading routes and to the monetary shocks. The model can be used to explain observed historical data and to predict counterfactuals.

A small amount of Euro-Asian trade took place in the middle ages through overland routes, but trade grew substantially after 1500. We emphasize the role of American precious metals as a cause to explain the observed growth in trade. However, alternative factors have been pointed out. de Vries (2003) raises three possibilities. First, was the trade boom induced by "new opportunities for arbitrage in regional differences in the purchasing power of silver"? (this is the factor we emphasize). Second, "was it the result of a major reduction of transaction

never as perfect as that of China. By the mid eighteenth century, all major European countries had or were about to have porcelain factories. A major interest in *chinoiserie* developed (Berg, 2004, 2005). This was not limited to porcelain, but also architecture, landscape gardening, lacquered furniture, and decorative arts.

[6]The statement in Hamilton is used to justify the smaller inflation in Asia in comparison with Europe, viewed as a puzzle, as precious metals were flowing in great amounts to Asia. In accordance with the observations, we obtain for Asia a delayed and initially smaller inflation.

costs, as new technologies and commercial organization lowered the cost of acquiring and shipping goods (...) [or] because political barriers to trade fell in the face of the military power of the trading companies"? Third, perhaps Euro-Asian trade grew due to rising incomes in Europe raising demand for imports from Asia? The possibilities raised by DeVries are evidently not mutually exclusive. We are able to evaluate their relative importance with our model. We decompose which part of the observed increase in early modern Euro-Asian trade can be attributed to the discoveries of precious metals, the decrease in transaction costs, or the increase of income levels in Europe.[7]

We calculate that the consumption of Asian goods in Europe increased up to twenty times its medieval value with the discovery of the sea routes (the Cape and Pacific routes) and the discovery of precious metals. Without the discovery of precious metals, the increase in consumption would have only reached at most seven times its medieval value. American precious metals explain the trade surplus of Asia: the fact that outgoing ships to Asia transported precious metals and little else, while returning ones brought goods such as silk, tea, and porcelain. We find that American precious metals can explain about half of the accumulated increase in consumption of Asian goods by Europe from 1500 to 1810.

2 Context and data

2.1 Precious metals and money

During the early modern period, precious metals such as silver were the key input for the production of money. As precious metals in Europe were available in inelastic supply for most of the medieval period, deflation was common. Credit acted as a complement, not a substitute, to coin (Palma 2018a). In Asia, unlike Europe, there was little difference between bullion and money, which did not circulate by tale.[8] In parts of Asia, notably China, there was a recurrent problem of scarcity of precious metals relative to the size of the economy.[9]

[7]Decomposing the effects with historical evidence alone is difficult because these events happened at roughly the same time. The Portuguese first arrived to China in 1513, just as the Spanish were beginning to extract silver and gold from America.

[8]Within individual European countries, coin usually circulated by tale (at a higher face value than the value of the intrinsic metal component). Although bills of exchange and copper-based coinage were used for small transactions, silver and gold coins were the most important components of the money supply.

[9]Fernández-Villaverde and Sanches (2022) show that the scarcity of precious metals under the gold standard implies suboptimal allocations and external vulnerabilities.

After around 1500, Europe experienced monetary injections of unprecedented magnitude as a result of the discovery of America. From 1500 to 1810, 85 percent of the world's silver and more than 70 percent of world's gold came from the Americas (Barrett 1990). There exists disperse data on money supply for a few European countries during the early modern period (Sousa 2006, Chen et al. 2021, and Palma 2018b). The quantity of bullion available provides an approximation to the money stock (Findlay and O'Rourke 2009). For international trade, the usage of hard money was critical. Lack of an enforcement mechanism implied that there were no debt mechanisms of notice used in transactions involving Asia. International settlements were hence made in bullion or more typically coin valued by weight.

We use data on the production of gold and silver in the mines in America from Palma (2022), who largely relies on TePaske (2010) and covers the period until 1790. Here, we use the same sources and procedures from Palma (2022) to extend the data to 1810. That year marks the end of TePaske's dataset as well as the beginning of the Spanish American wars of independence which greatly disrupted silver production and transportation to Europe.

Table 1: Population and Output in Europe and Asia

	Population (thousands)			Real Output per capita		
Year	Asia	Western Europe	Ratio	Western Europe, y_E	Asia, y_A	$\frac{y_E}{y_A}$
1500	268,400	57,268	4.69	999	804	1.24
1600	360,000	73,778	4.89	1091	747	1.46
1700	374,800	81,460	4.61	1202	695	1.73
1820	679,400	133,040	5.10	1341	647	2.07

Real output per capita in Geary-Khamis international dollars of 1990. Western Europe as defined by Maddison plus Spain and Portugal. Asia excludes Japan. Source: Maddison (2006, pp. 636, 642).

We express the value of gold and silver in silver-equivalent grams. The original sources for the production of precious metals show production values in monetary units. We take into account the fact that there were frequent changes in the content of precious metals in the monetary unit over time. The most common change is a debasement of the monetary unit, that is, a decrease of the content of precious metals. For example, the content of precious metals in the monetary unit of England decreased from 172 silver-equivalent grams in 1500 to 98 silver-equivalent grams in 1810. For Spain, it decreased from 13 to 4.9 silver-equivalent grams. We use data from Karaman et al. (2020) on the content of precious metals in the monetary unit. In this way, we take into account the debasements of the monetary unit to express our variable of interest in silver-equivalent grams for each year.[10]

To obtain a measure of per capita holdings, we need population over time. Table 1 shows population and output per capita in Europe and Asia. The population of Asia during the period was about five times larger than that of Europe. Real output per capita in Western Europe was about 20 percent higher than in China in 1500 and about two times that in China in the early 1800s (table 1).[11] We use the estimates of Maddison (2006) for real output and population, as no viable alternative for all countries exists; although there exist substantial improvements to Maddison's GDP figures for a number of European countries as well as for China in this period, no comparable data exist for either Europe or Asia as a whole. In any case, our main results are not sensitive to plausible changes in benchmark income levels, growth rates, or population.[12]

We divide the data on the production of precious metals by the population to obtain the flows of precious metals per capita for each year. Figure 1 shows the results. It shows the discoveries of precious metals in the Americas over time, expressed in silver-equivalent grams, relative to the population of Western Europe. The data in figure 1 will have an important role in the model of section 4.

Figure 2 gives another perspective on the flows of precious metals to Europe. According to Chen et al. (2021), initial holdings of silver in Spain in the late fifteenth century are 75 silver-equivalent grams of precious metals. We consider this value to be representative for Western Europe. The figure then shows the gross accumulated flows of precious metals in comparison with the holdings in the beginning of the period. Considering the gross flows from 1500 to 1600, holdings of precious metals of the average individual in Europe would increase three times, from 75 g to 249 g. From 1500 to 1810, the accumulated flows of precious metals imply an increase of 17 times from the initial individual holdings of precious metals.

[10]In appendix A, we give more details about the use of precious metals as money in the historical context and about the production and flows of precious metals across America, Asia, and Europe.

[11]There is a debate on whether output per capita from 1500 to 1800 was higher for Western Europe as a whole or just for its leading economies until the nineteenth century, Holland and Britain. Allen (2005) and Pomeranz (2001) claim that once a better measure for the price level is taken into account, real output per capita in Europe may not have been higher than that of Asia in the early modern period, in particular for China. However, the most recent estimates by Broadberry and Gupta (2006) and Broadberry et al. (2018) show higher levels of per capita output in Western Europe well before 1800.

[12]In the case of China, the biggest economy, alternative population data exists (Deng 2004). Our main results do not change if Deng's numbers are used instead.

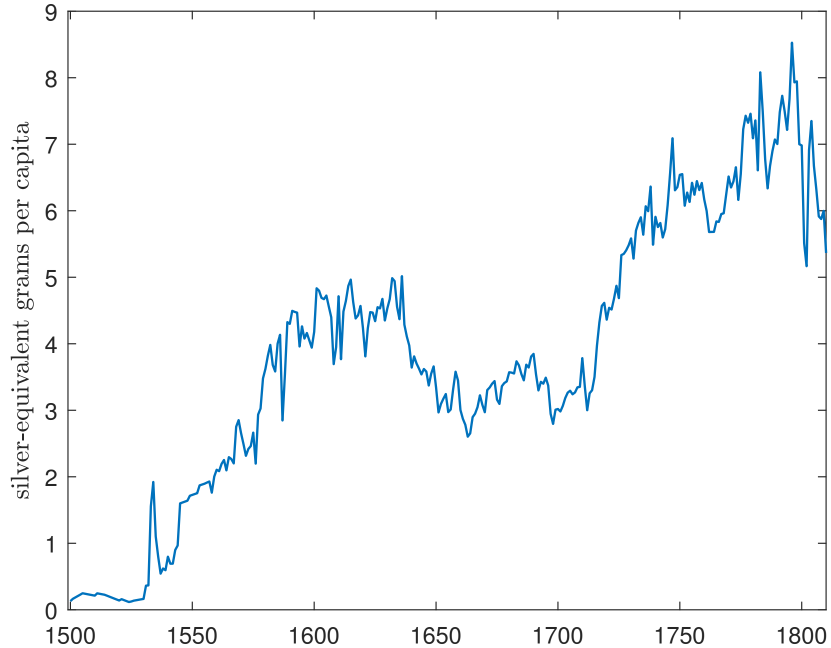


Figure 1: Discoveries of precious metals per capita. Source: Palma (2022) 1531–1790; and the same sources used by Palma (2022) for the remaining years.

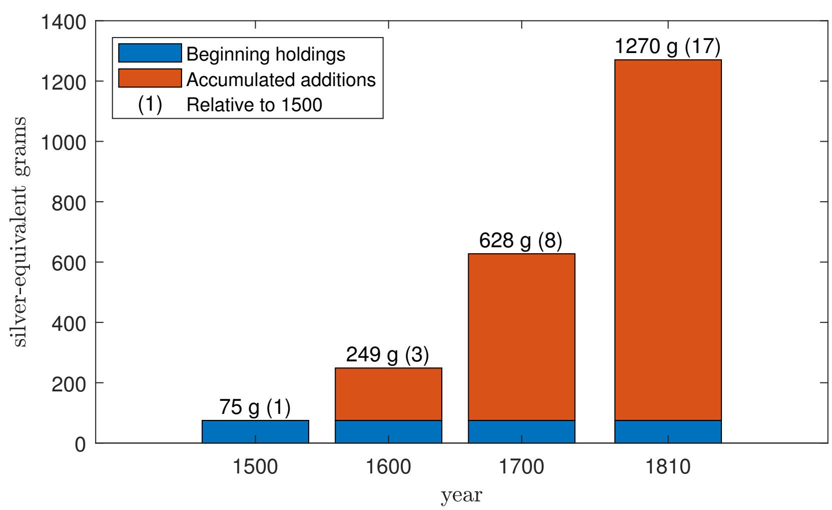


Figure 2: Accumulated gross inflows to Europe of precious metals per capita. Accumulated additions: sum of the annual injections of precious metals in figure 1. Source: see figure 1.

2.2 Asian luxuries and precious metals

The discoveries of the sea trade routes were motivated by the search for Asian luxuries. Europeans were interested in Asian goods, in particular luxury goods, which were cheaper to transport relative to their weight over long distances. From China, silk, porcelain and tea; from India and Southeast Asia, spices, pepper, drugs, aromatic substances and cotton cloth, among others. Some of these goods could only reach the West in meaningful quantities after the opening of the sea routes. The fragile nature of Chinese porcelain, in particular, implied that it was difficult to transport overland to Europe. However, the new sea routes alone cannot explain the magitude of the observed trade boom, because the European interest in Asian luxuries did not find a reciprocal demand.

