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The curse of Moctezuma: American silver and the Dutch disease☆

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Abstract

This study formalizes and empirically tests the conjecture that the discovery of large silver reserves in its American colonies during the 1540s triggered in Spain a case of Dutch disease, diverting factors of production to non-traded goods industries and undermining the Spanish comparative advantages in the Early Modern Age. I develop an open-economy model to mimic the economic conditions in Imperial Spain. I then present new consumption weights built from primary sources, which I combine with existing price data to produce price indexes for traded and non-traded goods; these are then used to test the implications of the model in a Markov-switching regression framework. I identify a strong and persistent increase in the relative price of non-traded goods coinciding with the silver discoveries, lasting for almost three decades and reversing itself only after the 1575 and 1579 crown bankruptcies.

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1. Introduction

According to a popular legend, the dying Aztec emperor Moctezuma used his last breath to utter a curse under which any strangers who plundered the riches of his land would suffer from painful diseases. As in the case of many legends, there is no historical evidence that the curse was actually uttered, and Spanish accounts of the emperor's death actually report that his last wishes were that Hernán Cortes, whom he still considered a god, took care of the upbringing of his children. For Spain, however, the plunder of Mexican and Peruvian mineral wealth may have indeed been at the root of its protracted economic stagnation in the Modern age.

Several reasons are often cited as causing or aggravating the Spanish decline of the 17th century, most importantly the failure to control fiscal outlays, the simultaneous and ill-fated involvement on several military fronts, and Malthusian dynamics.[1] Starting with the pamphleteers of the late 16th century (*arbitristas*), several authors have pointed to the influx of precious metals as a significant source of Spanish economic woes. Since Hamilton's, 1934 study, the bullion flows from the New World into Spain have been scrutinized time and again by the scholarly literature; unfortunately, interest in the topic has often drifted in a purely monetary direction, attaching little significance to the effects of the vast silver imports on long term trade and production patterns, as well as to the overall level of economic performance.[2]

Starting with Corden (1981, 1984) and Corden and Neary (1982), a vast literature has examined how the discovery of large quantities of tradable natural resources (or a sudden increase in the price of existing resources) can cause the manufacturing sector to shrink, a phenomenon known as the Dutch disease after the impact of 1970s natural gas price increases on the Dutch economy. Forsyth and Nicholas (1983) have suggested that these dynamics might have indeed been present in the Spanish case, where the natural resource in question happened to have a straightforward use as international currency; their article, however, does not present any empirical evidence.

Dutch disease phenomena have repeatedly been linked to economic stagnation. Wijnbergen (1984) and Krugman (1987) have argued that, in the presence of an industry learning curve, the effects of de-industrialization may not be reversible once the natural resources are exhausted or their prices fall below the threshold of profitability. Asea and Lahiri (1999) have further elaborated on the role of resource booms in slowing human capital accumulation; Baland and Francois (2000) have linked them to increased rent seeking activity and the ensuing loss of economic effi-

[1] See Phillips (1987) for a concise overview of Spanish decline and a discussion of a Malthusian framework.

[2] See Flynn (1978, 1979), Morineau (1985), and Fisher (1989) for just a few selected examples.

ciency, while Tornell and Lane (1999) have illustrated the distortions they might introduce in government policies. Although the term Dutch disease originally referred only to a reallocation of resources away from the manufacturing sector, in the wake of the recent literature it has come to evoke the whole set of adverse effects stemming from a resource windfall.

The Dutch disease hypothesis has several testable implications. The one that has emerged most robust across different models is a rise in the price of non-traded goods relative to that of traded goods.[3] The general equilibrium model I develop yields this prediction as well, which can be tested using only price and expenditure data, two of the few (if not the only) economic variables for which reliable time series covering this period can be assembled. I then proceed to construct price indexes for both traded and non-traded goods, relying on Hamilton's price data and my own weighting baskets, obtained from primary sources. I finally use a Markov-switching regression econometric framework to assess whether the evidence supports the Dutch disease conjecture.

Even if the presence of Dutch disease were confirmed at its strongest, its contribution to the decline of Spain would remain open to debate. With no national income or trade accounts available, determining the size and impact of a shift in resources away from the manufacturing sector is an arduous task. An obvious concern is the small percentage of national income accounted for by trade in early modern economies. Several authors, however, have pointed out the perils of focusing just on the volume of trade while overlooking its dynamic effects on specialization and growth.[4] In addition, a calibration exercise presented in Section 4 shows that large output shifts were a likely response to a resource boom of the magnitude of the American silver discoveries.

The ramifications of a resource boom can go far beyond altering patterns of trade and specialization. Resource abundance has recently been linked to the presence and perpetuation of rent-seeking behavior and institutions through a variety of transmission mechanisms.[5] My findings are therefore entirely consistent with an institutionalist view of Iberian failure, as a Dutch disease episode could have very well strengthened the perverse institutions that obstructed Spanish economic growth for centuries.[6]

[3] See, for example, Edwards (1984), Fardmanesh (1981), Musonda and Luvanda (1991). For an exception, obtained by imposing learning curves in both the booming and the lagging sectors of the economy, see Torvik (2001).

[4] For two recent examples closely related to early modern Spain, see Flynn and Giráldez (2002) and Pomeranz (2000). For a historical analysis of the dynamic effects of trade on the Cantabrian regional economy, see Grafe (2001).

[5] For formal Dutch disease models linking resource booms to rent seeking, see Tornell and Lane (1999), Baland and Francois (2000), Torvik (2002). For a discussion of the negative effect of rent seeking on the accumulation of human capital and economic growth, see Murphy et al. (1991, 1993). DeLong and Shleifer (1993) document a relationship between autocratic types of government and lower urban population growth (which they use as a proxy for economic growth) in the eight centuries preceding the industrial revolution.

[6] See, for example, North and Thomas (1973), Acemoglu et al. (2004), and Landes (1999, pp. 171–173).

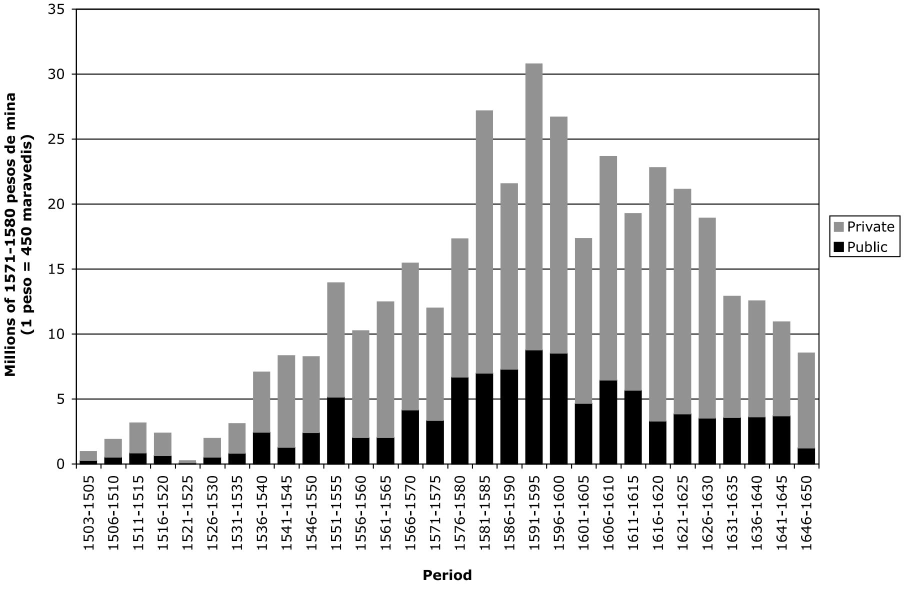


Fig. 1. Value of imports of American treasure.

2. Silver and economic conditions in imperial Spain

2.1. Silver, the natural resource

The fate of the Spanish empire was closely tied to the flows of American bullion. Fig. 1 shows the evolution of imports of American treasure in real terms, constructed using the data from Chart I in Hamilton (1934) and the silver price index reported in its Appendix VIII.[7] The flow of treasure did not become important until 1550, but after that date a river of silver ran through Spain. Another large increase came after 1580, coinciding with the annexation of Portugal and its dominions (but certainly not caused by it). Treasure imports peaked at the end of the reign of Philip II, coinciding with the zenith of imperial expansion. By 1560, the Crown derived 23% of its revenue from American bullion, a figure that grew close to a third before edging down.[8]

[7] There is some question as to the accuracy of the Hamilton figures for bullion imports, as they draw exclusively on official documents and are therefore susceptible to the effects of underreporting and smuggling. Morineau (1985) has argued that the decline in remittances reported by Hamilton is an artifact of ever increasing contraband. His competing series, constructed on the basis of journalistic and diplomatic reports published in Dutch *gazettes*, shows a steady flow of bullion throughout the 17th century. Morineau's figures, however, stand in stark contrast to the well-documented crisis in New World mining after 1620 (Flynn, 1982; Andrien, 1985). While the issue is far from settled, my empirical work focuses on the 16th century, for which both accounts are concurrent.

