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Spending a Windfall

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JEL Classification: E40, F40, N10

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

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Spending a Windfall*

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March 2022

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 increased up to 20 times compared with the counterfactual. Our simulations match the observed price dynamics. We find that American precious metals were at least as important as new routes for the observed trade patterns.

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1 Introduction

> 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.
>
> Charles K. Harley (2004), p. 179

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 their 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.

We find that consumption of Asian goods in Europe is up to twenty times as larger 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 (DeVries 2003).[1]

[1] Our dataset is based on annual production, as compiled by Palma (2021). It more precise than previously

The new opportunities initiated with the age of discoveries have been emphasized by recent 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 (see also Palma 2019 and Palma 2018a). 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 been difficult 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 in detail 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 bullion from America during the early modern era, there was no substitute which could have been used. Payment by means of debts of long maturities 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).[2]

Contemporaries were aware that Asia absorbed much of the precious metals that Europeans brought from the New World. For instance, a merchant in 1621 wrote that the world's silver flew to China as if it were its natural center (DeVries, 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, porcelain, and lacquered furniture. These goods induced extra work, specialization and market activity, and were increasingly consumed by people from all social classes (McCants 2007, 2008; Pomeranz 2001, p. 273;

available datasets. Much of American silver production was sent to Asia; see for instance, (Desaulty and Albarede, 2013).

[2] 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.

DeVries 2008; Hersh and Voth 2009). Trade of Asian goods such as Chinese porcelain and Indian textiles shaped European tastes and were a prerequisite to the subsequent British industrialization.[3]

The traditional explanation for the imbalance of Euro-Asian trade during this period relies on cultural factors. Hamilton states that "for some inexplicable reason Orientals have always had a penchant for hoarding treasure (...) even in response to a protracted inflow of specie, Oriental prices, unlike those of the Western World, did not rise sufficiently to induce a counter flow" (Hamilton 1934, p. 347). 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 view is still dominant (for example, 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.

We first show evidence on the size and effects of the monetary injections caused by the larger availability of precious metals. To understand trade flows as an equilibrium phenomenon, we review the relative size and development of Asia versus Europe during the period. 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 the counterfactual: what would have happened if no precious metals were available in America?

A small amount of Euro-Asian trade took place in the middle ages through overland

[3]The basic technique was eventually learned in Europe, though the fabrication method was 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*—which was not limited to porcelain, but also architecture, landscape gardening, lacquerware furniture, and decorative arts—developed (Berg, 2004, 2005).

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. DeVries (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 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.[4]

We calculate that the consumption of Asian goods in Europe increases up to twenty times its medieval value with the discovery of the sea routes (the Cape route and the Pacific route) and the discovery of precious metals. Without the discovery of precious metals, the increase in consumption would only reach 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 porcelain, silk, and tea. 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

We provide in this section a summary of the historical context and data. We give further details in the Appendix.

[4]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.

2.1 Precious metals and money

During the early modern period, Europe and much of Asia were under a commodity money system. Precious metals were the key input for the production of money. Since 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 parts of Asia, notably China, there was a recurrent problem of availability of precious metals relative to the size of the economy. Unlike in Europe, there was also little difference between bullion and money, which did not circulate by tale.[5]

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 (for instance, Sousa 2006, Chen et al. 2021, and Palma 2018b). The quantity of bullion available provides a good 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 (2021). The data in Palma relies on TePaske (2010), which covers the period until 1790. We use the same procedure in Palma to extend the period to 1810. The year 1810 marks the end of TePaske's dataset as well as the beginning of the Spanish American wars of independence.

We use exchange rates of the period to 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

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

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 precious metals. More precisely, in silver-equivalent grams for each year.[6]

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. Europe, the region that directly received precious metals from America, was considerably smaller than Asia. The population of Asia during the period was about five times larger.

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 includes Spain and Portugal. Asia excludes Japan. Source: Maddison (2006, pp. 636, 642).

Real output per capita in Western Europe was about 20% higher than in China in 1500 and about two times higher than in China in the early 1800s (table 1).[7] 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 or growth rates.[8]

We divide the data on the production of precious metals to the population to obtain the flows of precious metals per capita for each year. Figure 1 shows the results. It shows the

[6]In the appendix, 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.

[7]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 estimates by Broadberry and Gupta (2006); Broadberry et al. (2018) show a higher per capita output in Western Europe well before 1800.

[8]Plausible changes in population estimates do not imply significant changes to our results. This is illustrated by the case of China, the biggest economy, for which alternative data exist (Deng 2004). Our main results do not change if Deng's numbers are used instead.