The importance of precious metals in promoting Euro-Asian trade has been documented by historians. However, the importance of precious metals is usually explained by the lack of interest of Asian consumers in European goods. For example, Maddison (2007, p. 312), states that precious metals were important to finance European trade with Asians, "who were not very interested in buying European products," suggesting a cultural explanation.[13]

To our knowledge, there are only two examples in the literature of an economic explanation. The first (Chaudhuri, 1963) states that the main cause for the flow of precious metals from Europe to Asia was the large difference in the market price of gold and silver. According to Chaudhuri, the real price of silver was much higher in Asia than in Europe. As silver was the monetary standard in Asia, the difference in prices would have discouraged exports from Europe to Asia. However, this explanation takes prices as given rather than being the result of equilibrium outcomes. By contrast, we obtain equilibrium prices after the discoveries of precious metals and trading routes, and calculate the corresponding flows of goods and precious metals. The second economic explanation is provided by de Vries (2003), who argues that growing Asian demand for precious metals was related to growing population and monetization in that area, and that European exports of precious metals were never sufficient to fully compensate for those sources of demand. Our results provide quantitative support for DeVries's argument.

[13]Kindleberger (1989), Pearson (2001), Cranmer-Byng and Wills (2010) and others present similar cultural arguments.

3 Precious metals and trade through local projections

We now show that total shipping capacity from Europe to Asia increased in response to production of precious metals in America. To show this, we use data on the shipping capacity of a major trading company dedicated to trading with Asia. Shipping capacity is the total capacity of the shipping fleet in tons. We find that more precious metals produced in the Americas led to more shipping capacity.[14]

Our empirical specification follows a local projections method (Jorda 2005). For each time horizon h, we estimate the following equation,

$$\ln y_{t+h} - \ln y_{t-1} = \beta_h \,\text{metals}_t + \mathbf{\Psi_h x_t} + u_{t+h}, \tag{1}$$

where y_t denotes shipping capacity on period t and the left-hand side of equation (1) denotes the cumulative growth of shipping capacity from period $t-1$ to $t+h$. The independent variable metals_t is the production of precious metals in America relative to the stock of metals in Europe, taken from Palma (2022). The vector $\mathbf{x_t}$ contains a linear trend and four lags of the dependent variable $\ln y_t$. Palma (2022) shows that variation in American production of precious metals is uncorrelated with the prior and current states of the European economies. This suggests that the variable metals_t is uncorrelated with the error term which implies that we can interpret the coefficient β_h as its causal impact.

The local projection method proceeds by estimating a separate regression for each horizon h, where h runs from 0 to 20. The coefficients of interest consist of the β_h's for each horizon h. These coefficients capture the impact between $t-1$ and $t+h$ on the dependent variable of a 1 percent increase in the production of precious metals relative to the stock of metals in Europe. Hence, β_0 captures the instantaneous impact of precious metals on shipping capacity growth over the last period, $\ln y_{i,t} - \ln y_{i,t-1}$; β_1 captures the impact on growth between periods $t+1$ and $t-1$, $\ln y_{i,t+1} - \ln y_{i,t-1}$, and so on.

Figure 3 shows the resulting impulse response functions with 90 percent and 95 percent confidence intervals. An increase in precious metals implies a significant increase of shipping in the following years. The cumulative impact peaks around the 12th year. Around that time,

[14] For shipping capacity, we use the only available annual dataset, which concerns the shipping capacity of the English East India Company (Bogart and Del Angel, 2019).

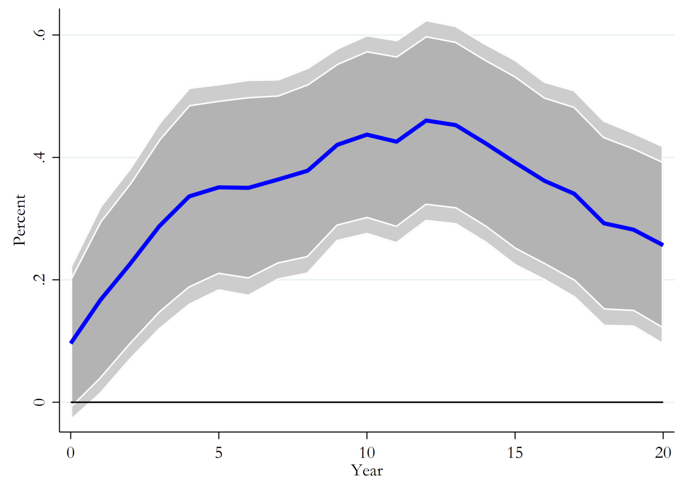


Figure 3: Impulse response of shipping capacity to a contemporaneous increase of 1 percent in precious metals relative to stock calculated using the Jordà (2005) local projection method. Variables in tons. Controls include a linear trend and four lags of the dependent variable. Robust standard errors are used to construct the confidence intervals. 90 percent and 95 percent confidence intervals shown. Source: see text.

in response to a 1 percent increase in production of precious metals in the Americas relative to Europe's stock of metals, East India Company shipping capacity increased by almost 0.5 percent. This finding confirms that the production of precious metals drove trade between Europe and Asia.

4 Model

Consider a model of international trade with two countries, two goods, and money. There are two infinitely-lived agents, which represent Europe and Asia, with identical preferences. Each agent owns a firm to produce the domestic good. The windfall of precious metals is received by the agent in Europe. The new trading routes are introduced by a decrease in transaction costs to international trade. Trade deficits are paid in money, that is, in precious metals converted into a common monetary unit. Payments in money are a consequence of the impossibility of international debt at the time. There is a common unit of money across regions, such as the Spanish silver dollar, used extensively during our period of study. All regions in the model trade in this common monetary unit.[15]

Time is discrete, $t = 0, 1, \ldots$ Let $C_{ij,t}$ denote consumption in region $i = e, a$ of good $j = e, a$ at time t, where e stands for Europe and a stands for Asia. Consumption of the different goods are combined into a composite good $C_{i,t}$, $i = e, a$. Let $M_{i,t}$ denote money holdings in region i at time t. There is a given initial value of money $M_{i,-1} > 0$. All variables are in per capita terms. Let P_{1t} and P_{2t} denote, respectively, the prices of the European good and the Asian good at time t and P_i denote the price index in region i.

The agents in each region maximize the following intertemporal utility function in terms of the composite good and real money holdings,

$$U\left(C_i, \frac{M_{i,t}}{P_{i,t}}\right) = \sum_{t=0}^{\infty} \beta^t u\left(C_i, \frac{M_{i,t}}{P_{i,t}}\right), \tag{2}$$

where $0 < \beta < 1$ is a parameter for intertemporal discounting and $i = e, a$. The time utility function u combines consumption and real money holdings at each time under constant elasticity of substitution,

$$u\left(C_{i,t}, \frac{M_{i,t}}{P_{i,t}}\right) = \frac{\left[aC_{i,t}^{\eta} + (1-a)\left(\frac{M_{i,t}}{P_{i,t}}\right)^{\eta}\right]^{\frac{1-\sigma}{\eta}} - 1}{1-\sigma}, \tag{3}$$

where $0 < a < 1$, $\sigma > 0$ and $\eta \in (-\infty, 1)$. The parameter a is the weight on consumption, σ is the inverse of the elasticity of intertermporal substitution, and $1/(1-\eta)$ yields the value of the elasticity of substitution between goods and real money holdings. The composite good C_i for each region, in turn, is also defined by a CES aggregator. The expressions of the composite goods of Europe and Asia are given respectively by

$$C_{e,t} = \left[\omega^{\frac{1}{\gamma}} C_{ee,t}^{\frac{\gamma-1}{\gamma}} + (1-\omega)^{\frac{1}{\gamma}} C_{ea,t}^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{4}$$

$$C_{a,t} = \left[(1-\omega)^{\frac{1}{\gamma}} C_{ae,t}^{\frac{\gamma-1}{\gamma}} + \omega^{\frac{1}{\gamma}} C_{aa,t}^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{5}$$

[15] The preferences are identical in the sense that they have the same specification and parameters. In particular, as we state below, both preferences include home bias and the home bias acts in the same way for both agents. The model share some elements of Chari et al. (2002) and Duarte and Wolman (2008). The main difference is that we focus on the final goods and remove nontradable goods, sticky prices, and monopolistic competition. The two regions trade directly the final goods. We introduce an iceberg cost to simulate the discoveries of new routes between Asia and Europe. We introduce temporary changes in money supply to proxy for discoveries of precious metals. Our simulations and objectives are different.

where $0 < \omega < 1$ denotes home bias, and $\gamma > 0$ denotes the elasticity of substitution between domestic and foreign goods. The home bias can be interpreted as a measure of the components used for the production of the final good. A value for $\omega > 1/2$ means that more domestic goods are used in the production of the final good. The consumption goods are traded directly in international markets. All goods are tradable.[16]

Let $P_{1,t}$ and $P_{2,t}$ denote the prices of domestic goods respectively produced in Europe and Asia. There are iceberg costs $b_t > 0$ for the acquisition of foreign goods. The domestic agent has to purchase $1 + b_t$ units of the foreign good so that one unit of the good arrives at the domestic port and can be consumed in the region. Exports and imports of precious metals or of the monetary common currency are not subject to the iceberg cost.[17]

The iceberg cost works as if part of the amount imported disappeared in transit before their arrival at their destination. These costs relate to the technical and organizational efficiency with which trading activities are conducted. They include transportation costs, agency costs, and the risk of international trade. In the simulations that follow, the discoveries of the new routes will be simulated by a permanent decrease in the value of b_t.[18]

The price indices $P_{e,t}$ and $P_{a,t}$ are obtained so that they they reflect the minimum expenditure to obtain one unit of the composite good. The cost minimization problems for Europe and Asia yield the following price indices,

$$P_{e,t} = \left\{\omega P_{1,t}^{1-\gamma} + (1-\omega)[(1+b_t)P_{2,t}]^{1-\gamma}\right\}^{\frac{1}{1-\gamma}}, \tag{6}$$

$$P_{a,t} = \left\{(1-\omega)[(1+b_t)P_{1,t}]^{1-\gamma} + \omega P_{2,t}^{1-\gamma}\right\}^{\frac{1}{1-\gamma}}. \tag{7}$$

[16] All goods are tradable in the model because the service sector was small for these economies in the Middle Ages and during 1500–1810. The service sector is considered nontradable because service goods usually cannot be exported. Tradable goods can be exported even though they may not be exported as a result of optimization given transportation costs. Our utility specification considers the services provided by precious metals rather than precious metals directly, that is, M/P rather than M. As standard in other monetary models, rather than money in nominal terms, the model states that agents cared for the services provided by money. See also Flynn and Giraldez (1995, 2004).

[17] According to Smith (2003, B II Ch 5, p. 471), "The transportation of those metals from one place to another, on account of their small bulk and great value, is less expensive than that of almost any other foreign goods of equal value. Their freight is much less, and their insurance is not greater; and no goods, besides, are less liable to suffer by the carriage."

[18] The transportation costs include "the construction and operation of ships, the [construction,] maintenance and defense of trading factories in Asia, administrative expenses, bribes and payoffs, and interest on borrowed capital" (de Vries 2003). Obstfeld and Rogoff (2001) discuss other interpretations for the iceberg cost, such as nontariff barriers and transaction costs associated with different languages.

Europe and Asia produce only their respective domestic consumption goods, the European and the Asian goods. There is a Cobb-Douglas production function that combines capital and labor to produce the domestic good. The share of capital is equal across regions, given by $0 < \theta < 1$. Capital is not tradable across countries. Capital in region i carried over from the previous period is denoted by $K_{i,t-1}$. Following standard convention, $K_{i,t-1}$ is available at the beginning of period t for production at time t. Without capital, then money would work as the only store of value available to agents, in addition to play its role as a means of exchange. The introduction of capital eliminates the need of money for store of value and emphasizes the role of money as a means of exchange.[19]

The agents can also purchase domestic bonds $B_{i,t}$, which pay $r_{i,t+1}$ units of the domestic good in the following period. Bonds have zero net supply. We introduce bonds to obtain a usual interpretation of the demand for money in terms of interest rates.