[8] Tortella and Comín (2001, p. 141).

The death of Philip II in 1598 is generally considered the beginning of Spanish decline, and it also marks the beginning of the decline in the flow of bullion. The sharpest decrease came in the period 1635–1640, at a time when the empire suffered its hardest blow with the independence of Portugal in 1640. The Peace of Westphalia in 1648 marked the demise of Spain as an European hegemonic power and reduced the Holy Roman Empire to a mere shell. By that time, American treasure was no longer among Spain's main sources of income.

Flynn (1982) traces the increase in the flow of silver from the Indies in the 1550s to the invention of the mercury amalgam mining process. American mines were particularly well suited for this procedure, and were also conveniently located in the vicinity of mercury sources. The reduction in remittances to Spain in the 17th century is attributed to reduced profitability, stemming from the decline in the purchasing power of silver and ever-increasing costs in the colonies.[9]

Silver constitutes a classic tradable booming sector as defined in the Dutch disease literature. It rose to prominence after a combination of discoveries of natural resources and technological advances, but less than a century later it had lost most of its appeal as a result of the continuous erosion of its profitability. Officially, the Crown was entitled to the "royal fifth" of all private imports of treasure. When supplemented with its own mining, the amount of bullion imports under the direct control of the Crown reached the average of 26% calculated by Hamilton.[10] In difficult financial times, however, most of the treasure ended up in the hands of the Crown anyway upon being tallied at the Casa de la Contratación, either through lending, voluntary or forced, or outright confiscation. The Spanish Crown relied on the silver flows as its hard-currency base to incur levels of indebtedness other rulers could only dream of. By the mid-16th century, Spain essentially faced an elastic supply of loanable funds, buttressed by the expectations that silver revenues would only grow.[11] The incorrectness of those expectations, together with the disastrous involvement in several military campaigns throughout the 16th century, forced the Crown to declare bankruptcy in 1556, 1575, 1579, 1607, 1627, 1647, and 1656.[12] As the rosy prospects of the first half of the century failed to materialize, the Spanish imperial adventure quickly gave way to a much starker picture.[13]

[9] Flynn (1982, p. 141), Andrien (1985, p. 61).

[10] Tortella and Comín (2001, p. 144) place the Crown's share even higher, at one third of total remittances.

[11] On this point, see Carande (1949a, p. 10), Carande (1949b, p. 25), Kamen (2003, p. 28), De Carlos Morales (2003, p. 90), and Ruíz Martín (1965, p. 16).

[12] The impressive string of bankruptcies conceals their different characteristics; in some of them, such as the 1557 one, only short-term loans contracted with the international banking houses were defaulted upon. In others (1575, for example) long-term bonds held by Spaniards also fell in default. A recent theoretical analysis of the Crown's sovereign debt strategy in the 16th century can be found in Conklin (1998).

[13] This particular course of events may even render moot the debate on the magnitude of the decline in bullion flows for the purposes of this study. The negative outcome of the Crown's military adventures meant that whatever quantities could possibly be extracted from the American mines would have had to be employed in meeting debt payments. While the insufficiency of bullion remittances forced the Crown to declare repeated bankruptcies, a higher flow of silver would have accrued directly to the foreign financiers of the Crown rather than to Spanish nationals.

2.2. The trading economy of the Early Modern Age

The bulk of economic activity in Spain took place in Castile, the central heartland where the Crown established its roots during the Moorish wars and where the system of fairs provided the main venue for commercial exchange and credit clearing. Andalusia emerged as a commercial center thanks to the privileged position of its Atlantic ports, at the gateway to the winds that enabled transatlantic voyages. Seville, the main Andalusian city, enjoyed a monopoly of colonial trade and housed the Casa de la Contratación, responsible for tallying the bullion remittances. Other important centers of activity were the Mediterranean ports of Barcelona and Valencia, as well as the cities on the Cantabrian shore.

The most important Castilian export was high quality wool from transhumant merino herds; it was followed by salt, cochineal (a reexport from the Indies), oil, iron, leather manufactures, hides, and sugar (also a reexport).[14] Important exports from other regions included wine and olive oil from Andalusia, salt from Ibiza, and iron, alum, and codfish from the Basque country.[15] Other exports included almonds, oranges, figs, raisins, and soap from Andalusia, nuts, legumes, sardines, and anchovies from the Mediterranean coast, and rice and saffron from Valencia.[16]

The decline of the Spanish traded goods sector became evident towards the end of the 16th century. Many commodities in which Spain was once self-sufficient, such as corn, rice, and sugar, became imports; in the early 17th century, even those goods she used to provide the world with, such as leather manufactures, iron, and alum, started to be procured abroad.[17] Production of fine wool declined sharply, spelling the demise of Burgos, the once thriving center of the wool trade.[18] The Basque country lost its competitiveness in iron goods and even the Newfoundland fisheries, successfully exploited by the Basques during most of the 16th century, were lost to the French in the 1580s, never to be recovered.[19] Livestock numbers were abruptly reduced, perhaps by as much as 60% between 1600 and 1619, and the size of the fleets trading with America declined significantly between 1575 and 1675.[20]

The traditional traded goods industries in 16th and 17th century Spain exhibit a behavior that conforms reasonably to the symptoms predicted by Dutch disease theory. It was already recognized at the time that foreign goods were taking over markets that had once been served by Spanish industries. Braudel (1972) quotes the

[14] Lynch (1991, p. 193), Braudel (1972, pp. 122, 228, 695), Rich and Wilson (1967, pp. 160, 182, 184, 280, 291).

[15] Lynch (1991, p. 193), Braudel (1972, pp. 82, 122, 228, 435, 695), Rich and Wilson (1967, pp. 160–162, 184).

[16] Salvador Esteban (1994, p. 37), Braudel (1972, pp. 42, 82, 119,122, 236, 376, 386, 422, 762, 861), Rich and Wilson (1967, p. 183), Hamilton (1934, p. 233).

[17] Hamilton (1938, pp. 170–172), Phillips (1987, pp. 542, 545).

[18] Phillips (1987, p. 548).

[19] Grafe (2001, p. 61), Phillips (1987, p. 553).

[20] Hamilton (1938, p. 170).

Cortes of Valladolid asking the King in 1586 "to tolerate no longer the importing of candles, glass trinkets, jewelry, cutlery, and similar objects from foreign countries which are exchanged, although they are useless luxuries, for gold, as if Spaniards were Indians..."[21] From providing for the needs of the domestic economy, generating surpluses for international trade, and sustaining vibrant mercantile centers such as Burgos, the Castilian fairs and the Atlantic ports in both Andalusia and the Basque country, Spanish industries gradually fell into stagnation and decline, remarkably when the silver boom was at its peak.

3. Resource booms in a simple open economy model

This section presents a Dutch disease framework of the Corden–Neary type. One major simplification is that I do not consider the natural resource as a separate industry, since the major input in silver production was slave native labor, and therefore did not require Spanish labor or capital in any significant quantities. This allows me to set up the model as a two-sector framework, rather than the standard three-sector one, making a rough calibration possible.

The utility function of the representative household is

$$U = (C^{\mathrm{T}})^{\gamma}(C^{\mathrm{NT}})^{1-\gamma}, \tag{1}$$

where C^{T} and C^{NT} denote consumption of tradable and non-tradable goods. Households will allocate their labor between the traded and non-traded goods sectors and public employment. Denoting by N^i the amount of labor allocated to sector i, and by N the total amount of labor in the economy, we have

$$N^{\mathrm{T}} + N^{\mathrm{NT}} + N^{G} = N, \tag{2}$$

where the superscript G denotes the government sector.

Traded and non-traded goods are produced according to Cobb–Douglas production functions, using fixed sector-specific capital endowments.

$$Y^{\mathrm{T}} = Z^{\mathrm{T}}(N^{\mathrm{T}})^{\alpha}(K^{\mathrm{T}})^{1-\alpha}, \quad 0 < \alpha < 1, \tag{3}$$

$$Y^{\mathrm{NT}} = Z^{\mathrm{NT}}(N^{\mathrm{NT}})^{\eta}(K^{\mathrm{NT}})^{1-\eta}, \quad 0 < \eta < 1. \tag{4}$$

Y^i denotes the output of sector i, and Z^i is the productivity factor for sector i. The only public employment is assumed to be in the army, which does not produce any good or service.[22]

[21] Braudel (1972, p. 519). The unearthing of the detail is attributed by Braudel to Karl Marx in his *Zur kritik der politischen oekonomie.*

[22] The army is necessary to fight wars, which could be modeled as a lottery with positive payoff only in the event of victory. However, given the insolvency of the Spanish dominions, it is unclear whether this was ever the case. Alternatively, the army can be thought of merely as a requirement for the economy's continued existence.