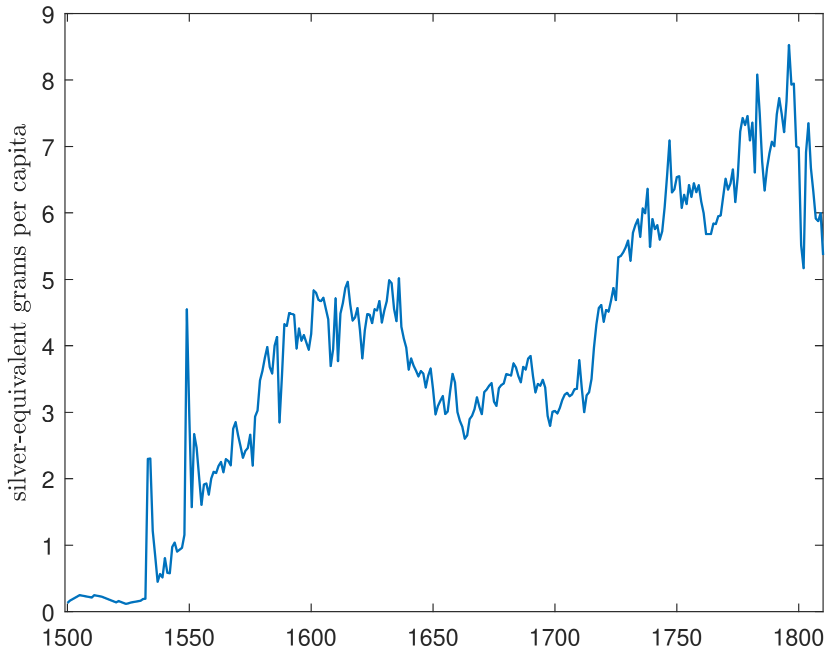


Figure 1: Data on the discoveries of precious metals per capita, D_t in the model of section 4. Source: see tables 1 and A.4.

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, denoted by D_t, will have an important role in the model of section 4. D_t constitutes monetary injections over time.

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 is 75 silver-equivalent grams of precious metals. We consider this value to be representative for Western Europe. The figure then puts in perspective the accumulated flows of precious metals in comparison with the holdings in beginning of the period. Considering the flows from 1500 to 1600, the holding of precious metals of average individual in Europe would increase three times, from 75 g to 252 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.

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

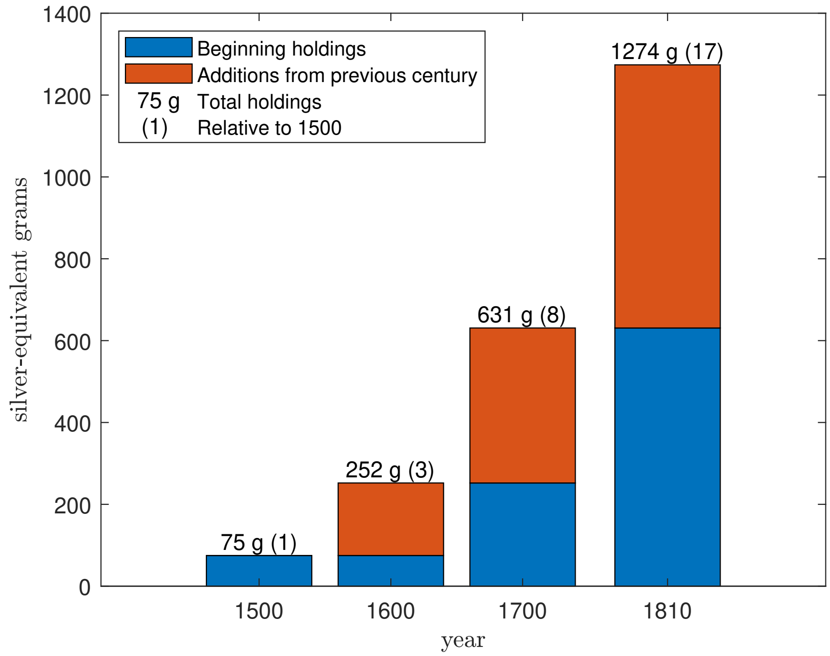


Figure 2: Accumulated flows of precious metals per capita in Europe. Source: see tables 1 and A.4.

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.

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 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," which suggests a cultural explanation.[9]

To our knowledge, there are only two examples in the literature of an economic explanation. The first, in 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

[9] Kindleberger (1989), Pearson (2001), Cranmer-Byng and Wills (2010) and others have similar arguments.

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. In 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 DeVries (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.

3 Precious metals and trade through local projection methods

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.[10]

Our empirical specification follows Jorda (2005) local projection methodology. 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 (2021).[11] The vector $\mathbf{x_t}$ contains a linear trend and four lags of the dependent variable $\ln y_t$. Palma (2021) 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.

[10]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).

[11]We use the baseline measure which adjusts for losses of precious metals resulting from shipwrecks.

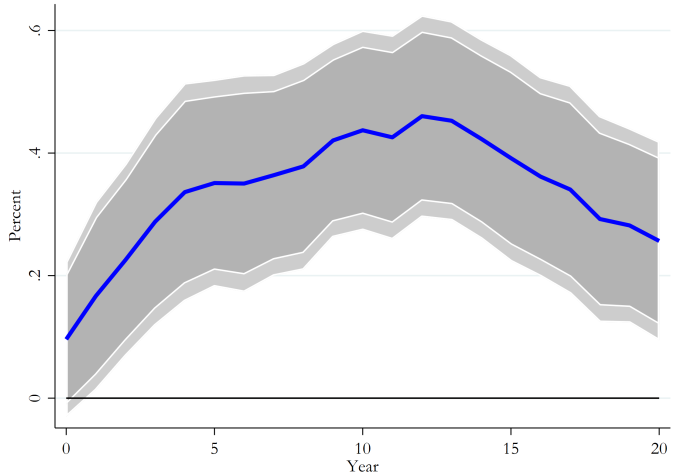


Figure 3: Impulse response of shipping capacity to a contemporaneous increase of 1% in precious metals relative to stock calculated using the Jordà (2005) local projection method. Variables in tons. Controls include a linear trend and four lags of the dependent variable. Robust standard errors are used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

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% 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% and 95% 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, in response to a 1% increase in production of precious metals in the Americas relative to Europe's stock of metals, shipping capacity increases about 0.5%. This finding suggests 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.

The demand for money is motivated by a money-in-utility specification. That is, the gains generated by transaction services of real money holdings are summarized with an argument in the utility function. 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, the Spanish silver dollar, used extensively during our period of study. All regions in the model trade in this common monetary unit.[12]

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

[12] 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 non-tradeable 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.