The budget constraint for the agent in Europe is given by

$$P_{e,t}C_{e,t} + M_{e,t} + P_{1,t}K_{e,t} + P_{1,t}B_{e,t} \leq P_{1,t}A_e K_{e,t-1}^{\theta} + P_{1,t}(1-\delta)K_{e,t-1} + M_{e,t-1} + P_{1,t}(1+r_{e,t})B_{e,t-1} + D_t, \tag{8}$$

where $M_{e,t-1}$ is money carried over from the previous period and A_e is a total factor productivity parameter. The production function takes into account that labor is supplied inelastically and set to one. D_t are the injections of precious metals, in silver-equivalent units. For the agent in Asia, these monetary injections are set to zero. The budget constraint is expressed in silver-equivalent grams of precious metals. The budget constraints imply that international trade can be made directly in precious metals.

The maximization problem of the agent in Europe is to maximize (2) subject to (8), given $K_{i,-1} > 0$ and $M_{i,-1} > 0$. The agent in Asia solves an analogous problem.

The windfall of precious metals, gold and silver, denoted by D_t, is expressed in silver-equivalent grams per capita as explained in section 2. We use data on the conversion rate $\xi_{i,t}$ of monetary units in region i into silver-equivalent precious metals D_t. The unit of $\xi_{i,t}$ is in silver-equivalent grams per monetary unit of account such as Spanish silver dollars. A

[19]We do not need capital for our main conclusions. Removing capital slightly increases the effects of the discoveries of precious metals.

debasement of the currency is expressed as a decrease in $\xi_{i,t}$. Let $\tilde{D}_t$ express production of precious metals in monetary units. The windfall of precious metals in silver-equivalent units is given by $D_t \equiv \xi_{e,t}\tilde{D}_t$.[20]

The conversion of currency $\tilde{D}_t$ to precious metals D_t implies a close use of precious metals as currency. As both regions followed a monetary standard based on precious metals, the factor of conversion $\xi_{i,t}$ is approximately constant for relatively long periods. Europe's prevailing commodity money system implied that precious metals were the fundamental input for the production of money. People could freely convert precious metals into coin at the mint. And in China, the means of exchange was silver itself, valued by weight (von Glahn 1996, p. 42; Irigoin 2009), which would imply $\xi_{a,t} = 1$. Even so, $\xi_{i,t}$ is subject to abrupt changes for particular periods. We take these fluctuations into account with data on $\xi_{i,t}$ to convert monetary units into precious metals.

Let L_i denote population and Y_i denote production in region $i = e, a$. The market clearing conditions for European goods, Asian goods, and precious metals are respectively given by

$$L_e(C_{ee,t} + K_{e,t}) + L_a C_{ae,t}(1 + b_t) = L_e Y_{e,t} + L_e(1 - \delta)K_{e,t-1}, \tag{9}$$

$$L_e C_{ea,t}(1 + b_t) + L_a(C_{aa,t} + K_{a,t}) = L_a Y_{a,t} + L_a(1 - \delta)K_{a,t-1}, \tag{10}$$

$$L_e M_{e,t} + L_a M_{a,t} = L_e M_{e,t-1} + L_e D_t + L_a M_{a,t-1}. \tag{11}$$

The definition of equilibrium is standard. An equilibrium in this economy is a collection of allocations and prices for each time t such that the allocations solve the maximization problem for the agents in Europe and Asia, given prices and initial values of money and capital, and such that the market clearing conditions hold.

We now determine a set of dynamic equations that characterizes the equilibrium of the model. The first-order conditions of the maximization problem for the European agent imply

$$\beta^t \frac{\partial u\left(C_{e,t}, M_{e,t}/P_{e,t}\right)}{\partial C_{e,t}} = \lambda_t P_{e,t}, \tag{12}$$

$$\beta^t \frac{\partial u\left(C_{e,t}, M_{e,t}/P_{e,t}\right)}{\partial M_{e,t}} = \lambda_t - \lambda_{t+1}, \tag{13}$$

[20]The silver dollars (*pesos de la ocho*) were commonly used in Southeast Asia and the United States into the nineteenth century. They were legal tender in the U.S.A. until 1857.

$$\lambda_{t+1}P_{1t+1}(\theta A_e K_{et}^{\theta-1}+1-\delta)=\lambda_t P_{1t}, \tag{14}$$

$$\lambda_{t+1}P_{1t+1}(1+r_{e,t+1})=\lambda_t P_{1t}, \tag{15}$$

where λ_t is the Lagrange multiplier associated with (8). Equations (12) and (13) imply an equation for consumption and money over time,

$$\frac{1-a}{a}\left(\frac{M_{e,t}}{P_{e,t}}\right)^{\eta-1}+\beta\left[\frac{aC_{e,t+1}^{\eta}+(1-a)\left(\frac{M_{e,t+1}}{P_{e,t+1}}\right)^{\eta}}{aC_{e,t}^{\eta}+(1-a)\left(\frac{M_{et}}{P_{et}}\right)^{\eta}}\right]^{\frac{1-\sigma-\eta}{\eta}}\frac{C_{e,t+1}^{\eta-1}}{P_{e,t+1}/P_{e,t}}=C_{e,t}^{\eta-1}. \tag{16}$$

Equations (12) and (14) imply an equation for consumption and capital,

$$\beta\left[\frac{aC_{e,t+1}^{\eta}+(1-a)\left(\frac{M_{e,t+1}}{P_{e,t+1}}\right)^{\eta}}{aC_{e,t}^{\eta}+(1-a)\left(\frac{M_{et}}{P_{et}}\right)^{\eta}}\right]^{\frac{1-\sigma-\eta}{\eta}}(\theta A_e K_{et}^{\theta-1}+1-\delta)\frac{C_{e,t+1}^{\eta-1}}{P_{e,t+1}/P_{1,t+1}}=\frac{C_{e,t}^{\eta-1}}{P_{e,t}/P_{1,t}}. \tag{17}$$

Similarly, we obtain an expression for the demand for money,

$$\frac{M_{e,t}}{P_{e,t}}=\left(\frac{1-a}{a}\right)^{\frac{1}{1-\eta}}C_{e,t}\left(\frac{1+R_{e,t+1}}{R_{e,t+1}}\right)^{\frac{1}{1-\eta}}, \tag{18}$$

where $1+R_{e,t}=P_{1,t}/P_{1,t-1}(1+r_{e,t})$ is the nominal interest rate. Real wages are given by $w_t=(1-\theta)AK_{e,t-1}^{\theta}$ and real returns to claims to physical capital by $r_{e,t}^{k}=\theta AK_{e,t-1}^{\theta-1}-\delta$. Bonds and claims to physical capital are perfect substitutes. A no-arbitrage condition yields $1+r_{e,t}=1+r_{e,t}^{k}$. The equations above have their analogous expressions for Asia.

Given the optimal values for $C_{e,t}$ and $C_{a,t}$, the local demands are given by

$$C_{ee,t}=\omega\left(\frac{P_{e,t}}{P_{1,t}}\right)^{\gamma}C_{e,t}, \tag{19}$$

$$C_{ea,t}=(1-\omega)\left(\frac{P_{e,t}}{(1+b_t)P_{2,t}}\right)^{\gamma}C_{e,t}, \tag{20}$$

$$C_{ae,t}=(1-\omega)\left(\frac{P_{a,t}}{(1+b_t)P_{1,t}}\right)^{\gamma}C_{a,t}, \tag{21}$$

$$C_{aa,t}=\omega\left(\frac{P_{a,t}}{P_{2,t}}\right)^{\gamma}C_{a,t}. \tag{22}$$

Let $\mathrm{XM}_{i,t}^{l}$ denote net exports of the good $l=e,a,m$ by the region $i=e,a$, where

$l = m$ refers to precious metals. Net exports of precious metals by Europe are given by $\text{XM}_{e,t}^{m} \equiv (M_{e,t-1} + D_t) - M_{e,t}$. If $M_{e,t} < M_{e,t-1} + D_t$ then Europe exports precious metals. In turn, net exports of precious metals by Asia are given by $\text{XM}_{a,t}^{m} \equiv M_{a,t-1} - M_{a,t}$, as $D_t = 0$ for Asia. If $M_{a,t} > M_{a,t-1}$, then Asia imports precious metals. For the consumption goods $i, l = e, a$, we have $\text{XM}_{i,t}^{l} \equiv L_i Y_i - L_i C_{il,t}$ when $l = i$ and $\text{XM}_{i,t}^{l} \equiv -L_l C_{il,t}$ when $i \neq l$.

Equations (4)–(7), (16)–(18), (19)–(22) together with the budget constraints for each region and the market clearing conditions define a set of dynamic equations that yield an equilibrium to this model. The model implies a unique equilibrium. A steady state is defined as an equilibrium for which $D_t = 0$ and the variables are constant over time. In particular, in the steady state, inflation is equal to zero, there are no flows of precious metals across regions, and there are constant imports and exports of goods across regions.

In the simulations that follow, we start from an initial steady state and obtain the equilibrium when the economy is hit by a surprise permanent decrease in the iceberg cost b_t and a surprise windfall of $D_t > 0$ from 1500 to 1810.

5 Construction of the counterfactual

5.1 Scenarios

The observed scenario is the one in which there was a discovery of new routes between Europe and Asia using the maritime via around Africa and, at the same time, there was a discovery of mines of precious metals in America. The discovery of the mines of precious metals constitutes the windfall. The counterfactual scenario is the one in which the new routes were discovered, but there were no discoveries of precious metals. Our objective is to compare the observed scenario with the counterfactual scenario.

The counterfactual scenario can be constructed with our model. We compare two equilibria under different sequences of precious metals D_t received by the European agent. Given the monetary standard based on precious metals, the discoveries of precious metals work as injections of money to Europe. They imply real effects of money because they arrived as a surprise and because Europe received the monetary injections whereas Asia did not receive them. Europe could benefit from the seigniorage revenues generated by the injections of money concentrated in the region.

The economies are initially in the steady state. We assign the time before the discoveries to $t = 1499$ and simulate the economy from $t = 1500$ and on. Most of the discoveries of precious metals in America occurred after 1500. Vasco da Gama reached India in 1498, marking the discovery of the new route to Asia.

The values for the injection of precious metals, D_t, are given in silver-equivalent grams of precious metals per capita. As explained in section 2, we obtain the values of D_t from data for the production of gold and silver in the mines in America. The values for the production of precious metals for each year are in figure 1. As it can be seen in the data, the amount of precious metals produced in America increased over time.[21]

Part of the production of precious metals went into non-monetary uses and were not put into circulation as money (Mayhew 2012). Another part stayed in America. To take these facts into account, we assume that 70 percent of the discoveries were effectively used for monetary transactions by the European agent from 1500 to 1700, and 50 percent for the period after 1700. The difference is justified by the increasing importance of the colonial economy in the eighteenth century, which absorbed an increasing amount of the production of precious metals. The final value of D_t in the model is then equal to the production of precious metals per capita per year in figure 1 times the correction for the precious metals used effectively for monetary transactions.

The discovery of the sea route between Europe and Asia is simulated by a permanent decrease in the iceberg cost, b_t. We denote b^i the iceberg cost before the new routes and b^f the iceberg cost after the new routes, $b^i > b^f > 0$. Therefore, $b_t = b^i$ for the calculations for the steady state before the shock, and $b_t = b^f$ for $t \geq 1500$.

Our baseline scenario corresponds to the observed scenario in which precious metals in America and a sea route between Europe and Asia were discovered simultaneously. In the baseline counterfactual, the sea route was discovered, but precious metals in America were not discovered. We also consider the medieval scenario in which neither new sea routes to Asia nor discoveries of precious metals in America were discovered.[22] These counterfactual

[21]The economic significance of the windfall can be gauged through figure 2 and table A.2. Table A.2, in particular, compares the discoveries of precious metals per capita with the wages of European agents.