The households' budget constraint is

$$Y^{\mathrm{T}} + pY^{\mathrm{NT}} + wN^G + s(1-\tau) = C^{\mathrm{T}} + pC^{\mathrm{NT}}, \tag{5}$$

where p is the price of non-traded goods in terms of traded goods (the reciprocal of the real exchange rate), w is the wage the government must pay for people to enlist in the army, s denotes the silver inflow, and τ is the rate at which silver is taxed.

The government collects taxes on private silver flows to fund its military operations and defray other expenses. Its budget constraint is

$$s\tau = wN^G + G, \tag{6}$$

where G represents government expenditures that do not require labor and are assumed to be exogenous and unproductive. Requirements of military labor are set exogenously, and thus

$$N^G = \bar{N}^G. \tag{7}$$

Keeping in mind that consumption of non-traded goods must equal their production, the first order conditions for the household's maximization problem yield:

$$\frac{1-\gamma}{\gamma}\frac{C^{\mathrm{T}}}{C^{\mathrm{NT}}} = p, \tag{8}$$

$$p\eta Z^{\mathrm{NT}}(N^{\mathrm{NT}})^{\eta-1}(K^{\mathrm{NT}})^{1-\eta} = \alpha Z^{\mathrm{T}}(N^{\mathrm{T}})^{\alpha-1}(K^{\mathrm{T}})^{1-\alpha} = w. \tag{9}$$

Eq. (8) determines the relative consumption levels of traded and non-traded goods given their relative price, and Eq. (9) states that the value of the marginal productivity of labor must be equal across sectors, and in turn equal to the wage for serving in the army.

3.1. Comparative statics: a boom in natural resources

After a positive wealth shock, such as the discovery of the silver mines, consumption of both goods will increase to reflect the expanded household budget constraint. Since non-traded goods must be produced locally, labor must switch from the traded goods to the non-traded goods sector. Physical marginal productivity of labor will increase in the traded sector and decrease in the non-traded sector; since the value of the marginal product of labor must be equal in both sectors by Eq. (9), w and p must increase. And by Eq. (8), consumption of traded goods will expand relatively more than consumption of non-traded goods. The trade balance will fall by the expansion in consumption plus the reduction in production of traded goods, with the trade deficit covered by the precious metals not claimed by the government. Table 1 summarizes the effects on the main variables of the model resulting from such an increase.

All the effects from the increase in natural resources will be permanent, matching the symptoms of the Dutch disease: an increase in wages and in prices of non-traded goods, as well as a contraction in the traded goods sector. A negative wealth shock will have the opposite effects. As the model stands, a resource windfall results in per-

Table 1
The effect of an increase in wealth

Output of traded goods	↓
Output of non-traded goods	↑
Consumption of traded goods	↑
Consumption of non-traded goods	↑
Labor allocated to traded goods	↓
Labor allocated to non-traded goods	↑
Price of non-traded goods in terms of traded goods	↑
Wages in terms of traded goods	↑
Trade balance	↓

manently increased consumption and utility. Wijnbergen (1984) rightly noted that such an outcome can hardly be labeled a "disease." His and the other works cited in Section 1 (Asea and Lahiri, 1999; Baland and Francois, 2000; Krugman, 1987; Tornell and Lane, 1999) all explore specific factors and situations, such as the presence of learning-by-doing, rent-seeking, or sector-specific human capital, that can lead to slower economic growth and long-run stagnation under Dutch disease conditions. I have elsewhere suggested that exaggerated expectations about silver income might have led to excessive consumption and a debt overhang in 16th-century Spain.[23] Since no quantitative data exist to test these hypotheses, I shall not model any of them formally. The calibration in Section 4 suggests that agents may have estimated the present value of future silver income at between 25 and 50% of a year's GDP, thus lending some support to the expectations scenario.

4. Price indexes and real exchange rates

The model offers several testable predictions to determine whether the behavior of macroeconomic variables is consistent with a Dutch disease episode, but verifying them all is an impossible task when dealing with developments in a pre-statistical era. Price data, however, are reasonably available for 16th and 17th century Spain, providing the raw material to construct price indexes for traded and non-traded goods. Once alternative explanations are ruled out, a significant decrease in the price ratio of traded to non-traded goods, tantamount to a real exchange rate appreciation, would be a strong indication of the presence of Dutch disease.[24] A reversal

[23] Drelichman (2003).

[24] The price of non-traded goods relative to that of traded goods is known as the "Australian" real exchange rate. While its usefulness as a measure of the competitiveness of a country has been questioned in the recent literature, here it is not chosen arbitrarily, but rather derived directly from the theoretical framework. Harberger (2004) identifies the two main shortcomings of this measure as its inability to reflect specific trade policy changes, and its undesirable response to variations in the price of natural resources whenever that same price is included in the traded goods price index. Since Spain did not experience significant trade policy changes during the 16th century, and the price indexes I constructed specifically exclude the price of silver, neither of these issues are a concern for my empirical work.

of this trend coinciding with the initial indications of the exhaustion of silver or with the Crown's bankruptcies would be consistent with the conjecture that Spain misjudged the magnitude of the resources available to her.

The price data for my indexes are taken from Earl J. Hamilton's *American Treasure and the Price Revolution in Spain: 1501–1650* [Hamilton (1934)] and consist of price series for 158 different goods across the historical regions of Andalusia, New Castile, Old Castile-Leon, and Valencia, spanning the period 1503–1650.[25] Coming from hospitals, monasteries, and royal households, the data differ from the typical household consumption basket in some significant ways; most notably, we do not have any indication of rent payments, since hospitals and monasteries owned the premises in which they functioned.[26] Despite its limitations (most of them already addressed by Hamilton himself), this dataset remains the standard source for Spanish price history of this period.

4.1. The problem of weights: some new data

While a rich literature has addressed the Price Revolution in Spain, the choice of a basket of weights has been perhaps its most persistent shortcoming. Hamilton did not use weights at all, and his indexes are arithmetic means of all the available prices.[27] Brown and Hopkins (1959) provided consumption weights for Valencia, based on a combination of their weight basket for 16th-century England with some anecdotal evidence. Martin Aceña (1992) adopted the Brown and Hopkins basket to calculate his price index for Castile. More recently, Llopis et al. (2000) have corrected some biases in the Brown-Hopkins basket and have enlarged it to include 31 goods. All these works, however, use very rough estimates of the consumption basket, based mainly on qualitative appreciations. I attempt to correct this shortfall in the literature by constructing what I believe are the first consumption baskets for 16th and 17th century Spain based on quantitative data extracted from primary sources.

[25] Hamilton defined regional boundaries by whether their product markets were integrated. While his data are silent on Galicia, Asturias, the Basque Country, Navarre, most of Aragon, Catalonia, Murcia, and Extremadura, the four included regions cover over 60% of the Spanish territory and as much as three-fourths of its population and economic life. See Hamilton (1934, pp. 139–151and Appendix I, p. 309) for an explanation of the sources and methods used in compiling the data. Although this description can be less than clear in some aspects, Hamilton's original worksheets, collected in The Earl J. Hamilton Collection at the Rare Book, Manuscript, and Special Collections Library at Duke University, allow a glimpse into the mechanics of his work. I examined in detail the data sheets and annotations corresponding to *American Treasure and the Price Revolution in Spain: 1501–1650*, to gain some insight into the construction of his series and obtained many of the sources that I later used to construct my consumption baskets.

[26] The interested reader can find some isolated observations of rent payments from peasant families to monasteries, the largest landowners of the time, in Brumont (1984, pp. 32–35). These observations, however, are quoted in kind, in terms of different goods, and cover only the period from 1550 to 1580, making it virtually impossible to obtain a reliable series from them.

[27] Hamilton (1934, p. 149).