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

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

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

where the parameter $0 < \omega < 1$ 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 tradeable. That is, we consider that the service sector, mainly composed of non-tradeable goods, was small for these economies in the Middle Ages and during 1500–1810.

The price index is obtained so that it reflects the minimum expenditure that should be incurred to obtain one unit of the composite good given the domestic prices. 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.[13]

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 shipping and trading activities are conducted. They are to be interpreted as including both 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.[14]

[13]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."

[14]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

The cost minimization problems of the two regions yield the following price indices for Europe and Asia,

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

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

Because of high transport and agency costs during this period, luxuries were the only goods that could be profitably transported over large distances. In exchange, Europe paid with precious metals, which were cheaper to transport.

The windfall of precious metals, that is, gold and silver, is expressed in silver-equivalent grams per capita, D_t, as explained in section 2. We use a conversion rate $\xi_{i,t}$ that transforms 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 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 $D_t \equiv \xi_{e,t}\tilde{D}_t$.[15]

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. In fact, the silver money of account *liang* in China was identical to its actual weight in silver (Von Glahn 1996, p. 42; Irigoin 2009), which would imply $\xi_{a,t} = 1$. Moreover, 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. 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.

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

capital" (DeVries 2003). Obstfeld and Rogoff (2001) discuss other interpretations for the iceberg cost, such as nontariff barriers and different languages.

[15]The silver dollars (*pesos de la ocho*) were the de facto numeraire, of wide acceptance in much of the world. They were also commonly used in Southeast Asia and the United States into the nineteenth century. They were legal tender in the US until 1857.

labor to produce the domestic good. The share of capital is equal across regions, given by $0 < \theta < 1$. The agents supply one unit of time of labor inelastically. Capital is not tradeable 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.[16]

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

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

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. The budget constraint is expressed in silver-equivalent grams of precious metals. As stated above, the production of precious metals $\tilde{D}_t$ (the windfall) yields the amount D_t in silver-equivalent units once the data for the content of precious metals in the currency is taken into account. For the agent in Asia, these monetary injections are set to zero. The budget constraints imply that international trade can be made directly in precious metals.

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

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

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

[16]We do not need capital for our main conclusions. In fact, removing capital slightly increases the effects of the discoveries of precious metals.

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

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

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

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

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

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

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

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. A decentralization of this model implies that 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 in this economy. Therefore, 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 the composite goods $C_{e,t}$ 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

$$\mathrm{XM}_{e,t}^{m} \equiv (M_{e,t-1} + D_t) - M_{e,t}. \tag{23}$$

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 $\mathrm{XM}_{a,t}^{m} \equiv M_{a,t-1} - M_{a,t}$, 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 $\mathrm{XM}_{i,t}^{l} \equiv L_i Y_i - L_i C_{il,t}$ when $l = i$ and $\mathrm{XM}_{i,t}^{l} \equiv -L_l C_{il,t}$ 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 historically-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 historically-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 of D_t 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. The economic significance of the windfall can be gauged through table A.3, which compares the discoveries of precious metals per capita with the wages of European agents.

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% of the discoveries were effectively used for monetary transactions by the European agent from 1500 to 1700, and 50% 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 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 historically-observed scenario in which precious metals in America and a sea route were discovered simultaneously. In the baseline counterfactual, a sea route between Europe and Asia was discovered, but precious metals in America were not discovered. We also consider a counterfactual in which neither new sea routes to Asia nor discoveries of precious metals in America were discovered. These counterfactual 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 to Asia 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 routes to Asia 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 routes to Asia 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

As mentioned above, all preference parameters are the same for the agents in 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.

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. Table 2 shows the values set 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	0.602

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. These are standard values in macro models. We set $a = 0.81$, which is the same value used in Duarte and Wolman (2008). For the value of η, we use the fact that the interest-rate elasticity of the demand for money is given approximately by $-1/(1-\eta)$. 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 of a long-run demand for money for example in Lucas (2000), Alvarez and Lippi (2009), and 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). Previously, the values used for this parameter in macroeconomic simulations were frequently between 1 and 2 (Chari et al. 2002; Duarte and Wolman 2008). However, recent estimates of this elasticity 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 for several countries 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. Therefore, 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 Cobb-Douglas production function and the steady state values of capital.[17]

As mentioned in section 2, 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 fifteenth century 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 equilibrium, conditional on the international transaction costs of the time.

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. We proceed in the following way to find the share of imports before and after the discoveries.

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

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

(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.[18] According to table A.3, 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 (DeVries, 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. It is common in the literature, for example, in Backus et al. (1994), Chari et al. (2002) and Duarte and Wolman (2008), to adjust the parameters related to home bias so that imports are a certain share of GDP. Our paper distinguishes from the literature as we have 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. 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 tradeable goods and the share of imports of 0.1 percent of income would require a high home bias without the iceberg cost.[19]

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

[18] 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.

[19] 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.

$b^f = 0.602$, 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 5.4 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. We hold the iceberg cost constant after 1500, under the period of our simulation (ending in 1810). 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 maintain the transportation 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. Moreover, the voyage was safer, cheaper, and could carry much more cargo.[20]

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 route between Asia and Europe. The discoveries of precious metals are shown in figure 1 and imply the monetary injections D_t in the model. The model is initially in a steady state equilibrium. We calculate the equilibrium transition 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

[20] Another evidence of the large trading costs are the difference in prices before 1500. According to Allen (2011), the sale prices of spices in Europe were 20 times their sales prices 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.