[22]We also simulate a counterfactual of no new sea routes, but discoveries of precious metals. The results of this additional counterfactual are in appendix A.3.

scenarios allow us to decompose which part of the observed increase in trade can be attributed to the discoveries of the new routes and to the discoveries of precious metals. In summary, we simulate the following scenarios:

1. Historical scenario: New sea routes and discoveries of precious metals. The parameter b_t is set to $b_t = b^i$ for the time before the shock, and $b_t = b_t^f < b^i$ for after the shock. The values of D_t are set to match the historical data.

2. Baseline counterfactual: New sea routes and no discoveries of precious metals. The parameter b_t is set to the values as above. D_t is set to zero for all time periods.

3. Alternative counterfactual: No new sea routes and no discoveries of precious metals. The parameter b_t is maintained constant at b^i, and D_t is maintained constant at zero.

5.2 Parameterization

We calibrate the model at annual frequency. We take some parameters from the literature while others are estimated using a combination of the structure of the model and historical data. All preference parameters are the same for both regions, in line with ruling out a cultural explanation. Specifically, we do not impose that the agent in Asia has any particular propensity to hoard precious metals. Table 2 shows the values for the parameters.

Table 2: Baseline Parameters

	Parameter	Value
Intertemporal discount factor	β	0.96
Inverse of the elasticity of intertemporal substitution	σ	2
Substitution parameter for goods and money	η	-1
CES parameter of domestic and imported goods	γ	2
Weight on consumption	a	0.81
Population in Europe in the steady state	L_e	1
Population in Asia in the steady state	L_a	4.82
Income per capita in Europe	Y_e	1158
Income per capita in Asia	Y_a	723
Home bias	ω	0.983
Iceberg cost before the new trade routes to Asia	b^i	3.3
Iceberg cost after the new trade routes to Asia	b^f	0.603

Parameters used in the simulations. The value of L_e was normalized to 1. L_e and L_a correspond to an average population of 85 millions in Europe and 410 millions in Asia during 1500–1810. The values of Y_e and Y_a are used to obtain the production function parameters A_e and A_a.

We use $\beta = 0.96$ for the intertemporal discount factor, $\sigma = 2$ for the inverse of the elasticity of intertemporal substitution, and $\alpha = 0.36$ for the capital share. Standard values in macro. We set $a = 0.81$, which is the same value used in Duarte and Wolman (2008). For η, we use the fact that the interest-rate elasticity of the demand for money is given approximately by $-\frac{1}{1-\eta}$. Therefore, $\eta = -1$ implies an interest-rate elasticity equal to -0.5, which is compatible with a standard Baumol-Tobin demand for money and agrees with the findings for a long-run demand for money (Lucas 2000, Alvarez and Lippi 2009, Silva 2012).

We set $\gamma = 2$ for the value of the elasticity of substitution between domestic and foreign goods. The literature reports a large range of values for this parameter (Obstfeld and Rogoff 2001, Bajzik et al. 2020). The values used for this parameter in macroeconomic simulations were frequently between 1 and 2 (Chari et al. 2002, Duarte and Wolman 2008). Recent estimates point to values above 2. Using methods based on Feenstra et al. (2018) and Imbs and Mejean (2015), Bajzik et al. estimate values for this parameter from 2.5 to 4.3. We use a conservative value, closer to the values used in simulations of macroeconomic models. The effects of the discoveries of precious metals increase as we increase γ. Our predictions are conservative given that we choose a smaller value for this parameter.

We set the populations of Europe and Asia, L_e and L_a, according to data on population shares, based on Maddison (2006, pp. 636-638). We normalize $L_e = 1$ and set $L_a = 4.82$, equal to the mean of the ratios in table 1. For real income levels, we use the 1500–1810 average of per capita income from table 1, $Y_{e,ss} = 1158$ and $Y_{a,ss} = 723$ Geary-Khamis international dollars of 1990 per person. We use these values to obtain A_e and A_a from the production function and the steady state values of capital.[23]

We set the initial quantity of silver in Europe to $M_{e,1492} = 75$ grams per capita, which is equal to the value for Spain in the late 15th c. as reported by Chen et al. (2021). We obtain the value for Asia $M_{a,1492}$ so that there are no flows of precious metals in the steady state before the discoveries of the new route and precious metals. Given the value of $M_{e,1492}$ and the steady state values for aggregate income, we obtain $M_{a,1492}$ to equalize the two money-income ratios, which implies no flows of precious metals in the steady state. Since no major precious metals shocks had been occurring for a long time, the world markets should be in a long-term

[23]That is, $A_e = Y_{e,ss}^{1-\theta} \left(\frac{\theta}{1/\beta - (1-\delta)} \right)^{\frac{\theta}{1-\theta}}$ and $A_a = Y_{a,ss}^{1-\theta} \left(\frac{\theta}{1/\beta - (1-\delta)} \right)^{\frac{\theta}{1-\theta}}$.

equilibrium.

We set the iceberg costs before and after the discoveries of the new sea routes, b^i and b^f, and the home bias parameter ω so that the model matches the share of imported Asian goods in Europe before 1500 and during the period 1700–1800. Before the discovery of the Cape route, the Euro-Asian trade was small, made mainly through Venice. In the late 1400s, according to Spufford (2002, p. 346), Euro-Asian trade was 660,000 duncats per year. Given the exchange rate of 1.375 ducats per ocho at the time (Morineau 2009, p. 73) and of 25.931 grams of silver per ocho (Munro 2003), we obtain an Euro-Asian trade of 23.532 tonnes of silver per year (one ocho is equivalent to one peso of 8 reales).

We then divide the value in tonnes of silver by the population in 1500 of the main countries served by the previous trade routes. They were Italy, England, France, Belgium, Holland, and Germany, according to modern borders. This implies a population of 43,792 thousand (Maddison 2006, p. 636). Dividing the value in tonnes of silver by the population implies that the expenditures in Asian goods prior to the new routes correspond to 0.54 grams of silver per person per year.[24] According to table A.2, the daily wage in Europe before 1500 was 2.1 grams. With 250 working days per year, we obtain that share of annual income spent on Asian imports before the new routes, in the Middle Ages, was on average 0.1 percent.

For the share of imports after the discoveries, we focus on the period of the 1700s. According to (de Vries, 2003, p. 91), a worker in England or Holland in the 1750s spent in Asian goods between 0.8 to 1.4 percent of annual average wage income. As England and Holland were relatively richer than the other countries in Europe at the time, we set the target for the imports of Asian goods after the discoveries to 1 percent.

We therefore set the iceberg cost before the discoveries b^i and the home bias ω so that the share of imports of Asian goods in Europe is 0.1 percent of income for the first steady state. We set $\omega = 0.983$, equal to the value of Tretvoll (2018). We choose an upper bound for the home bias in the literature, as our model has only tradable goods and the share of imports of 0.1 percent of income would require a high home bias without the iceberg cost.[25]

[24] The countries listed do not include all Western European countries that used the previous trade routes. However, we use the population of 1500, which was higher than that after the Black Death years.

[25] The notation in Tretvoll implies that the corresponding value in our notation is given by $0.972^{0.6} = 0.983$. If $b^i = 0$, our model implies a share of imports of 1.8 percent. It is common in the literature to adjust the parameters related to home bias so that imports are a certain share of GDP (for example, Backus et al. 1994, Chari et al. 2002 and Duarte and Wolman 2008). Our paper distinguishes from the literature as we have

Given the value of ω, we then set $b^i = 3.3$ so that the share of imports is equal to 0.1 percent in the first steady state, before the discoveries. For the final iceberg cost, we set $b^f = 0.603$, so that the transition period in the simulations implies an average share of imports equal to 1 percent from 1700 to 1800. The iceberg cost for after the new routes is about 5.5 times smaller that its corresponding value before the new routes, which is reasonable given the higher efficiency in security, direct costs, and time of the new routes. As most of the gains in transportation efficiency from 1500 to 1810 were obtained with the new routes, in the beginning of the period, we hold the iceberg cost parameter constant after 1500. In fact, according to Menard (1997), it is reasonable to assume that the transportation costs were constant after the new routes were discovered.

Obstfeld and Rogoff (2001) define the iceberg cost as the fraction $1-\tau$ of goods that arrive in the destination given the initial delivery of one good. In their benchmark calibration, $\tau = 0.25$. Following their notation, the iceberg cost in our model decreases from $\tau = 1-1/(1+3.3) = 0.767$ in the Middle Ages to about half, 0.376, in the eighteenth century.

The discovery of the new sea routes cut significantly the trade costs between Europe and Asia. Before 1500, a roundtrip to Asia took three years via the overland routes (Spufford, 2002, p. 344). After the new sea routes, a roundtrip to Asia could be done in months. The voyage was safer, cheaper, and could carry more cargo.[26]

6 Results

We subject the model to two simultaneous shocks: a surprise decrease in transportation costs and the discoveries of precious metals. The decrease in transportation costs (a decrease in b_t) represents the discovery of the new trading routes between Asia and Europe. The discoveries of precious metals imply the monetary injections D_t in the model. The model is initially in the steady state. We calculate the equilibrium dynamics after the shocks.

The simulation answers the following question: What happens after the discoveries of precious metals become available to Europe together with the availability of a new trading

separate parameters for the home bias and the iceberg cost. We have separate parameters because we use the iceberg cost to proxy for the discoveries of the new routes.

[26]Another evidence of the large trading costs is the difference in prices before 1500. According to Allen (2011), the sale price of spices in Europe was 20 times the price in Asia. This would imply $\tau = 0.95$ or $b = 19$.

route between Europe and Asia? We additionally break down the effects of the precious metals from those of the new sea routes.

6.1 Simulation of the observed scenario

In the observed scenario, the two shocks arrive together. The discovery of the new routes and the initial discovery of the new precious mines happened at approximately the same time, around 1500. Figures 4–9 show the results. The figures show the transition period from 1500 to 1810. The monetary injections imply real effects during the transition. After the transition, the real variables converge to a steady state with lower transportation costs. The second steady state is such that consumption and real money holdings are larger and inflation returns to zero. During the transition, the agent in Europe benefits from the real effects of money from the fact that this region was the recipient of the discoveries of precious metals.[27]

Figure 4 shows the results on consumption goods and real money holdings. The values are relative to the initial steady state, with continental trade and no discoveries of precious metals. The initial levels of imported goods are small given the initial high transportation costs. Panel 4a shows the effects on consumption. Consumption in Europe of Asian goods such as tea and silk, C_{ea} increases substantially after the shocks with respect to the previous steady state, up to 19 times. At the beginning, the new trading routes increase consumption about 7 times. With the arrival of precious metals, consumption of Asian goods in Europe gradually increases until it reaches 19 times of its value in the first steady state.[28]

Consumption of European goods in Asia also increases with respect to the initial steady state (panel 4a). Imports of Europeans goods by Asia, such as weapons, in fact increased at the time. However, consumption of European goods in Asia eventually decreases, although it is always larger than before the shocks. Agents in Asia substitute European goods by precious metals. This behavior agrees with the reports about the increase in the consumption of Asian goods in Europe without the corresponding increase in the consumption of European goods

[27]The real effects of precious metals in the model vanish in the long run. Real money holdings are slightly larger in the second state because of the decrease in iceberg costs.

[28]A way of understanding the dynamics after the shocks is the following. The new precious metals and the new iceberg cost make the initial steady state prices and quantities not an equilibrium anymore. Given the new situation, prices of Asian goods become cheap in Europe. At the same time, prices of European goods become expensive in Asia. This situation stimulates agents in Europe to decrease consumption of domestic goods, increase consumption of Asian goods, and export precious metals to Asia. Prices and quantities then adjust accordingly over time.

in Asia. As discussed above, after the 1500s, imports of European goods by Asia other than precious metals were negligible, but the imports of Asian goods by Europe were substantial.