Table 2
Consumption baskets

Category	Queen Joanna (1546)		Cinco Llagas (1623)		Llopis poor	Llopis rich
	Percentage of expenditures	Of which percentage traded	Percentage of expenditures	Of which percentage traded	Percentage of expenditures	Percentage of expenditures
Meat	12.92	0.00	7.90	0.00	17.00	19.00
Live animals	5.86	0.00	32.30	0.00	2.00	3.50
Animal products	4.00	45.96	1.35	38.78	4.00	6.75
Cereals	17.45	100.00	25.39	100.00	45.90	31.00
Bread	18.23	100.00	0.00			
Fruit	4.09	28.94	1.45	53.80	1.00	2.00
Vegetables and legumes	2.22	58.21	0.73	87.83	0.50	0.50
Plants and herbs	0.34	0.27				
Vegetable products	7.42	35.21	5.16	76.80	1.50	3.00
Medicines	0.64	100.00	0.69	20.20		
Fish	4.51	92.28	4.99	87.80	2.50	4.00
Wine and vinegar	10.02	100.00	3.32	100.00	16.00	15.00
Spices	1.00	100.00	2.27	100.00	0.10	0.50
Elaborated foods	0.46	10.61	0.06	9.04		
Manufactures	5.47	99.27	3.41	90.77	1.50	4.75
Textiles	1.44	100.00	7.57	100.00	10.00	16.00
Fuels and minerals	2.65	41.21	2.52	79.74		
Miscellaneous	1.62	8.18	0.56	91.33		

Table 2 reports the consumption baskets obtained from the household of Queen Joanna in Tordesillas (Old Castile) in 1546,[28] the weights from the Hospital de las Cinco Llagas in Seville in 1623,[29] and, for comparability purposes, those presented in Llopis et al. (2000) for rich and poor households.[30] Since these baskets were constructed using all available transactions for a given year, they contain dozens of different goods; to facilitate the exposition and comparison with previous work, I grouped them into relevant categories, but the price indexes I present later are computed using the weights for individual goods.[31] For the two baskets that I computed, I also report the percentage of each category composed of traded goods.[32] I used less complete or reliable sources to check the consistency of the computed weights. These

[28] Archivo de Simancas, Casas y Sitios Reales 12 (29), Simancas (Valladolid).

[29] Archivo de la Diputacion Provincial, Hospitales 114, Sevilla (Sevilla).

[30] The Llopis baskets, which subsume all the previous research in the area, are reproduced here for comparison purposes. It should be noted that both of them add to slightly more than 100%.

[31] The basket computed from Queen Joanna's accounts, for example, is based on 3583 separate entries for 215 different goods, although many of them appear only once and carry very small weights. Llopis's baskets, in contrast, contain 31 goods for the rich households and 24 for the poor ones.

[32] I classified virtually all of the goods into *traded* and *non-traded* according to whether the goods were actually, rather than potentially, being imported or exported. This choice of criterion was prompted by the difficulty of establishing the susceptibility of a good to being traded, while the extensive literature on Modern Age trade in Europe makes it relatively easy to assess whether a good was actually traded or not. See Section 2 for specific examples.

include books that report only expenditures on certain categories, such as the kitchen accounts of the Hospital de Esgueva for 1569 (Old Castile);[33] books that report only a summary of expenses aggregated in broad categories, such as the Convento de San Pablo in Toledo (New Castile);[34] and sources that seemed suspicious because of extremely abnormal weights in some of the leading goods, such as the books of Hospital de las Cinco Llagas in 1587[35] or the Household of Prince Philip.[36]

The institutions whose records have survived to the present day hardly resemble the Spanish representative household of the time. Royal households represent the extreme upper tail of the income distribution, while hospitals and monasteries will exhibit consumption patterns that reflect their specific institutional goals. Hospitals, on the other hand, devoted most of their expenses to social assistance functions (such as feeding the poor), thus providing a glimpse into the consumption of the lower classes, for which otherwise no records exist.

The series from the household of Queen Joanna is comparable to the Llopis basket for rich households, since they come from roughly the same period, region, and social stratum. When relevant categories are considered together (such as meat and live animals, or cereal and bread) the weights are roughly in the same range, except for wine (which Llopis estimates at a high 15% of consumption) and textiles (which are somewhat low in my estimates, but perhaps too high in Llopis's). My basket, however, exhibits a much wider array of goods, enabling me to include more price series in the indexes. While many of these commodities represent small expenditures, some of them gain relevance when estimating separate indexes for traded and non-traded goods.

4.2. The nuts and bolts of constructing the price indexes

Since the availability of price series varies significantly across regions, I faced the task of converting the baskets yielded by the primary sources into a set of weights that could be applied to the available price data. To lessen the effects of the asymmetric representation of different categories in my indexes, I used a category-based reweighting procedure. After gathering all the suitable series for a region (which I define as series that registered observations for at least 50% of the years), I calculated the percentage of each of the categories in Table 2 represented by them. I then assigned to each good a weight equal to its raw weight in the primary sources divided by the percentage of its category covered by the available price data, thus increasing the final weight of goods in categories with poor representation. This reweighting procedure rests on the assumption that the prices of goods in the same category tend to fluctuate together.[37]

[33] Archivo Historico Municipal, Hospital 120 (313), Valladolid (Valladolid).

[34] Archivo Historico Nacional, Clero Secular Regular Libros 16026, Madrid.

[35] Archivo de la Diputacion Provincial, Hospitales 109, Sevilla (Sevilla).

[36] Archivo de Simancas, Casas y Sitios Reales 74, Simancas (Valladolid).

[37] The categories I used in reweighting differ slightly from the ones presented in Table 2, because in some cases products in different categories could represent the same underlying good, as bread and wheat do. In fact, some institutions bought the cereal and baked their own bread, while others purchased the final product. To keep a certain consistency across institutions, I merged the two relevant categories to perform the reweighting. This is why bread is classified in Table 2 as a traded good.

Rather than impute or interpolate values for the many gaps in Hamilton's data, I chose to evaluate the seriousness of the missing data through a non-parametric bounds exercise as in Manski (1995). I replaced each missing observation alternatively with minimum and maximum likely values, and then used the resulting datasets to construct upper and lower bounds on the (unknown) true price index.[38] The real exchange rate will therefore be expressed as a set of bounds, where the lower bound is constructed by dividing the lower bound on the appropriate traded goods index by the upper bound on the corresponding non-traded goods index. Conversely, the upper bound is constructed by dividing the upper bound on the traded goods index by the lower bound on the non-traded goods index. The results are expressed as an index of the relative price of traded goods in terms of non-traded goods; a fall in the index indicates a real exchange rate appreciation, the movement predicted by the Dutch disease model. In all my indexes I adopted the decade 1601–1610 as a base because of its relatively central position in the series and the few missing data instances occurring in it. Since the real exchange rate series result from division of two price indexes with the same base, they are anyways free from any biases induced by the choice of base period.

Fig. 2 shows a 4-year moving average of my estimates of the upper and lower bounds for the real exchange rate in each of the four regions for the full 150 year period covered by Hamilton's data. The thin lines in each picture represent the upper and lower bounds for the real exchange rate, while the solid black line is their mean value. The first striking feature is the high volatility, with the maximum observed values for the real exchange rate being twice as high as the minimum ones in some cases. Some of the troughs coincide exactly with large demographic changes, such as the recurring plagues in the opening years of the 17th century; since a fall in population would have the effect of decreasing available labor, thereby increasing the price of non-traded goods, this observation is a very welcome consistency test for the model. Other extreme values are more difficult to explain; while the volatility is undoubtedly linked to the high weight of food staples in the indexes, some of them, such as wheat, fall into the traded category, while others, such as fresh meats, are non-traded. Bad harvests, a breakdown in trade, a cattle epidemic, and many other factors could result in substantial movements in the series. Finally, while the 16th century was largely free of inflation driven by fiat money, 17th century monarchs normally resorted to minting copper money, changing the units of account, and debasing the currency, in ever more desperate attempts to cover fiscal deficits and service their overwhelming debt.[39] These large monetary disturbances may have had diverse effects on different categories of goods, causing large swings in the real exchange rate.

[38] The minimum theoretical value of any price is zero, and the maximum infinity. Using these values to replace missing observations would clearly have been an irrelevant exercise. Instead I used the low price and high price immediately contiguous to the missing observation as my likely minimum and maximum values. Since the 16th century experienced a secular trend of increasing prices, this procedure will yield reasonable bounds in the vast majority of instances.

[39] See MacKay (1981). For a comprehensive account of monetary units and changes in their gold content in the 16th and 17th century, Hamilton (1934) provides a good starting point; however, the corrections by Motomura (1994, 1997) must be kept in mind.