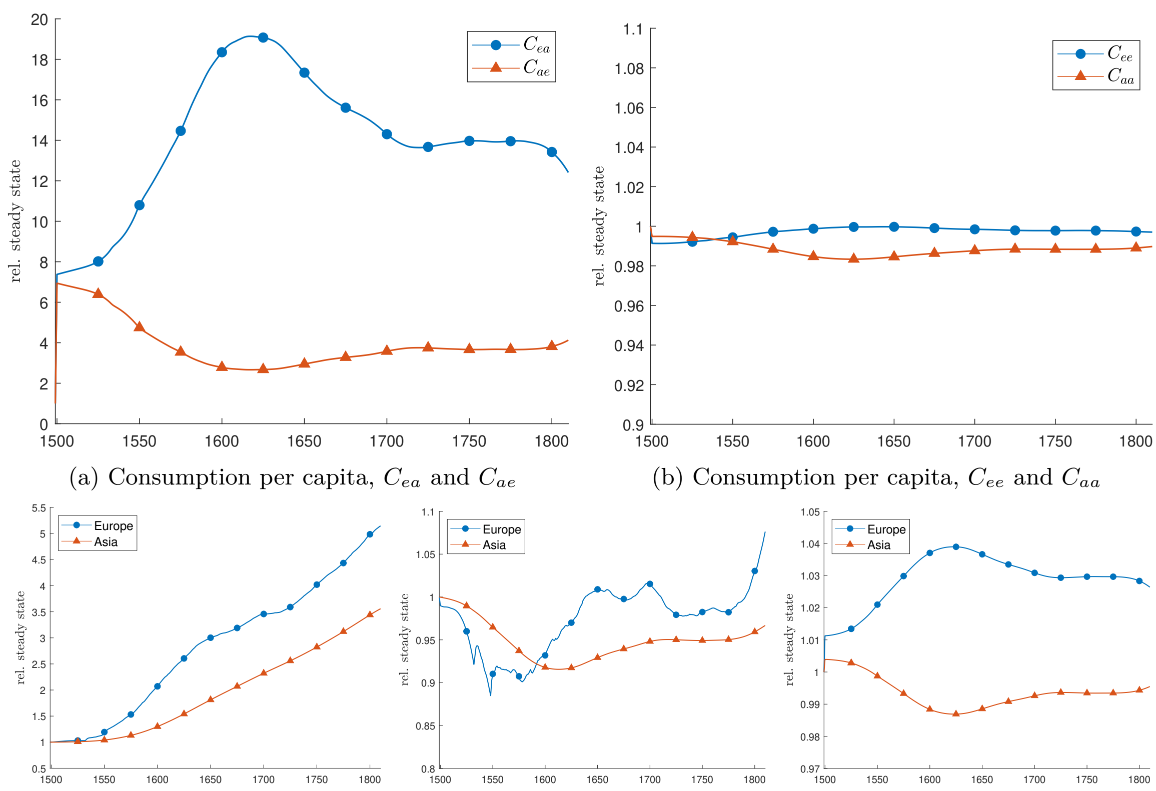
6.1 Simulation of the observed scenario

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.[21]

Figure 4 shows the results on consumption goods and on real money holdings, that is, the variables in the preferences and composite goods as stated in (2), (4) and (5). 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 of international trade on consumption. Consumption in Europe of Asian goods, C_{ea} increases substantially after the shocks with respect to the previous steady state, up to 19 times. At the beginning, the new trading route increases 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.

Consumption of European goods in Asia also increases with respect to the initial steady state, as shown in panel 4a. However, the increase in precious metals makes consumption of European goods in Asia eventually decrease, 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 in Asia. As discussed above, after the 1500s, the imports of European goods by Asia other than precious metals were negligible, but the imports of Asian goods by Europe were much more important.

[21] 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.



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

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

(c) M_e and M_a

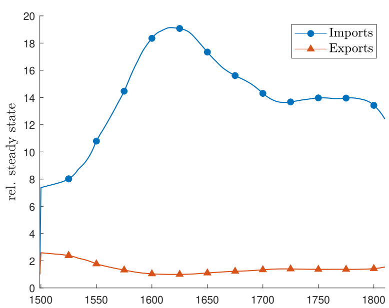
(d) M_e/P_e and M_a/P_a

(e) Composite goods, C_e and C_a

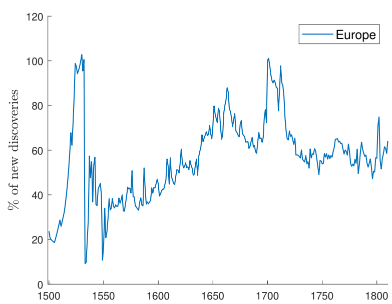
Figure 4: Results from simulations: consumption and money. M_i/P_i denotes real per capita money holdings in region i. C_{ij} denotes per capita consumption in region i of goods of region j (e.g. C_{ea} denotes per capita consumption in Europe of Asian goods).

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 in Europe decreases whereas it decreases in Asia.

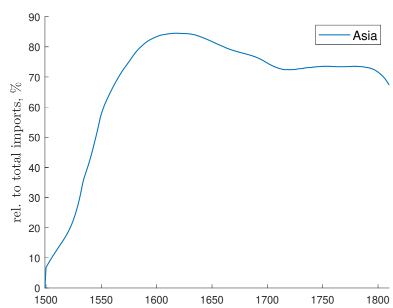
Figure 5 focuses on international trade. Panel 5a shows imports and exports of goods of Europe relative to the initial steady state. Both imports and exports increase with the new trading routes. Imports increase almost 20 times from its initial level with the combined effect of the new routes and the precious metals.[22] 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 56% of the discoveries. Most of the precious metals found in America is exported by the agent in Europe to receive Asian goods in return.