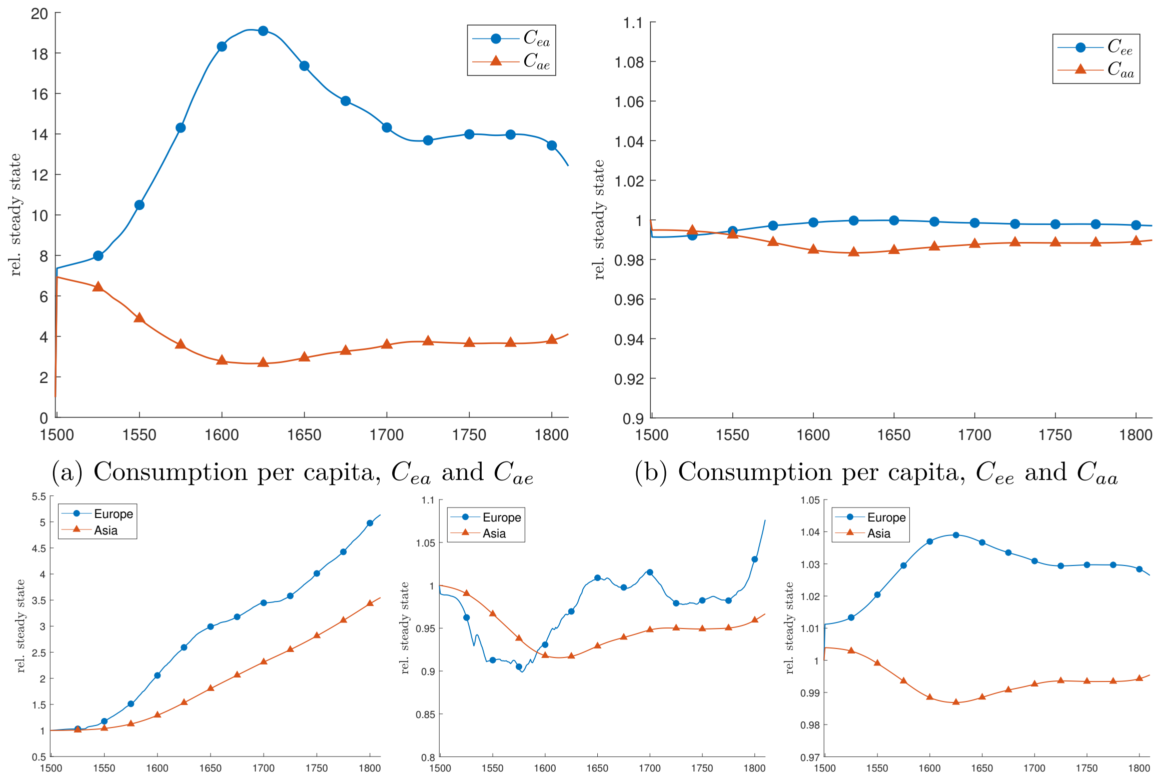
Panel 4b shows that domestic consumption changes little either for Asia and Europe, as C_{ee} and C_{aa} are approximately constant after the shocks. Most of the effects occur in international trade. Panels 4c and 4d show the effects on nominal and real money per capita. The injections of money increase money holdings in Europe and in Asia; faster in Europe as it is the recipient of the precious metals. Money holdings increase in Asia as precious metals are shipped to this region (GDP per capita is smaller in Asia, which implies smaller money holdings per capita in equilibrium). A surprising effect is the decrease in real money holdings in Europe and in Asia. This is a result of the increase in inflation in both regions, as it will be seen below, which decreases the real demand for money. For Europe, the decrease in real money holdings is compensated by an increase in consumption. Panel 4e shows that the composite consumption good decreases in Asia whereas it increases in Europe.

Figure 5 focuses on international trade. Panel 5a shows imports and exports of goods of Europe relative to the initial steady state. Both imports and exports increase with the new trading routes. Imports increase almost 20 times from its initial level with the combined effect of the new routes and the precious metals. Panel 5b shows the exports of precious metals relative to the new discoveries of precious metals. Our simulations imply that most of the new discoveries were exported to Asia. Exports of precious metals during the transition are on average 55 percent of the discoveries. Most of the precious metals found in America is exported by the agent in Europe to receive Asian goods in return.[29]

Panel 5c shows imports of precious metals by Asia relative to total imports. The panel shows that most of the imports of Asia are made of precious metals. From 1600, precious metals constitute on average 77 percent of the value of all imports of Asia. The model predicts that the ships that traveled from Europe to Asia were almost filled with precious metals, which agrees with the evidence we previously discussed and with the contemporaneous accounts.

Figure 6 shows the dynamics of capital during the transition as well as the dynamics of nominal wages and nominal interest rates. Prices are in units of silver in the model, therefore

[29] We define exports by Europe as the goods produced in Europe minus net investment minus C_{ee}. We define imports by Europe as the Asian goods that are effectively consumed in Europe (that is, the Asian goods that arrived in Europe, net of the iceberg cost). Panel 5a relates to panel 4a as imports of Europe are equal to C_{ea}.



(a) Consumption per capita, C_{ea} and C_{ae}

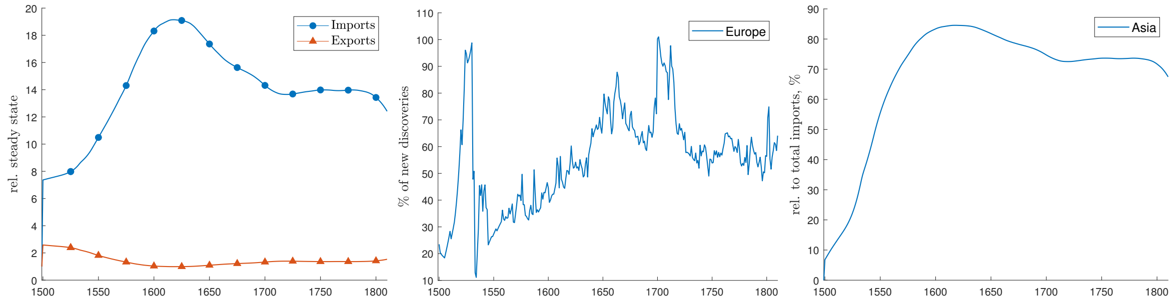
(b) Consumption per capita, C_{ee} and C_{aa}

(c) M_e and M_a

(d) M_e/P_e and M_a/P_a

(e) Composite goods, C_e and C_a

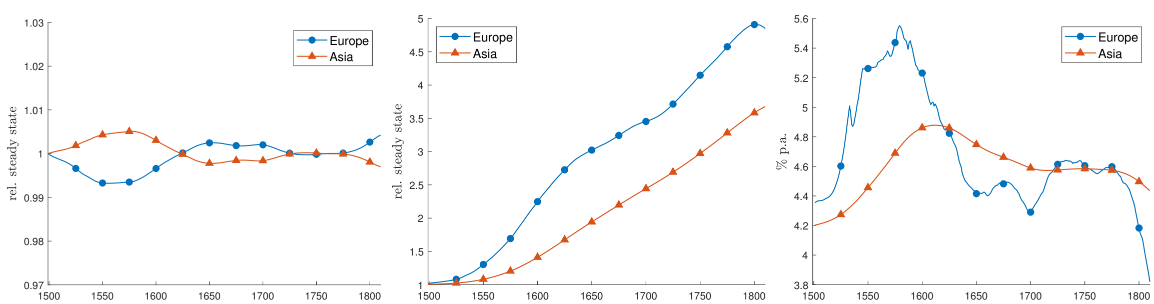
Figure 4: Results from simulations: consumption and money. M_i/P_i: real per capita money holdings in region i. C_{ij}: per capita consumption in region i of goods of region j (e.g. C_{ea} denotes per capita consumption in Europe of Asian goods).



(a) Goods trade, Europe (b) Exports of precious metals (c) Imports of precious metals

Figure 5: Results from simulations: international trade of goods and precious metals

wages and interest rates in silver are nominal values. Most of the dynamics of the model is in the changes in the demands for goods and real money holdings. Capital changes little, but the difference in the dynamics in Europe and in Asia is revealing. Panel 6a shows that capital decreases in Europe and increases in Asia with the discoveries of precious metals. The agent in Europe uses the windfall to consume more both Asian goods and domestic goods. To help with this objective, the agent in Europe decreases investment to make room for additional exports of precious metals and additional consumption. On the other hand, the agent in Asia increases production to allow an increase in exports of goods and an increase in imports of precious metals. As a result, investment and capital increase in Asia. As the shock is temporary (it is a windfall), the optimal solution for the agent in Asia is to temporarily increase capital to increase production, export more and import more precious metals.



(a) Capital (b) Wages in silver (nominal) (c) Interest rates in silver (nominal)

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Figure 6: Dynamics of capital, silver nominal wage and silver nominal interest rate. Capital decreases temporarily in Europe as agents export more precious metals and import more Asian goods. Asia increases capital so that production increases and exports increase. The increase in capital allows Asia to export more goods and import more precious metals.

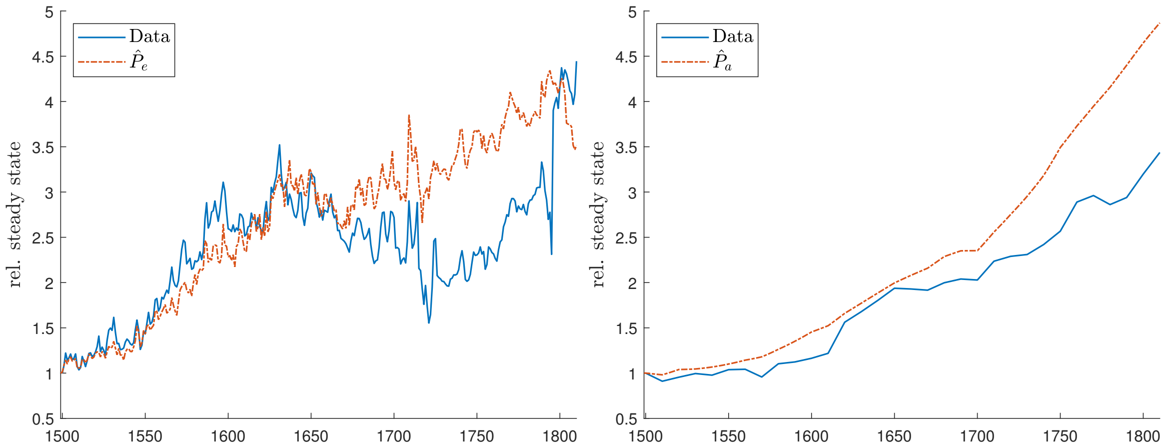
The dynamics of wages and interest rates are shown in panels 6b and 6c. Labor productivity is approximately constant as capital changes little. This implies that real wages are approximately constant and that the dynamics of nominal wages follows inflation (we discuss the dynamics of prices below). In particular, nominal wages increase less into the 1600s as the inflation rate decreases. Real interest rates are approximately constant and slightly decrease for Asia. As a result, nominal interest rates increase faster in Europe, although not much, from about 4.4 percent to about 5.5 percent. Nominal interest rates in Europe then decrease in the 1600s as the inflation rate decreases in this period (as capital increases, there is also a small decrease the real interest rates). The behavior of wages and interest rates is compatible with the evidence for the period.[30]

6.2 Price dynamics

Figure 7 shows the dynamics of prices during the transition together with data for the CPI for the same period. To compare our simulation results with the data, we adjust the price level for GDP per capita growth, as output is constant in our model. For Europe, we focus on the most important countries involved with the Atlantic trade: England, France, Holland, Portugal and Spain. For Asia, we focus on the most important countries for international trade with Europe: China and India. Average GDP per capita growth is calculated first by obtaining the log trends of GDP per capita and of population for each country. We then average GDP per capita using population as weights. Our raw data is GDP per capita for each country in 1990 G-K dollars and population for each country per year. Similarly, we weight the country CPIs by the population to obtain an average CPI. To construct the CPI in silver, we use data on the nominal CPI and take into account the debasements of the precious metals content of the currency during the period. We can then compare the predictions of our model, in silver as unit of account, with the CPI data in silver. All countries in the sample used a monetary standard in precious metals.