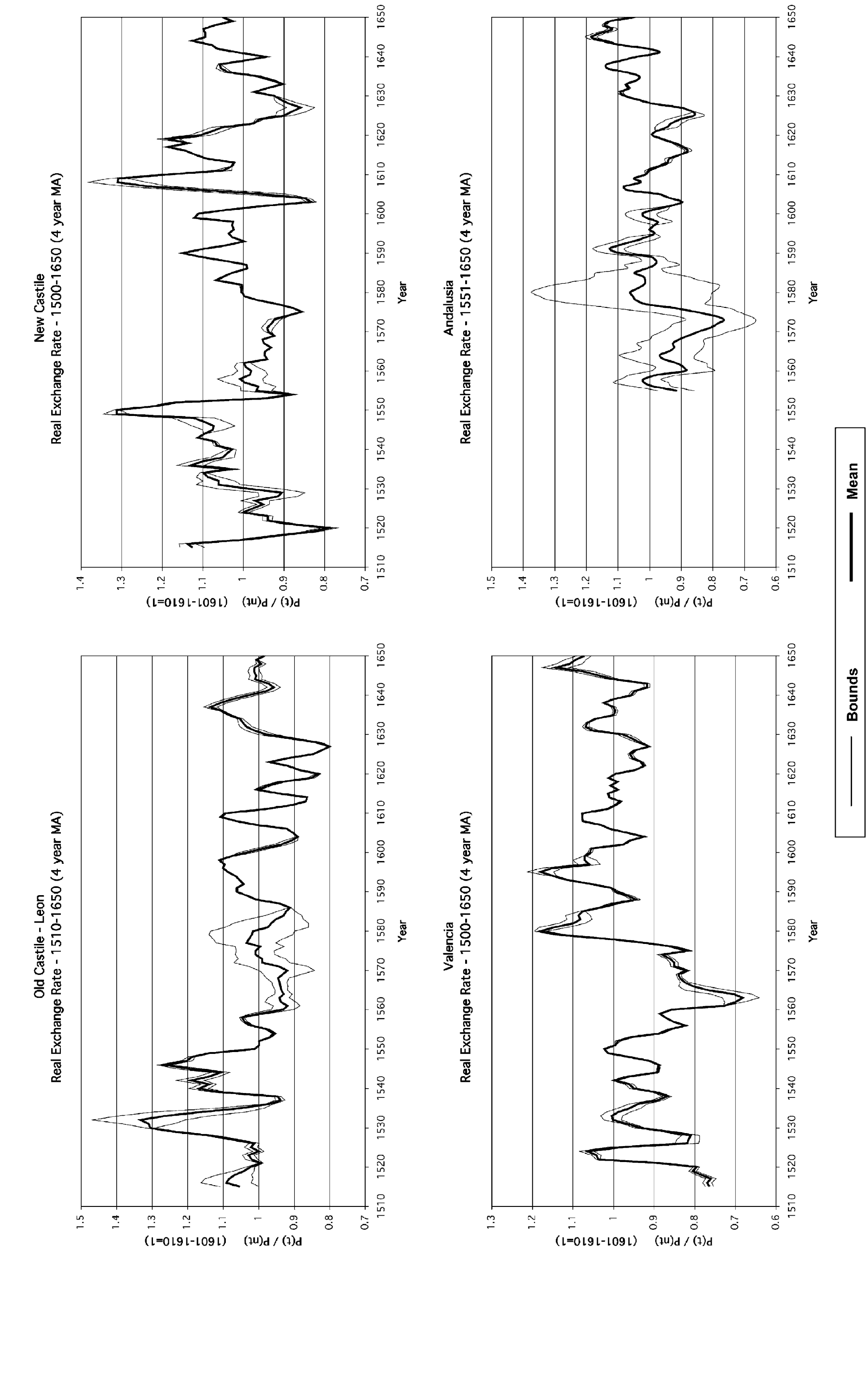


Fig. 2. Real exchange rates.

A simple inspection of the bounds reveals that the Andalusian data are too weak to be useful; there are almost no price observations before 1550, and in the second half of the 16th century missing data are so pervasive that the bounds are too wide to draw useful conclusions. Not without regret, we need to abandon the study of this region, which held a crucial position in the colonial trading system, until more consistent price series are compiled.

5. Estimating the timing and size of regime changes

The model presented in Section 3 predicts discrete jumps in the price of non-traded goods relative to traded goods whenever a wealth shock is realized. If a Dutch disease episode did indeed take place, one would expect to see a substantial real exchange rate appreciation when the knowledge of newly found wealth is incorporated by decision makers; conversely, a negative wealth shock, such as the realization that silver was not that plentiful or valuable after all, that a bankrupt government was likely to confiscate any new bullion shipment, or that military defeats would mean higher taxation, would be associated with a real exchange rate depreciation.

The variable of interest in this setting is the agents' wealth. This is an unobserved magnitude, but one that the theoretical framework links to the observable real exchange rate. One would therefore like to test if the real exchange rate in Spain was subject to regime changes, and, if so, to date them and estimate their magnitude. Regime changes associated with the discovery of silver mines and real exchange rate appreciations would strongly support the Dutch disease hypothesis; similarly, regime changes coinciding with adverse wealth shocks and real exchange rate depreciations would help to determine the point at which New World wealth accruing to Spaniards took a sudden downturn.

Most econometric specifications used to estimate the magnitude of regime changes require that the timing of the change be exogenously specified. The timing of a real exchange rate appreciation, however, is a crucial piece of evidence in linking it to the silver flow; imposing the timing exogenously would strip the estimation of most of its identifying power. It is highly preferable to let the data reveal whether there was a regime change and, if so, when it took place. I therefore adopt an econometric specification based on Hamilton's (1995) model of structural change, which makes it possible to estimate the timing as well as the magnitude of any change in mean and variance the real exchange rate series may exhibit. I later check its results for robustness against a more standard framework.

While the available price data, and hence my real exchange rate indexes, span the period 1501–1650, there are obvious problems with using the full extension of the sample in the context of a structural change econometric framework. The econometric specification is naturally silent on the source of exchange rate movements, which becomes an issue in light of the plagues, fiscal crises, demographic changes, and monetary disturbances that became commonplace after 1600. Another likely source of trouble is the low quality of the data in the first quarter of the 16th century, a period for which only a few sources survive, and those that do are far less systematic and reliable than comparable ones later on.

Since the complexity of estimating a Markov-switching framework increases in the number of states of the world being considered, I concentrate on the years 1531–1600, which are relatively free of major exogenous shocks except for the mineral discoveries. The largest silver mines were discovered in the mid-1540s and the fiscal crisis did not become severe until the 1580s (which also witnessed the first large-scale military disasters); this time frame thus allows between at least two decades on each side of the period where I expect to identify a Dutch disease phenomenon. My period of analysis is still over three times longer than the usual time frame in which Dutch disease phenomena are commonly studied, and the robustness checks below consider more extended periods as well.[40]

The Markov-switching specification, while having the advantage of estimating the timing and size of regime changes endogenously, still requires the number of regimes and autoregressive lags to be specified prior to estimation.[41] Garcia and Perron (1996) discuss a number of tests to select the number of regimes; I adopted the Davidson and McKinnon J test for non-nested hypothesis, which selected a specification with three regimes for each of the three regions.[42]

Once the number of regimes is determined, several information criteria can be used to determine the optimal number of autoregressive lags; I used the Akaike Information Criterion and the Bayesian Information Criterion, which concurred in selecting two lags for New Castile and Valencia, and no lags for Old Castile. The equations to be estimated are therefore

$$y_t - \mu(s_t) = \phi_1[y_{t-1} - \mu(s_{t-1})] + \phi_2[y_{t-2} - \mu(s_{t-2})] + \sigma(s_t)\varepsilon_t, \quad s \in \{1,2,3\} \tag{10}$$

for Old Castile and Valencia, and

$$y_t - \mu(s_t) = \sigma(s_t)\varepsilon_t, \quad s \in \{1,2,3\} \tag{11}$$

for New Castile. y_t is the real exchange rate in period t and $\mu(s_t)$ is the mean real exchange rate associated with the agents' perception of their permanent wealth at time t, so the dependent variable is the deviation of the real exchange rate from its (state-dependent) mean. ϕ_1 and ϕ_2 are autoregressive coefficients, and $\sigma(s_t)$ is a state-dependent coefficient multiplying the error term, which is assumed to have a standard normal distribution.

The unobserved regime variable, s_t, is assumed to follow a Markov process with the associated matrix of transition probabilities P, where each element p_{ij} is defined as the probability that $s_t = j$ given that $s_{t-1} = i$, and the sum of each column is equal to 1.

[40] As an example, Edwards (1984) analyzes the period 1968–1982; Musonda and Luvanda focus on 1966–1987.

[41] This, however, is also required in more traditional trend-break models.

[42] Davidson and McKinnon (1981). This test for non-nested hypotheses is appropriate in light of the identification restrictions I discuss later on.

$$P = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix}. \tag{12}$$

As a result of the flexibility allowed by the Markov-switching specification, a series with high volatility can make it difficult to distinguish between strong negative autoregressive behavior and a constant alternation between states.[43] While this can be a problem in some settings, it is very unlikely that agents would constantly alter their perceptions about their wealth in a dramatic way, changing from feeling extremely rich one year to extremely poor the next one, year after year. It is therefore safe to adopt an identification restriction that would explain the volatility through autoregressive effects rather than by constant regime switching. A straightforward way of achieving it is to impose $p_{12} = p_{23} = p_{31} = 0$; this "cycling" restriction requires that, following a transition from one state to another, the model has to pass through at least a third state before returning to the original one.[44] This prevents the oscillating movement characteristic of autoregressive behavior from being identified as constant regime switching.