(a) Goods trade, Europe



(b) Exports of precious metals



(c) Imports of precious metals

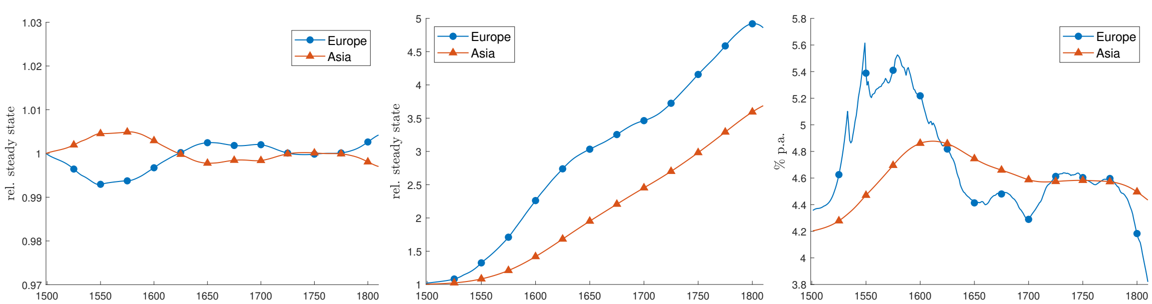
Figure 5: Results from simulations: international trade of goods and precious metals

Panel 5c shows imports of precious metals by Asia relative to total imports. The panel

[22]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}.

shows that most of the imports of Asia are made of precious metals. From 1600, precious metals constitute on average 77% 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 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)

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 reflect the dynamics of capital, as 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). 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 5.4 percent. The behavior of wages and interest rates is compatible with the evidence for the period.[23]

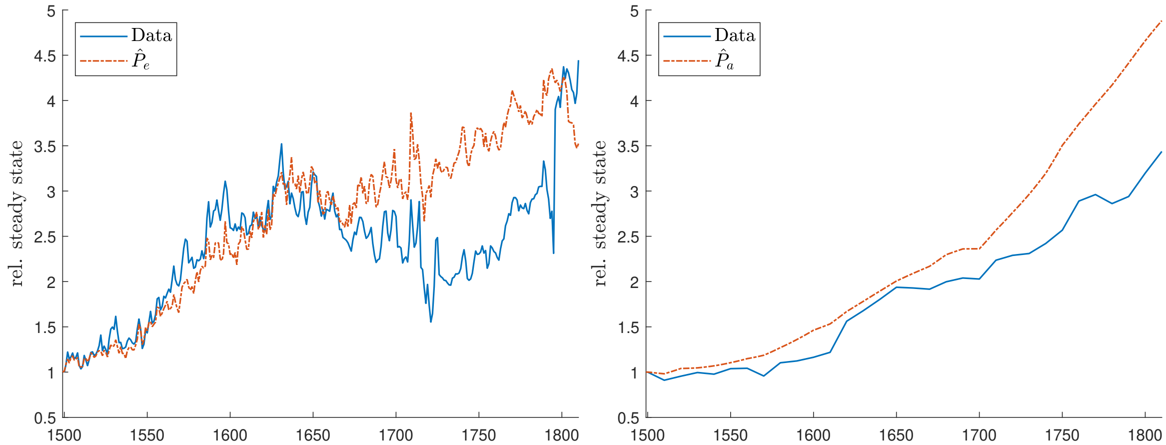
6.2 Price dynamics

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.

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 a 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

[23] 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 in Europe and Asia for the period 1500–1700.

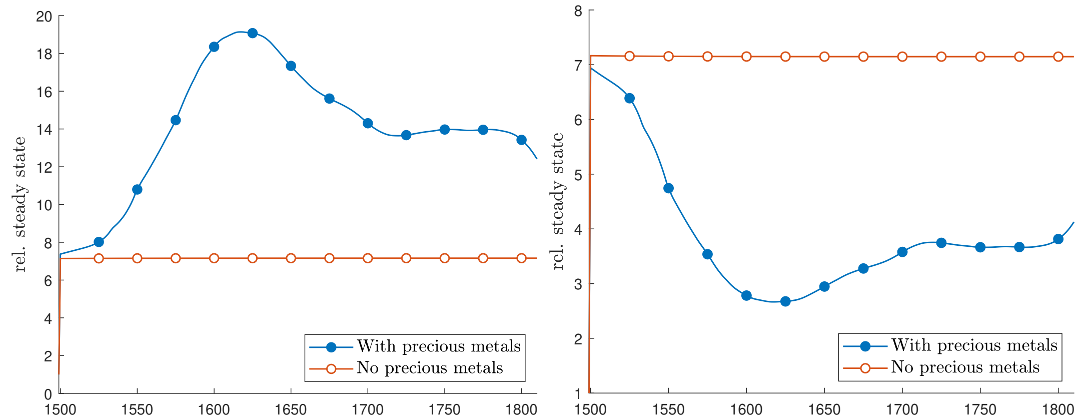
data until 1650. We note that we have not used data on prices to calibrate the model. Taking as a whole, the model is able to explain a great part of the coincident increase in prices in Europe and in Asia. This is an indication that the discoveries of precious metals in America had a great impact on 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 the 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 found in America. 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 the precious metals, imports of Asian goods increase further especially after 1550 and its peak reaches almost 20 times the initial steady state level. The windfall allows the agent in Europe to greatly increase consumption of Asian goods.[24]



(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 and with and without the discovery of precious metals.