Inflation is smaller in silver, but there is still substantial inflation. According to our calculations, as it can be seen in figure 7, the data imply that prices in silver increased on average about 4.5 times in Europe and 3.5 times in Asia.

[30]The dynamics of real wages and of real interest rates are not shown. The marginal productivity of capital and labor change little, as capital changes little, so real wages and real interest rates are approximately constant.



(a) Europe (b) Asia

Figure 7: CPI data and simulations results. CPI data in silver. $\hat{P}_i$ denotes equilibrium price indices adjusted for GDP per capita growth. The discoveries of precious metals can explain a great part of the inflation process in Europe and Asia for the period 1500–1700.

Panel 7a shows that the model is able to explain the increase in prices in Europe from 1500 to around 1670. After this date, prices in Europe decrease more strongly than the predictions of the model, and the model predicts an earlier return in the increase in prices, as the discoveries of precious metals continue to flow. It is interesting that the model captures the decrease in prices from 1630 to 1670. Prices in Europe increase strongly after 1720, which makes the model approximate the overall evolution of prices until 1810. For Asia, in panel 7b, the simulated prices overshoot the CPI data for the overall period, but it follows closely the data until 1650. We note that we have not used data on prices to calibrate the model. Taking as a whole, the model is able to explain a great part of the coincident increase in prices in Europe and in Asia. This is an indication that the discoveries of precious metals in America had a great impact on prices in Europe and in Asia.

6.3 Disentangling the effects of precious metals and new sea routes

We now break down the effects of precious metals from those of the new sea routes between Europe and Asia. What was more important to explain the volume of international trade, the new sea routes or American precious metals? The fact that they happened almost at the same time makes it difficult to answer this question. We use our model to answer this question by decomposing the relative contribution of each of these factors.

Figure 8 shows imports of goods after the shocks together with the counterfactual of the discovery of a new sea route but no precious metals. The counterfactual is obtained by decreasing the iceberg cost to $b^f < b^i$ and setting new precious metals D_t to zero for all t.

Panel 8a shows that the discoveries of precious metals played a prominent role for the increase in Asian goods in Europe. Without precious metals but with a new sea route, imports of Asian goods increase about 7 times. We model the change in the iceberg cost to happen at once, and so the economy converges fast to the new steady state, as the real shock to iceberg costs happens. With precious metals, imports of Asian goods increase further especially after 1550 and its peak reaches almost 20 times the initial steady state level. Precious metals and the new sea routes interact with each other to magnify the final effect. The windfall allows the agent in Europe to greatly increase consumption of Asian goods.[31]

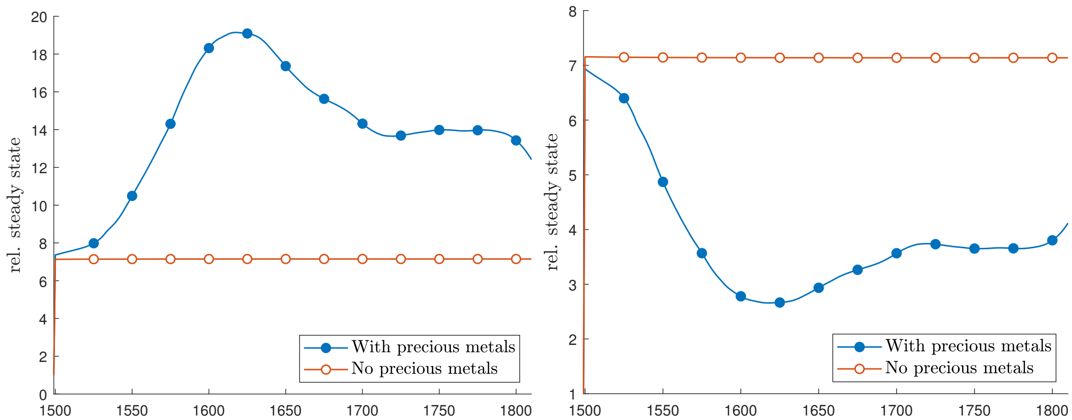
Panel 8b shows the response of Asia with the new sea route with and without precious metals. A surprising result is that the consumption of European goods decreases with respect to the counterfactual with the discovery of precious metals. Without new precious metals, the Asian economy increases the consumption of European goods, as we would observe in case of a sole decrease in transportation costs. With precious metals, the Asian economy substitutes consumption of European goods for precious metals. The discovery of precious metals by Europe can answer the puzzle for why consumption of European goods have not increased in Asia as the consumption of Asian goods increased in Europe.

To assign a numerical value to the effects of the new routes and precious metals across different scenarios, consider the scenario 0 of no discoveries of sea routes and precious metals, D of discoveries of sea routes, and PM of discoveries of precious metals. Scenario 0 corresponds to the medieval scenario of a continental route between Asia and Europe. Define the ratios of accumulated consumption from time zero to a certain time t,

$$q_{it}^{j} \equiv \frac{\sum_{\tau=0}^{t} C_{ea\tau}^{j}}{\sum_{\tau=0}^{t} C_{ea\tau}^{i}}, \tag{23}$$

where i and j assume the values 0, D or DPM (D together with PM). Different specifications of the model yield different values for C_{eat} and C_{aet}. The ratio in (23), on the other hand, is

[31]The fast decrease in the transportation costs agrees with the factual accounts. The strategy of decreasing the iceberg cost at once facilitates the comparison between the cases with or without precious metals but it is not essential for our conclusions.



(a) Imports of Asian goods by Europe

(b) Imports of European goods by Asia

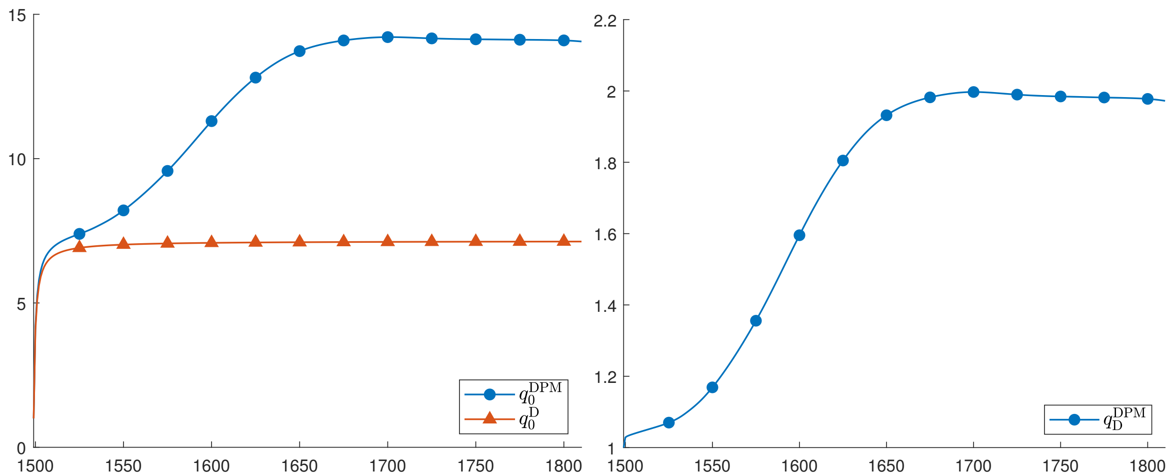
Figure 8: Imports with the discovery of a new sea route with and without the discovery of precious metals.

approximately stable, which facilitates the isolation of the effects in each scenario.

According to (23), q_{0t}^{DPM} measures the impact of the new routes and precious metals over the medieval situation. The impact is measured by the increase in consumption of Asian goods by the agent in Europe. Analogously, $q_{\text{D}t}^{\text{DPM}}$ is the ratio of accumulated consumption of Asian goods in Europe with new routes and precious metals relative to the scenario with the new routes, but no precious metals. $q_{\text{D}t}^{\text{DPM}} > 1$ implies that the discovery of precious metals makes accumulated consumption higher than in a situation without precious metals in the case of the discovery of new sea routes. It isolates the impact of precious metals.

Figure 9 shows the values of q_{it}^{j} during the transition for different scenarios. Panel 9a compares the effects over the medieval scenario. The peak of the effects occurs around 1700. The new routes imply a substantial increase in accumulated consumption over the continental routes, $q_{0,1700}^{D} = 7.1$. Adding the discoveries of precious metals accumulated consumption reaches 14.2 in 1700. Panel 9b isolates the effects of the discoveries of precious metals. The value of $q_{\text{D}t}^{\text{DPM}}$ reaches 2 in 1700. Consumption of Asian goods increased substantially in Europe after the 1600s, reaching a peak in the eighteenth century. The value of $q_{\text{D}t}^{\text{DPM}}$ of 2 around 1700 allows us to conclude that the model implies that the discoveries of precious metals explain half of the increase in consumption of Asian goods.[32]

[32]We have also simulated a separate counterfactual dynamics of discoveries of precious metals but no new sea routes. The results can be seen in appendix A.3. We confirm a strong effect of precious metals and that it is the interaction between new routes and precious metals that magnifies the effects.



(a) Ratios over medieval scenario

(b) Ratio over new routes, but no precious metals

Figure 9: Ratios of accumulated consumption q_{it}^{j} defined in (23) for scenario j relative to i. Scenarios: 0: medieval scenario of continental routes and no discoveries of precious metals; D: new routes, but no precious metals; DPM: new sea routes and discoveries of precious metals.

We also calculate the welfare consequences of the new routes and of precious metals. We measure the consequences on welfare by the annual income compensation that an agent would require to live under an initial scenario. We use the utility function in (2) from $t = 1500$ to 1810. We find that an agent in Europe would require an annual income compensation of 0.97 percent to live under the medieval scenario of no new routes and no precious metals instead of living in a scenario with new sea routes. Adding the precious metals increases the income annual compensation to 1 percent, which is an implication of the result that the discoveries of precious metals under the new routes imply an additional annual income compensation of 0.04 percent. The income compensation for an agent in Asia to live with the new sea routes, but no discoveries of precious metals is negative, -0.41 percent. The income compensation for an agent in Asia to live under the medieval scenario is still positive, 0.47 percent (which implies a welfare gain with new routes but no precious metals). But the seigniorage gains concentrated on the agent in Europe decrease the overall trade gains for the agent in Asia. If possible at the time, a modern policy prescription would be for the economy in Asia to abandon at least temporarily the monetary standard based on precious metals. To our knowledge, we are the first to calculate the welfare consequences of the discoveries of the new routes in the 1500s and of the discoveries of precious metals in America.

Given the large gains of consumption for the agent in Europe, it is surprising to obtain a small income compensation of 0.04 percent for a scenario without the precious metals. There are seigniorage gains for the agent in Europe, as the injection of money was concentrated on Europe, but the increase in money supply also increases inflation and decreases real money holdings, which decrease the welfare gains. This is a general equilibrium effect generated by the fact that all agents in Europe want to increase consumption at the same time.[33]

Seigniorage gains are larger if the increase in money supply arrive as a surprise. As shown in figure 1, however, the announcement of the new mines occurred around 1500, but the arrival of large quantities of D_t occurred only after 1550. Therefore, the increase in money supply that occurred later was to a larger extension announced in the beginning of the period. We then simulate a scenario in which the new injections of money arrive as a constant flow, equal to its mean from 1500 to 1810. The income compensation for the agent in Europe with the sea routes but without the precious metals increases from 0.04 to 0.76 percent. The negative income compensation for the agent in Asia decreases from -0.41 to -1.61 percent (as the seigniorage gains increase, the agent in Asia has a higher loss). The gains to trade with the new routes but no precious metals are maintained at 0.97 and 0.47 percent for Europe and Asia. However, the predicted seigniorage gains would be much larger in this case.[34]

6.4 Robustness

We have made several robustness checks. We changed parameters as well as shares of imports, and initial levels of income and money holdings. Decreasing initial income increases slightly the real effects of the discoveries of precious metals. In our benchmark, we consider the average income for the period, which decreases the effects because income is higher in the

[33]Silva (2012) also finds that the welfare losses of inflation are much larger when general equilibrium effects are taken into account. The monetary shocks increase the volatility of consumption. Although the seigniorage gains are positive for Europe, the agent in Europe has to adapt to the shock as the the increase in money supply was not a choice, but a monetary shock. The monetary injection would be different if the agent in Europe could set production of precious metals endogenously to maximize seigniorage gains. Furthermore, there are several mechanisms via which additional precious metals and money affected the European economy which we do not consider here, such as the effect of higher liquidity, and the evidence suggests that the welfare effects from precious metals were large for some countries but small for others (Palma, 2020; Chen et al., 2022).