The above specification can be estimated using the non-linear filter derived by Hamilton (1995), which yields estimates for the parameters and the elements of the transition probability matrix. I report the estimates for the three selected models in Table 3.[45]

A crucial byproduct of the estimation procedure are the so-called smoothed probabilities, which indicate the probability that the system is in each state at each point in time. When the smoothed probability that the system is in a low real exchange rate regime equals one, for example, there would be a strong case for suspecting the presence of Dutch disease. The smoothed probabilities can be calculated using the Hamilton (1995) non-linear filter in combination with the algorithm presented in Kim (1993).

Figs. 3–5 show the results for each of the three regions. In the top panel of each figure, I reproduce the real exchange rate series, while in the bottom panel, I report the smoothed probabilities for the process being in each of the three states at each point in time. The solid line represents the probability of the series being in the state with the lowest mean ("low state") and the dotted line represents the probability of it being in the state with the second lowest mean ("medium state"). The probability of being in the state with the highest mean ("high state") is just one minus the other two probabilities. Thus, when the solid line approaches a value of 1, it reveals that the

[43] Technically, the likelihood function exhibits two very close local maxima, the rank of which is extremely sensitive to small variations in the data.

[44] Note that this restriction converts alternative hypotheses with different number of regimes into non-nested ones, hence the choice of the J test to identify the number of regimes.

[45] All the estimations of the Markov switching model, as well as the calculation of the smoothed probabilities, were conducted using James D. Hamilton's software, available from http://econ.ucsd.edu/~jhamilto/software.htm.

Table 3
Estimation results

Region	New Castile	Old Castile	Valencia
States	3	3	3
Lags	0	2	2
μ_1 (high state mean)	1.400 (0.251)	1.276 (0.096)	1.075 (0.024)
μ_2 (medium state mean)	1.068 (0.025)	1.024 (0.034)	0.939 (0.026)
μ_3 (low state mean)	0.950 (0.019)	0.974 (0.014)	0.806 (0.029)
σ_1 (high state volatility)	0.063 (0.064)	0.037 (0.019)	0.009 (0.003)
σ_2 (medium state volatility)	0.020 (0.005)	0.005 (0.001)	0.008 (0.009)
σ_3 (low state volatility)	0.008 (0.002)	0.004 (0.001)	0.009 (0.003)
ϕ_1		0.513 (0.132)	0.389 (0.127)
ϕ_2		−0.259 (0.108)	−0.180 (0.128)
p_{11} (high state persistence)	0.444 (0.512)	0.865 (0.116)	0.977 (0.035)
p_{22} (medium state persistence)	0.970 (0.033)	0.967 (0.043)	0.979 (0.026)
p_{33} (low state persistence)	0.953 (0.038)	0.963 (0.030)	0.980 (0.020)
Log L	106.681	135.606	123.728
N	70	70	70
K	9	11	11
B statistic	0.85 (0.468)	0.97 (0.300)	0.37 (0.999)
$J2$	0.017	0.173	
$J3$	0.069	0.950	

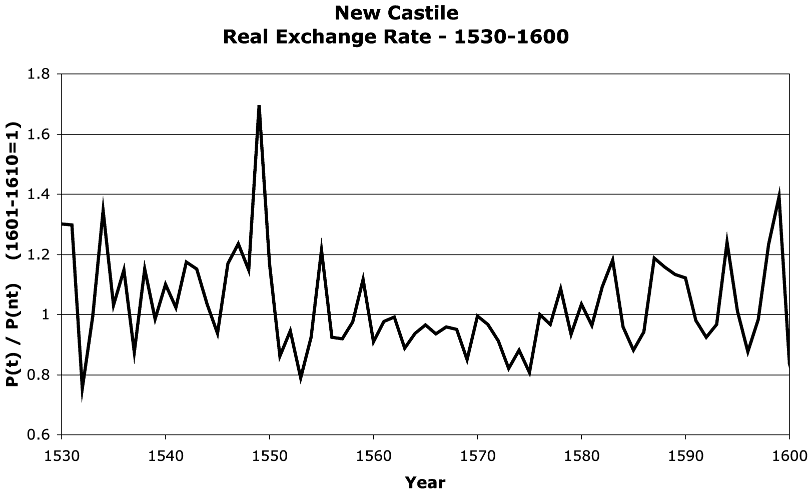
Equation for Old Castile and Valencia: $y_t - \mu(s_t) = \phi_1[y_{t-1} - \mu(s_{t-1})] + \phi_2[y_{t-2} - \mu(s_{t-2})] + \sigma(s_t)\varepsilon_t$, $s \in \{1,2,3\}$. Equation for New Castile: $y_t - \mu(s_t) = \sigma(s_t)\varepsilon_t, \quad s \in \{1,2,3\}$.
Models were estimated with the restriction $p_{12} = p_{23} = p_{31} = 0$. Figures in parentheses for the parameter estimates are standard errors. Figures in parentheses for Bartlett's statistic are p values. Bartlett's statistic is used to test the null hypothesis that a series is white noise. I use it on the model's residuals to verify that no serial correlation remained. $J2$ is the p value for the J test for a two-state null hypothesis versus a 3-state alternative hypothesis. $J3$ is the p value for the converse test. Values are not reported for the Valencian model because the estimation for the 2-states model yielded non-persistent states.

economy is in a low exchange rate state, and is therefore likely to be experiencing a Dutch disease episode.

In the results for New Castile, shown in Fig. 3, the high state was needed only to accommodate the peak of 1549, while all the other years correspond to the medium and low states. The low state is in effect between 1550 and 1577; from the estimates in Table 3, the real exchange rate during that period is on average 11% lower than in the medium state years.[46] The volatility of the real exchange rate in the low state is less than one-half of that in the medium state. These results are strongly consistent with the presence of Dutch disease; while the real exchange rate on occasion sinks to low values outside the 1550–1577 period, the appreciation is nowhere so persistent as during these three decades.

The results for Old Castile follow a similar pattern. A high mean, high volatility state is present in the years 1539–1546, while the rest of the period is split between the

[46] The magnitude of the real exchange rate appreciation is calculated by subtracting the low-state mean in Table 3 from the medium-state mean, and dividing by the former.



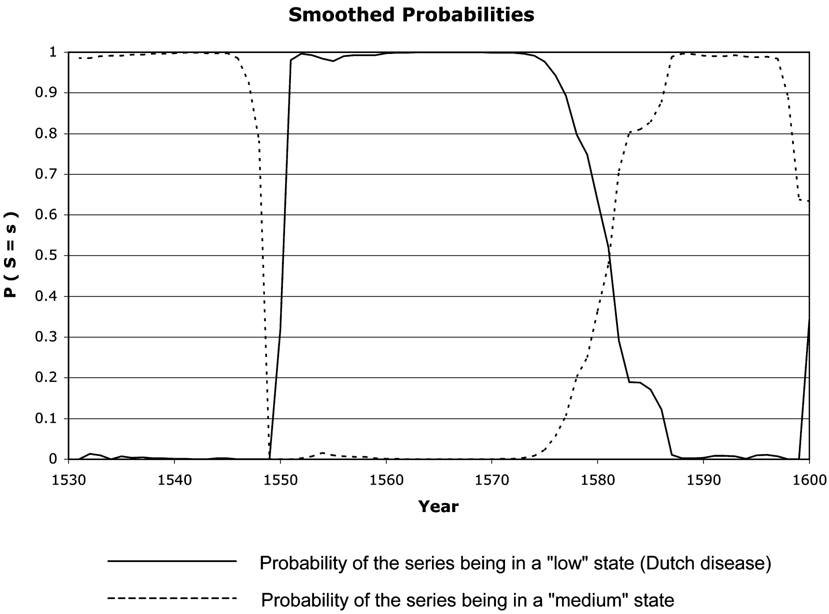


Fig. 3. Real exchange rate and smoothed probabilities for New Castile.

low and medium state in a fashion similar to that of New Castile. The appreciation episode starts in 1547 and gradually disappears during the 1570s and 1580s. However, the difference between the low and the medium states is only 5.3%. While significant at the 1% confidence level, this magnitude comes across as somewhat small given the noisy nature of the data.