Panel 8b shows the response of Asia with the new sea route and 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

[24]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.

accumulated consumption from time zero to a certain time t,

$$q_{it}^{j} \equiv \frac{\sum_{\tau=0}^{t} C_{ea\tau}^{j}}{\sum_{\tau=0}^{t} C_{ea\tau}^{i}}, \tag{24}$$

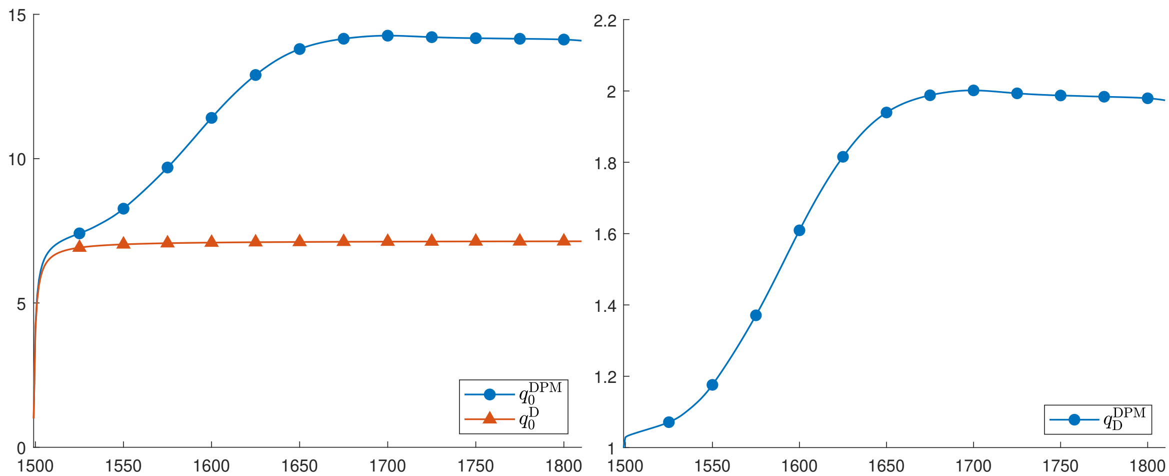
where i and j assume the values 0, D or DPM (D together with PM). Different specifications of the model yield different values for C_{eat} and C_{aet}. The ratio in (24), on the other hand, is approximately stable, which facilitates the isolation of the effects in each scenario.

According to (24), 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, $q_{\mathrm{D}t}^{\mathrm{DPM}}$ 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. $q_{\mathrm{D}t}^{\mathrm{DPM}} > 1$ 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 14.3 in 1700. Panel 9b isolates the effects of the discoveries of precious metals. The value of $q_{\mathrm{D}t}^{\mathrm{DPM}}$ reaches 2 in 1700. Consumption of Asian goods increased substantially in Europe after the 1600s, reaching a peak in the XVIII century. The value of $q_{\mathrm{D}t}^{\mathrm{DPM}}$ of 2 around 1700 allows us to conclude that the model implies that the discoveries precious metals explain half of the increase in consumption of Asian goods.[25]

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

[25] We have also simulated a separate counterfactual dynamics of discoveries of precious metals but no sea routes. We confirm a strong effect of precious metals.



(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 (24) 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.

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, −0.42 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.[26]

[26]Silva (2012) also finds that the welfare losses of inflation are much larger when the general equilibrium

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 0.77 percent. The negative income compensation for the agent in Asia decreases from -0.42 to -1.62 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.[27]

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 baseline specification, we consider the average income for the period, which decreases the effects found because income is higher in the final periods. A decrease in initial money holdings makes the effect of new discoveries larger, as they 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 conclusion is maintained for a plausible range of alternative parameters. In particular, the results in figure 9 are stable.

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, 2019).

[27]The model does not have other kinds of frictions that would affect welfare and other 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 the model to consider all possible variations that could have occurred in the period.

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

The magnitudes simulated for the historical scenario are in line with the empirical facts. This increases our confidence with respective to the simulations from the model for the counterfactual scenarios.

First, the value of intercontinental trade was only a small fraction of total output. Our model matches this fact. Intercontinental trade corresponds to a small fraction of total output in our simulations for the historical scenario, corresponding to what was indeed the case.

Second, a substantial portion of the value of European exports to Asia during the early modern period consisted of silver. Our model matches this fact. In the simulations for the historical scenario, the main export from Europe to Asia is silver. Relative to the counterfactual, Europe's consumption of both goods increases. At the same time, consumption of domestic goods in Asia shows the reverse trend: silver spent on the domestic good decreases, though little. However, relative to the counterfactual, the imports of the European good to Asia are greatly reduced, to 37 percent of what they would have been per individual by 1620 (figure 8b). By contrast, European imports of Asian goods are up to 2.7 times of what they would have been without European access to American precious metals (figure 8a). Therefore, in the counterfactual with no precious metals, Asia would have consumed more European goods, despite the fact that the total value of Euro-Asian trade would have been smaller.

A surprising implication of the model is that, following the discoveries of precious metals, the purchases of Asia of European good are smaller. This results from the fact that the shock affects relative prices. Asia becomes poorer in relative terms following the shock, which directly affects only Europe. Asia's stock of money is now relatively smaller, which helps determine prices.[28] This conclusion stands in sharp contrast with some of the traditional interpretations of this episode, which claim that Europe was forced to export bullion to Asia to finance a recurring trade deficit.[29]

[28] Under an helicopter drop where each agent gets a proportional share of a monetary injection, no frictions exist, and all agents are homogeneous, all prices would rise simultaneously and the injection would not affect real allocations. Here, the European agent first benefits from the injection which is then transmitted through trade. Relative endowments are affected and end up affecting not just the aggregate price level but also relative prices and the volume and structure of trade. As the European agent gets richer, it spends more on the domestic goods and on imports. The converse happens for the Asian agent.