[34]We maintain the other parameters of the model. The model does not have other kinds of frictions that would affect welfare and other equilibrium values. For example, exports of precious metals are not subject to convex adjustment costs, information about future changes are available without costs, and so on. It is beyond the objectives of our exercise to consider all possible variations that could have occurred in the period.

final periods. A decrease in initial money holdings increases the effect of new discoveries, as new discoveries increase in relative terms, and a steeper increase in prices. Changing initial money holdings changes the dynamics of the price level but do not change real variables in a significant way. We also computed the simulations without capital. Capital works as a substitute for money. When we remove capital the effects of precious metals increase even further. Our main conclusions are maintained for a plausible range of alternative parameters. In particular, the results in figure 9 are stable.

6.5 How do the results compare with what we know empirically?

The results of our simulations are in line with the empirical facts. This increases our confidence in the simulations for the counterfactual scenarios. We emphasize the following four points.

First, a substantial portion of the value of European exports to Asia during the early modern period consisted of silver. Our model matches this fact.

Second, in the simulations, imports of Asian goods by Europe increase substantially. They are up to 2.7 times of what they would have been without precious metals (figure 8a). At the same time, there is not a counterpart increase in imports of European goods by Asia. To the contrary, imports of European goods by Asia are reduced to 38 percent of what they would have been without the precious metals by 1620 (figure 8b). These predictions are in accordance with historical observations. In particular, Asia did not experience an increase of foreign, exotic goods that happened in Europe.[35]

A surprising implication of the model is that, without precious metals, Asia would have consumed more European goods, despite of the fact that the total value of Euro-Asian trade would have been smaller. This results from the effect of the shock on relative prices. Asia becomes poorer in relative terms following the shock. The stock of money of Asia is now relatively smaller, which helps determine prices. This conclusion stands in sharp contrast with some of the traditional interpretations of this episode, which claim that Europe was forced to export specie to Asia to finance a recurring trade deficit.[36]

[35]These large changes in international trade occur simultaneously with domestic consumption maintained approximately constant for Europe and Asia (figure 4b), which was also observed at the time.

[36]Under a proportional helicopter drop, no frictions, and homogeneous agents, all prices would rise simultaneously. The monetary injection would not affect real allocations. Here, the agent in Europe first benefits from the injection which is then transmitted through trade. Relative endowments are affected and end up affecting the aggregate price level, relative prices, and the volume and structure of trade. As the agent in Europe gets

Third, Europe experienced a price revolution, but not Asia (de Vries 2003, pp. 94 and 105). Our simulations replicate this fact (figure 7). An increase in the price level would have implied a decrease in the price of silver in Asia, which would have eliminated the trade imbalance. We show that the behavior of the price level in Asia is an equilibrium result. In contrast, the literature in history usually assumes that the lack of a fall in the price of silver in Asia was the result of a particular Asian tendency to demonetize precious metals for hoarding. As de Vries (2003), we do not endorse this interpretation. We reproduce the observed factual scenario without assuming different preferences for the agents in Asia and Europe, which is the dominant explanation for the trade patterns in the historical literature.[37]

Fourth, historians have long asked why nominal prices were higher in Europe and why the difference persisted for so long. For instance, Allen (2005, p. 123) states that "wages expressed in grams of silver were lower in China and India than in Europe.[38] Our model offers an answer, as shown in figure 6b. Europe received the monetary injections. This leads to an increase in inflation in Europe relative to Asia.

7 Conclusion

Without precious metals from America, Euro-Asian trade in 1500–1810 would not have been possible in the observed magnitude. Europe did not produce goods that Asia was willing to purchase in significant quantities. Previous explanations for the import of precious metals by Asia typically relied on cultural elements, such as an inclination in Asia for hoarding. In contrast, we show that the observed trade pattern can be explained with a dynamic model with no cultural differences.[39]

We also obtain the following novel conclusions. First, if Europe did not have access to the precious metals from America, the volume of trade would have been much smaller. While this has been previously suggested qualitatively, we quantify the magnitude of the effect for

richer, the agent spends more on domestic goods and on imports. The converse happens for the agent in Asia.

[37] We assume a home bias, as it is standard in the trade literature, but it is equal for both agents.

[38] Allen continues, "This is important since it was the proximate cause of Asia's competitive advantage in textiles and luxury manufactures and was, thus, the basis for Asian-European trade in the early modern period. Why these differentials persisted for hundreds of years is an important question in international and monetary economics that must be addressed to explain the dynamics of the world economy in this period."

[39] Cultural elements might have mattered as well. What we show is that they are not essential to understanding the pattern of Euro-Asian trade in the period.

the first time. Under our baseline scenario, purchases of Asian goods by Europe were several times what they would have been without precious metals. Second, Asian would have a more eclectic mix and higher overall quantity of European goods without precious metals. To our knowledge, this has never been suggested before. Third, rather than the main factor, the discovery of a new sea route between Europe and Asia was complementary to precious metals to explain the growing importance of Euro-Asian trade during the early modern period. American precious metals deserve at least as much center-stage. As stated in Hamilton (1952), "No matter how the [European] price level and domestic trade might have been maintained through monetary manipulation, commerce with the Far East could not have flourished as it did without the great supply of bullion from the New World."

Our results show that monetary factors have an important effect on real allocations. In the period we cover, the need of Asia of a means of payment stimulated international trade. Euro-Asian trade started off a dynamic process with broad consequences for Europe. Although foreign trade accounted for a small percentage of European GDP at the time, it provided expansion opportunities at the margin (Palma 2016). The degree of interest of Asian goods in Europe can be measured by the costs of this trade. European mercantile companies lost an average of one life for every 4.7 tons of Asian cargo imported to Europe during 1500–1810. By the mid eighteenth century, when in average each European was consuming one pound of Asian commodities, this trade required between six and seven thousand European lives and around 150 tons of silver each year (de Vries, 2003, p. 74).

Early modern trade between Europe and Asia led to the emergence of mercantile companies such as the Dutch VOC and the English East India Company: the prototype for modern multinationals.[40] It permitted the development of modern financial markets in Amsterdam and London (Neal 1993). It induced an industrious revolution (de Vries 2008) which encouraged market participation in Europe (Humphries and Weisdorf 2019), and it stimulated urbanization (Allen 2009, Palma 2016). These were likely preconditions for the industrial revolution and the emergence of modern economic growth. Trading with Asia and America may have also induced a shift in the wealth and political power from the land-owning elite to the hands of a merchant, entrepreneurial class (Jha 2015). Positive spillovers resulted from the increased

[40] Smith (2003, p. 278) connects Euro-Asian trade to the emergence of the European mercantile companies. See also Irwin (1991).

inter-continental exchange of ideas. Finally, the expansion of the trade routes and the warfare associated with them were powerful drivers behind European state-building, which had developmental implications as well (Besley and Persson 2008, Dincecco and Katz 2016).

These facts suggest the strategic importance of Euro-Asian trade during the period for Europe. According to our results, understanding early modern Euro-Asian trade is impossible without taking into account the monetary injections of the period. Hence, our results contrast with those of Clark et al. (2008), who argue that trade with America only mattered marginally for European industrialization. As we show, without precious metals, imports of Asian goods would have been impossible at a volume close to the observed volumes. Without imports of Asian goods, early modern history would have been considerably different. Understanding the true impact of American precious metals for early modern Europe holds much promise in our understanding of the takeoff of Europe.

A Appendix

A.1 Precious metals and money

Paper money became prevalent in Europe only in the nineteenth century. Prior to fiat money, the options for monetary expansion were limited (Palma, 2020). Until the rise of paper money, monetary authorities had two ways of increasing a monetary base composed essentially of coin. The first was to debase it by decreasing the precious metal content of the coins. This policy was constrained by competition with foreign mints and political costs. Another way was through increased access to precious metals, the critical input in the production of specie.[41]

During the fifteenth century there was increasing production of silver in Saxony and Bohemia and associated technical change made silver available at lower cost (Munro 2003). But these quantities were small compared with those to come. Following the discovery of America around 1500, Europe experienced monetary injections of unprecedented magnitude. The first wave was comprised of gold in moderate quantities which the Spanish brought from the Caribbean (Vilar 1977). Next, there were large quantities of precious metals (mainly

[41]See O'Brien and Palma (2020) for the change of regime to a system of paper money in England from the late eighteenth century. In other countries such as Spain, the predominance of coin as a share of overall money stock was even larger and lasted until later (Chen et al. 2021).

silver) most importantly from Peru (which included Potosí in modern Bolivia) and Mexico. The last sources were of considerable magnitude and were combined with purifying techniques developed in central Europe to produce unusually large monetary injections. Finally, in the eighteenth century, large gold reserves were found in Brazil, and the decreased volumes of silver production in Potosí were compensated with increased production in Mexico.

Table A.1: Production and Movement of Precious Metals (silver equivalent tonnes)

	American Production (1)	European Arrivals (2)	Exports via the Pacific (3) = (1)−(2)	Exports from Europe (4)	Production Remaining in Europe (5) = (2)−(4)
1501–1550	4,250	1,064	3,186	NA	NA
1551–1600	13,250	7,765	5,485	NA	NA
1601–1650	18,375	11,413	6,962	5,625	5,788
1651–1700	23,625	16,786	6,839	7,125	9,661
1701–1750	30,000	25,189	4,811	10,000	15,189
1751–1800	44,000	32,872	11,128	10,250	22,622
Total	133,500	95,089	38,411	33,000	62,089

1 tonne = 1 metric ton. Source: Our calculations based on Morineau (2009, p. 578) for column 2, and on Barrett (1990, p. 242) for columns 1 and 4.

From 1500 to 1810, 85 percent of the world's silver and more than 70 percent of world's gold came from America (Barrett 1990). See Palma (2020) for the overall quantities of precious metals produced in America in each century and a comparison with initial stocks. Table A.1 shows the magnitude of the injections and their distribution. Barrett (1990) gives a lower bound of 150,000 tonnes of silver *produced* in Latin America from 1500 to 1810. Therefore, less than 50 percent of the total ever arrived to Europe. Some of the precious metals went to Asia and elsewhere through Manila, and some stayed in the New World.[42]

Table A.2 shows the importance of the monetary imports relative to wages in Europe. Specie injections were of considerable real magnitude. For regions with higher wages, it was up to the value of a day of work. For regions with smaller wages, it was equivalent to several

[42]Comparative figures are given by Hamilton (1934) for 1503-1660: outflows from the Spanish empire to Spain of 16,886 tonnes of fine silver, plus 181 tonnes of gold. Nevertheless, because of smuggling, the imports need to be interpreted as lower bounds. Note additionally that Morineau's figures for Europe include only amounts across the Atlantic, but trade through the Philippines benefited European agents as well. Because of the small size of the American economies (from negligible initially to non-negligible at the end of the period but still small relative to Europe) and because of imports through the Philippines as well as smuggling, the actual windfall may be closer to the production figures (Pieper 2015). While there was some production in central Europe until the middle of the sixteenth century (Munro 2003), we only consider American production.