Valencia, the final region, exhibits a different behavior. There are no outlying observations, and therefore no need to use a state to account for them. The real ex-

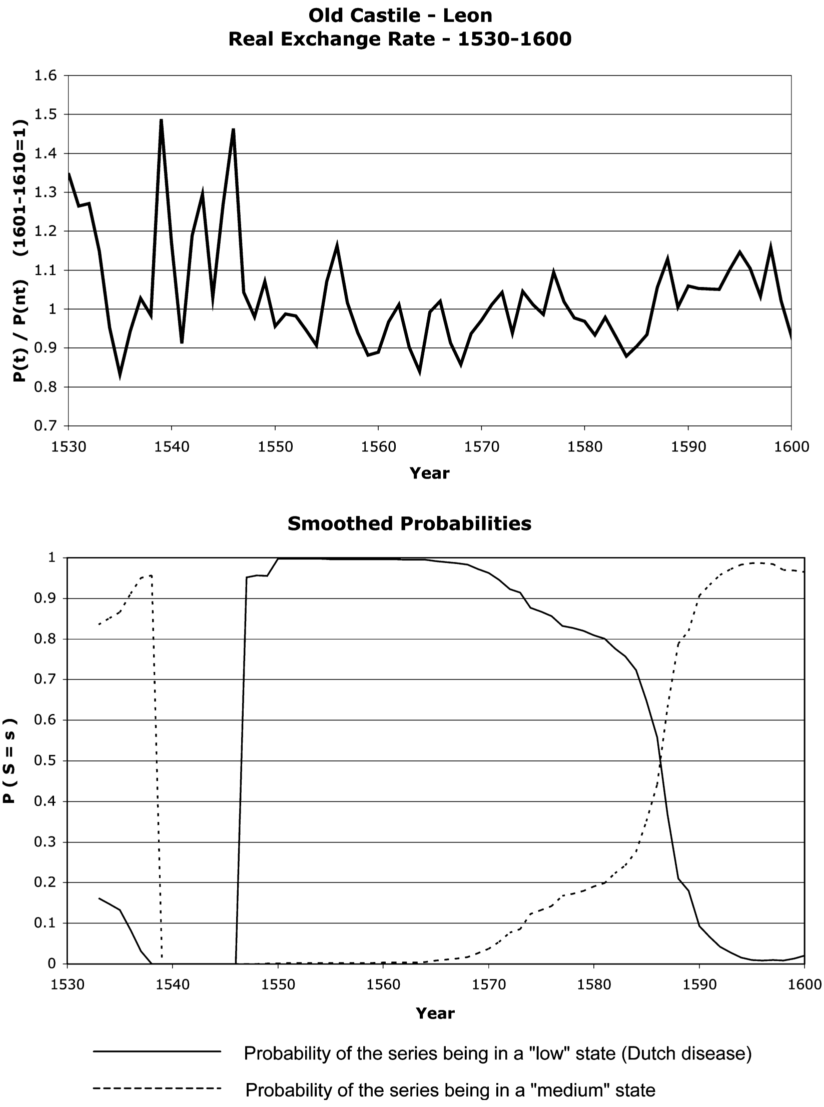


Fig. 4. Real exchange rate and smoothed probabilities for Old Castile.

change rate, however, hovers around different values before and after the appreciation episode. The series starts in a medium state, falls into a low state around 1554, and switches to a high state in 1577. In the low state, the real exchange rate is on average 14.2% lower than in the medium state, and 25% lower than in the high state. The volatility does not change from state to state. These results are again consistent with a period of Dutch disease between 1554 and 1577. This episode of real exchange rate appreciation, while a few years shorter on each end, is consistent with the ones estimated for New and Old Castile.

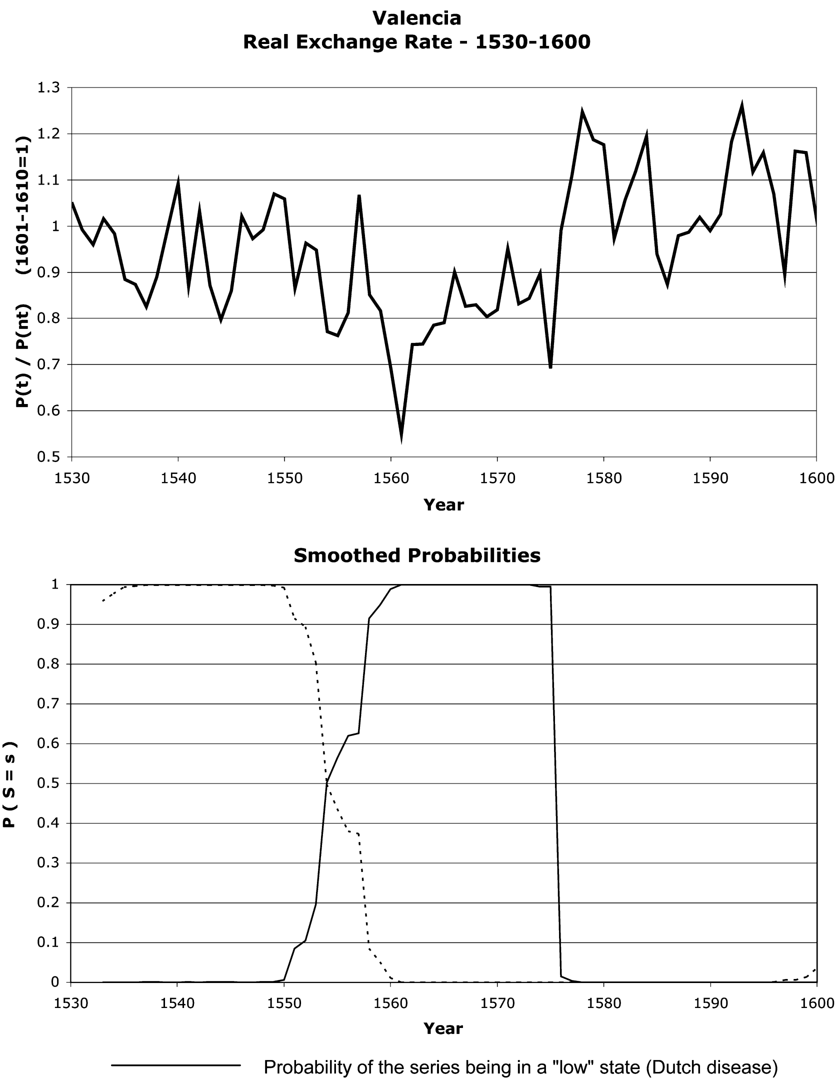


Fig. 5. Real exchange rate and smoothed probabilities for Valencia.

In all three regions, the econometric framework detects a persistent real exchange rate appreciation starting between 1547 and 1554, and concluding in the late 1570s. The beginning of the appreciation episodes coincides remarkably with the discovery of American silver reserves and the development of the industrial processes needed to exploit them; their conclusion, some three decades later, coincides with the 1575 bankruptcy. This timing, endogenously estimated through the econometric framework, supports the conjecture that the silver discoveries were treated as a large increase in permanent income; the real depreciation at the end of the 1570s points to the bankruptcy both as a negative wealth shock in itself and as an ominous signal of worse ones to come.

5.1. Robustness

The Markov-switching regression framework has the unique feature of endogenously estimating the timing of structural breaks, something standard trend-break models cannot do when there is more than one break in the series.[47] Since the Markov framework requires some specification choices that might influence its results, however, it is desirable to check their robustness against more standard setups. I therefore estimated the simplest possible specifications for stationary time series with two structural breaks for each of the three regions. Using again the Akaike and Bayesian information criteria to select the appropriate time lags, I estimated the equation

$$y_t = \alpha + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \gamma_1 B_{1t} + \gamma_2 B_{2t} + \varepsilon_t \quad (13)$$

for Old Castile and Valencia; y_t again represents the relative price of traded goods, while B_1 and B_2 are dummy variables that take the value 1 if t is, respectively, greater than the date of the first and second breaks, and zero otherwise. For New Castile, the information criteria indicated that no lags should be used with the 1531–1600 series, but two should be included when using the full 1501–1560 range. To err on the side of caution, I used both zero and two lags on both samples.

Since this simple specification requires the timing of the breaks to be specified exogenously to construct the dummy variables (as do all models except the Markov-switching one), I used the years suggested by the smoothed probabilities for each region. I estimated all four equations twice, once using the same dataset as in the Markov specification (1531–1600) and again using the full range of available data (1501–1650).

To validate the results of the Markov specification four conditions must be met: (1) the coefficients on B_1 and B_2 must be statistically significant; (2) the coefficients on B_1 and B_2 must be jointly different from zero; (3) the magnitudes of the real exchange movements must be in the neighborhood of those estimated by the Markov model; and (4) the results must not be significantly altered by using the full range of the available data rather than the restricted period.

As Table 4 reveals, almost all coefficients on B_1 and B_2 are significant at either the 5% or the 1% level. The exception are the coefficients on B_2 for Old Castile, but this is still consistent with the results of the Markov specification, which did not detect a strong second break for the region. The F-statistics always reject the null hypothesis $B_1 = B_2 = 0$ at the 5% level or better. While the coefficients themselves are not comparable across specifications, the estimated shifts in the real exchange rate, reported

[47] In the case of a single break, an alternative is offered by the sup-Wald test described by Andrews (1993).