[29] They also differ from the idea that there was nothing in Europe that China wanted or didn't have, as set out in emperor Qinglong's well-known letter to King George.

Third, Europe experienced a price revolution, but Asia did not (DeVries 2003, pp. 94 and 105, has a summary of the evidence). 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 of the Euro-Asian trade. Our results show that the smaller decrease 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 DeVries (2003), we do not endorse this interpretation. We are able to reproduce the observed factual scenario without assuming different preferences for the Asian agent relative to the European agent, which is the dominant explanation for these trade patterns in the historical literature.[30]

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.[31] Our model offers an answer, as shown in figure 6. 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.[32]

Our results also suggest the following novel conclusions. First, without European access to 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

[30] We assume a home bias, as it is standard in the trade literature, but it is symmetric to both agents.

[31] 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."

[32] 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, European purchases of Asian goods 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 if we exclude precious metals. To our knowledge, this has never been suggested before. Third, the discovery of a new sea-route to Asia was complementary to precious metals rather than the main factor 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. The evidence suggests that 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 (DeVries, 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.[33] It permitted the development of modern financial markets in Amsterdam and London (Neal 1993). It induced an industrious revolution (DeVries 2008) which encouraged market participation in Europe (Humphries and Weisdorf 2019), necessary preconditions for the process of modern economic growth and for the industrial revolution itself. It stimulated urbanization (Allen 2009, Palma and Reis 2019). 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

[33]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 (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. In particular, 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 to Europe, 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 Europe's take-off.

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Note: The pages in parenthesis state where the reference is cited in this text.

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A Appendix – Historical context

A.1 Precious metals and money

Paper money became prevalent in Europe only in the nineteenth century. In England, as late as 1790, the monetary base was composed of £44 million of commodity-based coin but only £12 million in notes. Inland bills of exchange and other money substitutes were also used, but they had a small share of the monetary base (Capie 2004, Palma 2018b).[34] Until the rise of paper money, monetary authorities had two ways of increasing the 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. Individuals could obtain this either by direct production (mining) or through a secondary market. Monetary policy was conducted by means of the monetary authority setting the mint price at which private agents could coin currency from bullion, after payment of a mint cost and a seigniorage fee. Prior to fiat money, the options for monetary expansion were quite limited.

Precious metals in Europe were available in inelastic supply for most of the medieval period. Persistent deflationary tendencies were common during the Middle Ages (Cipolla 2004, pp 171, 214). The availability of per capita precious metals increased with the Black Death, during the mid-fourteenth century, and pressure lessened. Within a century, economic growth was strangling available supplies of specie and increasing the price of precious metals used in coins. Although broader forms of money were available, they acted more as complements rather than substitutes to currency (Nightingale 1990, Mayhew 1999, Capie 2004). Monetary expansion was constrained. In China, in particular, there was a recurrent problem of availability of precious metals relative to the size of the economy (Pomeranz and Topik 2012, p. 14 and Von Glahn 1996).

From the mid-fifteenth century to about 1520, the exploration of the Africa coast by the Portuguese brought to Europe quantities of gold at lower cost than had been previously entered with the trans-Saharan caravan trade, but it is not clear if net positive quantities

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

entered in this way. 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 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 of Precious Metals in America (silver equivalent tonnes)

	Lower Bound	Benchmark	Upper Bound
16th c.	8,829	13,318	20,823
17th c.	28,199	29,999	42,637
18th c.	58,061	64,809	84,354
Total	95,089	108,126	147,814

Source: Lower bound estimates from Morineau (2009, p. 578). Upper bound estimates from Barrett (1990, p. 228). Benchmark estimates from TePaske (2010, p. 20-21). The unit tonnes refers to metric tons.

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). Table A.1 shows the quantities of precious metals produced in America in each century. Table A.2 shows the magnitude of the injections. 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.[35]

We consider additional estimates for the gold discovered in Brazil during the eighteenth century. The shipments to Portugal lasted in significant quantities into the early nineteenth

[35] 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.

century. During 1720 to 1807, about 556 tonnes of gold were imported Costa et al. (2013). Prior to 1720, transfers had been going on for around 30 years, and there must have been some additional smuggling as well. These facts indicate that Brazilian gold may have doubled the stock of gold in Europe (Palma, 2019). Portugal exported most of this gold to England and other European countries. The increased availability of gold in Europe, in turn, permitted additional silver exports to Asia.

Table A.2: 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)
1525	4,250	1,064	3,186	NA	NA
1575	13,250	7,765	5,485	NA	NA
1625	18,375	11,413	6,962	5,625	5,788
1675	23,625	16,786	6,839	7,125	9,661
1725	30,000	25,189	4,811	10,000	15,189
1775	44,000	32,872	11,128	10,250	22,622
Total	133,500	95,089	38,411	33,000	62,089

*Precious metals exported to Asia via the Pacific plus remaining production in America. Source: Our calculations based on Morineau (2009, p. 578) for column 2, and on Barrett (1990, p. 242) for columns 1 and 4.

Table A.3 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 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.

Table A.3: 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)
1525	3.2	2.8	2.1–4.2	2.8–6.8
1575	8.4	6.5	1.9–6.6	3.3–12.5
1625	9.9	7.2	3.2–8.8	5.2–20.1
1675	12.2	9.0	2.7–9.7	3.9–15.1
1725	14.7	11.2	1.9–10.5	3.0–11.7
1775	16.4	11.1	2.9–11.5	3.2–17.8

Source: production and imports from table A.2, wages from Allen (2001, p. 416) (range across different regions in Europe), population from Maddison (2006, pp. 636, 639).