Table A.2: Importance of Monetary Imports Relative to European Wages (grams of silver)

	American Production (annual, per capita)	Imports (annual, per capita)	Wage, unskilled (per day)	Wage, skilled (per day)
1501–1550	3.2	2.8	2.1–4.2	2.8–6.8
1551–1600	8.4	6.5	1.9–6.6	3.3–12.5
1601–1650	9.9	7.2	3.2–8.8	5.2–20.1
1651–1700	12.2	9.0	2.7–9.7	3.9–15.1
1701–1750	14.7	11.2	1.9–10.5	3.0–11.7
1751–1800	16.4	11.1	2.9–11.5	3.2–17.8

Source: production and imports from table A.1, wages from Allen (2001, p. 416) (range across different regions in Europe), population from Maddison (2006, pp. 636, 639).

days of work. The discovery of specie was associated with increases in the availability of money because specie was the critical input in the production of money. As a consequence, Europe experienced major monetary injections.[43]

About wage levels, the lower bound of the range is more representative, as the distribution is skewed. An example is that for the period 1600-1649, where the wage of a building craftsman in Madrid is 20.1 but the second highest observation, in Antwerp, is 12.6. More generally, the upper bound is usually representative of only one or two cities such as Madrid, Antwerp, Amsterdam, or London. For this reason, using the upper bound leads to a (very) conservative value for the relative size of the injection. For the 1500-1549 period, such an individual earned a wage which ranged from 2.1 grams of silver per day in Augsburg to 4.2 in Valencia. If we ignore Spain, the variation is up to 3.3 in Naples (Allen, 2001, p. 416). For these individuals, receiving 5 grams of silver in a year from the windfall would be the equivalent of what they earned in up to 2 days of work. The windfall was not equally distributed, but this calculation shows how large the silver injections really were. For the 1650-1699 period, the variation ranges from 2.7 in Warsaw to 9.7 in London.

[43] Table A.2 is constructed in the following way. First, because of differing sources, there is a difference of 1 year relative to table A.1. Second, since population levels are only available for 1500, 1600, 1700 and 1820, each value in the two first columns is actual production divided by initial population of the period in question. For example, for 1500–1549, we use the 1500 levels (as population was growing, there is a slight upward bias in the numbers). For the years in which data on population are not available, an average is used. For instance, for 1550–1559, $8.4 = \frac{26.5\times 10^6}{50\times(52268+73778)/2}$. For 1750–1799, population used is that of 1820. Since population was increasing during the early nineteenth century, this produces a conservative estimate. The wage for an unskilled in Europe is proxied by that of a building laborer and that of a skilled worker by a building craftsman.

A.2 Asian luxuries and precious metals

Euro-Asian trade was residual during the Middle Ages. The small trade flows reflected equilibrium responses to relative endowments and price levels before American precious metals became available and the new sea trade routes to Asia were open. It was only after 1500 that advances in maritime technology, internal developments in Asia, and the discovery of the American precious metals interacted to ensure scope for trade.[44]

Europeans were interested in Asian luxury goods which were cheap to transport over long distances relative to their value and weight. But Asian imports had to be paid for. Europe and its colonies paid 90 percent of their imports from China during the early modern era using silver (Pomeranz, 2001, p. 159).[45] Most of the silver which Europeans brought to Asia went to China.[46] A conservative estimate is that 75 percent of the 400 million pesos of Spanish American silver bound to the Philippines during 1565-1820 ended up in China to pay for imports. The single most important Chinese export was silk. At the peak of this trade, China exported silk goods of value up to four million pesos per year (Ma 1999).[47]

Two aspects justified a low price of Asian manufactured goods relative to European goods, according to Smith (2003). First, Asian nominal wages were low. This claim has modern empirical support: Allen (2005) attributes Asia's proximate cause of competitive advantage in textiles and luxury manufactures to low nominal wages. This might be partially compensated by low food prices but it would nevertheless mean that Europeans had cheaper access to imported Asian goods than conversely. Second, China was able to support large manufactures as a result of the division of labor made possible by a large internal market (Smith 2003, pp. 280 and 866). For Smith, the fact that China had a larger market than Europe explains the higher value of precious metals in China, but the differences persisted because of transportation costs, which prevented arbitrage (Smith 2003, p. 257).

The economic size of Asia would imply that much American precious metals would end

[44]See de Vries (2003) for quantitative data on departing and returned ships, tonnage, and personnel. DeVries also provides numbers on the growth of Euro-Asian trade during the period, measured by volume and value.

[45]The lower estimate gives 80 to 90 percent paid for in silver up to 1760, and about 50 percent thereafter (Cranmer-Byng and Wills 2010).

[46]Irigoin (2009) states that “Undoubtedly China was the main and ultimate destination—directly or through intermediaries—of Spanish American silver since the sixteenth century”.

[47]One silver peso of 8 reales or 272 maravedís corresponds to 25.931 grams of silver (Munro 2003). This rate between a nominal amount and a physical weight was approximately constant during 1500-1810.

up in Asia. The relative endowments suggest large arbitrage gains even under the prevailing transport technology and institutional settings. Accordingly, a large part of the American precious metals in fact ended up in Asia (von Glahn 1996, Irigoin 2009, 2013).

Table A.3: Exports of Silver and Gold from Western Europe, 1601–1780 (tonnes of silver equivalent)

Year	To the Baltic	To West Asia	VOC to Asia	EIC to Asia	Total to Asia
1601–1650	2,475	2,500	425	250	4,006
1651–1700	2,800	2,500	775	1,050	4,847
1701–1750	2,800	2,500	2,200	2,450	7,900
1751–1780	1,980	1,500	1,445	1,450	5,270
Total	10,055	9,000	4,845	5,200	22,027

VOC: Vereenigde Oost-Indische Compagnie (Dutch East India Company). EIC: English India Company. Source: Maddison (2007, p. 113), Barrett (1990, p. 251). During the period, 9,000 tonnes went to the Eastern Mediterranean, and it is possible that some of this ended in Asia as well (Maddison 2006, p. 67). Total to Asia differs from Barrett and Maddison by the inclusion of totals sent through the Philippines (Barrett 1990).

The importance of precious metals for Asia is also supported by the evidence on the scarcity of means of payments in the region. See, for example, von Glahn (1996) for China and de Vries (2003) for South Asia. There had been experiments with paper money in China. The inability of the government to commit to a limited supply led to hyperinflation. By 1425, public confidence was finished. The Ming were unable to prevent widespread use of silver as store of value and means of transaction. Following the state's official acceptance of silver by the 1430s, silver displaced all other currencies. By mid-century, China was a silver economy (von Glahn 1996, p. 79; Atwell 1998, p. 381). In the 1570s, the government unified the tax system and adopted silver as a means of tax payment. China had one fourth of the world's population at the time, with urban centers of more than one million. The demand further extended to the neighboring countries, which were covered by China's silver-based tributary system (Flynn and Giraldez 1995). During the sixteenth century, Spanish silver currency served as international currency of Asia and Europe (von Glahn 1996, p. 282, n. 44; Reid 1988, p. 26). These facts exerted a strong pull of silver toward Asia (table A.3).[48]

These numbers compare favorably with the total silver and gold production in Spanish and Portuguese America: between 27,640 and 34,435 silver-equivalent tonnes were produced in the

[48] The injections to Asia were such that the breakdown of the South American monetary system in the early nineteenth century had serious consequences in China (Irigoin 2009, 2013). Fernández-Villaverde and Sanches (2022) show that a country under the gold standard but with scarcity of precious metals is more vulnerable to external shocks.

seventeenth century and between 39,157 and 58,530 in the eighteenth century (Barrett 1990, p. 228). Nonetheless, some historians claim that most of the flow of precious metals from Europe to the East went through the Levant (Pearson 2001), which is not included in table A.3. Moreover, the trading activities of Spain and the Portuguese Estado da India are not included in the table. Finally, smuggling was common. These considerations suggest that the amounts in table A.3 are lower bounds to the totals that actually went to Asia. As discussed above, the totals to Asia would have been at least half of the production in America.[49]

A.3 Additional results

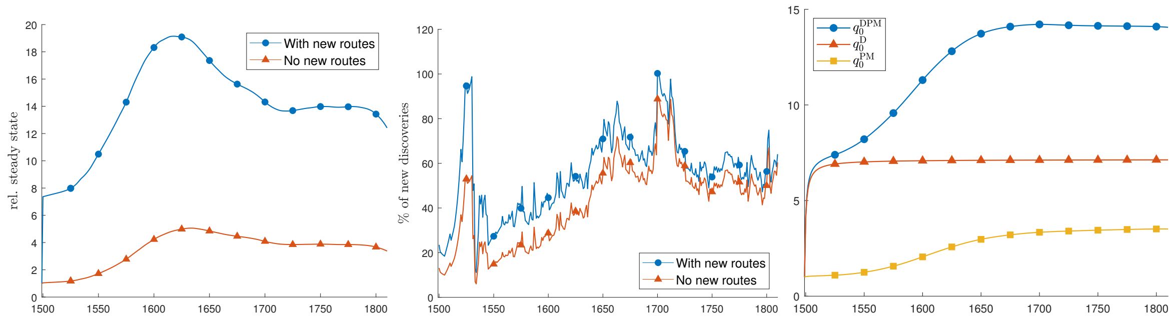
We simulate in the body of the text the following scenarios: (DPM) discoveries of new sea routes together with new precious metals; (D) new sea routes, but no precious metals; and (0) the medieval scenario with no precious metals and no new sea routes. We now simulate an additional scenario: (PM), for the counterfactual scenario of no discoveries of new sea routes, but with new precious metals.

In this scenario, America has not been discovered and there is not a new route to India and China. But a large new deposit of gold and silver has been found in Europe. We can compare this new scenario with the medieval scenario. This new exercise further isolates the effects of precious metals. The new scenario is simulated by keeping the iceberg cost fixed at its medieval level, together with the injections of precious metals D_t.

The results are in figure A.1. Panel A.1a shows consumption in Europe of Asian goods, C_{ea}. This value has a peak of about 20 times its medieval value for the combined effect of new sea routes and precious metals. Without the new sea routes, C_{ea} increases at its peak to five times its medieval value. Notice that this is net consumption, after the high medieval iceberg costs. Consumption of Asian goods still increases substantially, but the medieval iceberg costs decreases the benefits of international trade.

Panel A.1b shows how much of the new precious metals is exported to Asia (we remind that precious metals are not subject to iceberg costs). It is costly to export and import goods, as there are no new trading routes. So, the agent in Europe does not send to Asia

[49]Silver mines were also discovered during the sixteenth century in Japan. The relative importance of Japanese silver was small. Manila and Macao received more silver from America than from Japan or Goa even at the peak of the production in Japan (Boyajian 2008). As early as 1580, Mexico and Peru were the most common origins of the silver in China (Boyajian 2008, p. 64).



(a) C_{ea} with or with no new routes (b) Exports of precious metals (c) q_{0t}^{PM}: PM, no new routes

Figure A.1: Effects of precious metals: with or without the discoveries of new routes. C_{ea} : consumption by the agent in Europe of Asian goods. q_{it}^{j} defined in equation (23). PM : precious metals.

the same quantities of precious metals. Panel A.1c summarizes the effects. The accumulated consumption of Asian goods is substantially larger than its counterpart with with no new routes and no precious metals, 3.5 times, that is $q_{0t}^{\mathrm{PM}} \approx 3.5$. However, the effect is much smaller than the combined effect of new trading routes and precious metals, $q_{0t}^{\mathrm{DPM}} \approx 14$.

We confirm that the effects of precious metals are substantial. Moreover, the new simulations make clear that the effects of the new sea routes and precious metals are not additive. The discovery of the new sea routes allows a more intensive use of the precious metals. International trade is more effective because of the new sea routes, which stimulates Europe to export more precious metals and import more goods. The interaction between precious metals with the new sea routes magnifies the effects of precious metals.

Data Availability Statement

The replication files that support the findings of this study, including codes and data, are openly available in "Replication package for: Spending a Windfall" at https://doi.org/10.3886/E192963V3. Citation: Palma, Nuno, and Silva, André C., Replication package for: Spending a Windfall, Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2023-07-25, https://doi.org/10.3886/E192963V3, (Palma and Silva 2023).

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