Table A.3 is constructed in the following way. First, because of differing sources, there is a difference of 1 year relative to table A.2. 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 19th 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. Because of the small size of the American economies—from negligible initially to non-negligible towards 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 (see evidence in Pieper 2015). Second, there was some production in central Europe until the middle of the sixteenth century (Munro 2003), but we only consider American production. Third, Morineau's figures for Europe include only amounts across the Atlantic. But trade through the Philippines benefited European agents as well. 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.

A.2 Asian luxuries and precious metals

The discoveries of the transoceanic trade routes were motivated by the search for Asian luxuries. Vasco da Gama had instructions from the Portuguese king to find spices and porcelains when he sailed for India in 1497 (Atwell 1998). Contemporary observers reported continued European interest in Asian luxuries (Boxer 2004, p. 112). Adam Smith commented extensively on the continued large flows of silver to the East Indies (Smith 2003). He attributed these flows, among other reasons, to the fact that Asia had larger markets. Smith states that the value of precious metals in China and India was much higher than in Europe.[36]

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. This interest was not exclusive to Europe and its colonies. Asian luxuries such as Chinese silk and porcelain, Southeast Asian spices and Indian textiles were perceived as the pinnacle of sophistication everywhere and sought after by the elites of the Middle East and East Africa, not to mention intra-Asian demand.[37]

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 observed trade boom, because the European interest in Asian luxuries did not find a reciprocal demand.

It is a fact that Asian consumers did not demand European goods, only precious metals. The Chinese case is the best documented and the most important. Chinese traders were disdainful of foreign manufactured goods and demanded payment in silver (Atwell 1998).

[36] According to Smith (B I Ch 11.3, p. 278), "The silver of the new continent seems in this manner to be one of the principal commodities by which the commerce between the two extremities of the old one is carried on, and it is by means of it, in a great measure, that those distant parts of the world are connected with one another." For the Portuguese trade with Asia, see Subrahmanyam (2012) and Boyajian (2008). For the English and Dutch trade with India, see Prakash (2001).

[37] Large quantities of Ming porcelain have been found in Southeast Asia, Sri Lanka, India, Syria, Iraq, Egypt, and East Africa. In the Middle East, great collections exist in the Topkapi Sarayi Miizesi in Istanbul and that of the Ardebil Shrine in the Archaeological Museum in Tehran (Atwell 1998). The interest in porcelains as goods of status is reflected in their frequent depiction in Middle Eastern and European art.

Although China was not interested in most goods produced in Europe, it was interested in precious commodities, as they were a source of credible monetization of its large economy.[38]

In accordance with this view, Irigoin (2009) states that "Undoubtedly China was the main and ultimate destination—directly or through intermediaries—of Spanish American silver since the sixteenth century".[39] First-hand observers such as Gaspar da Cruz share this view (Boxer, 2004, p. 112). Pomeranz and Topik (2012, p. 16) summarize the situation as follows: "Long distance trade (...) reached new heights in the 1500's, but then a new medium of exchange was available, silver (...) For the next 300 years, close to half of the world's silver production found its way to China's money supply."

India followed the same pattern. Trade was based on export of American bullion by Europe in exchange for Indian textiles until in the mid-eighteenth century (Prakash 2003, 2004; Steensgaard 1990). For Southeast Asia, analogously, there was little demand for European goods other than precious metals (Pearson 2001). We have evidence that over this period silver became the base metal for transactions.[40]

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.[41]

Asian imports had to be paid for in bullion. As mentioned above, Europe and its colonies paid 90 percent of their imports from China during the early modern era using silver (Pomeranz, 2001, p. 159).[42] Most of the silver which Europeans brought to Asia went to China. 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

[38] Von Glahn (1996, p. 201), Pomeranz (2001, p. 4 and p. 159), Flynn and Giraldez (1995a), Boxer (1970). First-hand observers writing until the last quarter of the sixteenth century typically refer to silver being used for transaction purposes (Boxer, 2004, p. 407). Later writers made reference to minted Spanish pesos in circulation (Atwell, 1998). We note that China did not have any significant internal source of precious metals, being that its silver mines had been exhausted by 1430 (Von Glahn, 1996, p. 114).

[39] See also Pomeranz (2001, p. 190).

[40] In Burma, about 97% of land sales were made exclusively in silver during 1750-1830 (Tarling 1992).

[41] See DeVries (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.

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

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).[43]

Two aspects justified a low price of Asian manufactured goods relative to European goods, according to Smith. 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. Smith also states that 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 size of Asia's economy (table 1) would imply that, without trade barriers, much American precious metals would end up in Asia. The relative endowments suggest large arbitrage gains, even under the prevailing transport technology and institutional settings. Accordingly, as we previously mentioned, a large part of the American precious metals in fact ended up in Asia (Von Glahn 1996, Irigoin 2009, 2013).

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 DeVries (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.

Consequently, 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

[43] 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 operated in an approximately time-invariant way during 1500-1810.

countries, which were covered by China's silver-based tributary system (Flynn and Giraldez 1995b). 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 towards Asia in general and China in particular (table A.4).[44]

Table A.4: 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
1625	2,475	2,500	425	250	4,006
1675	2,800	2,500	775	1,050	4,847
1725	2,800	2,500	2,200	2,450	7,900
1775	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). During the same period 9,000 tonnes went to the Eastern Mediterranean, and it is possible some of this ended up 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).

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 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.4. Moreover, the trading activities of Spain, as well as the Portuguese Estado da India are not included in the table. Finally, smuggling was common. These considerations suggest that the amounts in table A.4 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.[45]

[44]The injections to China were such that the breakdown of the South American monetary system in the early nineteenth century had serious consequences in China (Irigoin 2009, 2013).

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