Table 4
Robustness checks

	New Castile				Old Castile		Valencia	
Period	1531–1600	1501–1650	1531–1600	1501–1650	1531–1600	1501–1650	1531–1600	1501–1650
Lags	0	0	2	2	2	2	2	2
Breaks	1550, 1577	1550, 1577	1550, 1577	1550, 1577	1547, 1580	1547, 1580	1554, 1576	1554, 1576
Constant	1.110[b]	1.066[b]	1.221[b]	0.802[b]	0.880[b]	0.471[b]	0.782[b]	0.661[b]
	(33.64)	(43.72)	(7.44)	(7.95)	(6.26)	(6.34)	(6.56)	(7.95)
B_1	−0.171[b]	−0.117[b]	−0.177[b]	−0.099[a]	−0.128[b]	−0.077[b]	−0.117[b]	−0.085[b]
	(−3.93)	(−2.88)	(3.86)	(−2.51)	(−3.48)	(−2.90)	(−3.64)	(−2.98)
B_2	0.097[a]	0.091[a]	0.096[a]	0.074[a]	0.032	0.009	0.222[b]	0.159[b]
	(2.39)	(2.38)	(2.35)	(2.04)	(1.066)	(0.39)	(5.58)	(5.095)
$Y(t-1)$			0.130	0.392[b]	0.377[b]	0.627[b]	0.351[b]	0.421[b]
			(1.14)	(4.71)	(3.22)	(7.69)	(3.10)	(5.21)
$Y(t-2)$			−0.227	−0.139	−0.147	−0.037	−0.175	−0.137
			(−1.95)	(−1.68)	(−1.34)	(−0.48)	(−1.58)	(−1.72)
DW	1.85	1.302	2.03	1.97	1.89	2.00	2.01	1.97
F[c]	8.018	4.305	7.641	3.250	6.088	5.293	15.572	13.824
p value	0.000	0.013	0.001	0.040	0.003	0.006	0.000	0.000
N	70	150	70	150	70	150	70	150
Estimated effects								
First break	−15.41%	−10.98%	−14.50%	−12.34%	−14.55%	−16.35%	−14.96%	−12.86%
Benchmark	−11.05%	−11.05%	−11.05%	−11.05%	−5.27%	−5.27%	−14.16%	−14.16%
Second break	10.33%	9.59%	9.20%	10.53%	4.26%	2.28%	33.38%	27.60%
Benchmark	12.42%	12.42%	12.42%	12.42%	5.57%	5.57%	33.37%	33.37%

Figures in parentheses are t-statistics.
[a] Significant at the 5% level.
[b] Significant at the 1% level.
[c] F-statistic for the joint hypothesis test $B_1 = B_2 = 0$.

in the bottom section of Table 4, are always within close range of the Markov benchmark; in the few cases where the differences are significant, such as in column 1 and in both equations for Old Castile, the effects estimated through the reduced-form equations are *larger* than in the Markov specification. Expanding the dataset to the full range of available data, while predictably biasing the raw estimates towards zero, does not affect the estimated magnitude of the changes in the real exchange rate in any significant way.

5.2. Ruling out alternative explanations

The synchronization and persistence of the real exchange rate appreciation in all three regions makes it easy to rule out alternative explanations. While many economic and demographic events might result in an increase in the price of non-traded goods, few would be capable of sustaining it for almost three decades across the whole territory of Spain, and much less go unnoticed. The strongest contenders for such an effect are large demographic changes, persistent monetary disturbances, and state bankruptcies.

While Spain suffered from tremendous population shocks in the early 17th century, including the severe plagues of the first decade of the century and the expulsion of the *moriscos*, its population was fairly stable between 1530 and 1600.[48] Monetary concerns can also be ruled out quite easily, as the Habsburgs maintained a rigid policy of sound money even in the face of the Crown's financial hardships. After the currency reform enacted by the Catholic kings in 1497, the metallic content of Spanish coins remained completely unaltered until 1599.[49]

Sixteenth-century Spain witnessed three "defaults," in 1557, 1575, and 1579. The 1557 episode, however, affected only short-term external debt, which was converted into 5% long-term bonds. Domestic bondholders did not suffer in any way from the restructuring, and hence their permanent wealth was unaffected. If anything, the default on foreign short-term loans guaranteed the continuing service of domestic debt. In 1575, however, while the default was still nominally on external debt, that debt was entirely secured by domestic bonds, which bore the brunt of the Crown's insolvency.[50] Since the empirical evidence points to an end of the Dutch disease episode at around 1575, the bankruptcy of that year could very well be the source of the negative change in agents' wealth.

A further robustness test is allowed by the heterogeneity of the price data across the different regions. The baskets I used, while based on the same fundamental weights, vary substantially across regions, reflecting the surviving price series in each case. These differences are particularly noticeable in the case of non-traded goods. Additionally, each region was very likely subject to idiosyncratic shocks, which did not transfer to the others. Since the timing and magnitude of the increase in the relative price of non-traded goods is consistent across regions despite the variation in the baskets and possible idiosyncratic shocks, the scale is further tipped towards a large common external event as the source of the appreciation.

6. Calibration

A real exchange rate appreciation can be a strong indicator of the presence of Dutch Disease once alternative explanations have been ruled out. The magnitude of the decline in the output of traded goods, however, cannot be inferred from the variation in relative prices alone. Here I offer a glimpse into the quantitative implications of the model by performing a calibration exercise.

Calibrating a general equilibrium model to an Early Modern economy poses significant challenges, most of which will severely limit the ability to obtain useful predictions from such an exercise. The only accurate data are the prices and consumption baskets that have already been presented. Indications of wages and rental rates of capital are scant and questionable at best; factor shares and productivity parameters can only be guessed at; output, capital stock, and trade pose even greater problems, as the modern definitions of those terms become blurred in economies with substantial non-market components. Any results should clearly be taken

[48] See Perez Moreda (1994).
[49] See, for example, Elliott (1961, pp. 125 and 304).
[50] See, for example, Marcos Martín (2000, p. 443), Tortella and Comín (2001, p. 149).

Table 5
Calibration results

Parameters		Variables	$s = 0$	$s = .1$	$s = .25$	$s = .5$
α	0.800	Y^{T}	0.555	0.530	0.494	0.435
η	0.800	Y^{NT}	0.372	0.396	0.431	0.485
γ	0.666	C^{T}	0.740	0.810	0.916	1.095
Z^{T}	1.000	C^{NT}	0.372	0.396	0.431	0.485
Z^{NT}	1.000	N^{T}	0.479	0.452	0.414	0.353
K^{T}	1.000	N^{NT}	0.321	0.348	0.386	0.447
K^{NT}	0.671	p	1.000	1.028	1.068	1.136
$\bar{N}$	1.000	w	0.927	0.938	0.954	0.985
N^{G}	0.200	r^{T}	0.111	0.106	0.099	0.087
		r^{NT}	0.111	0.121	0.137	0.164
		C^{T}/C^{NT}	1.990	2.045	2.126	2.259

in a suggestive tone only; the most one can aspire to show is that the model does not conflict with large reductions in the output of traded goods for a broad range of parameter values.

Table 5 reports the results of the calibration procedure described in the Appendix. I first solved the model for the benchmark case of no resource revenue, found in the column labeled $s = 0$, and then for $s = .1$, $s = .25$, and $s = .5$, where s is the perceived value of the natural resource windfall, expressed as a percentage of total output. The values of p for each level of s reveal the real appreciation induced by the windfall. When $s = .5$, for example, the corresponding value of $p = 1.136$ indicates an appreciation of 13.6% over the benchmark value of $p = 1$.

Recall that the observed real exchange rate appreciations for the different regions, as obtained from the econometric model estimates, range between 5.3 and 14.2%. According to the results in Table 5, an appreciation of 6.8% would require the magnitude of the natural resource windfall to be perceived by decision makers as 25% of total output. A 13.6% appreciation would likewise imply a resource revenue stream estimated by agents at 50% of domestic product, always in present value terms. If one were to accept the calibration exercise at face value, relative price movements of the magnitudes revealed by the data would imply that economic agents considered the mineral resource discoveries as a very large increase in their wealth.

Turning to the changes in output, a silver windfall valued by agents at 25% of initial output would cause a decline in production of traded goods from the benchmark value of .555 to a level of .494, a fall of 11%. If the windfall were valuated at 50% of initial (total) output, the decline in production of traded goods would amount to 21.6% of the benchmark level. These declines in traded output are certainly large and substantial, and yet not as large to arouse suspicions over the validity of the theoretical framework.

Of course, taking the calibration exercise at face value is not an option, as its results rest on a large number of assumptions, and on matching parameter values to data of varying accuracy. What should be gleaned from it is that, for a reasonable range of parameter values, the theoretical framework implies that the possibility of large perceived resource windfalls and consequent large declines in the production of traded goods cannot be rejected. I offer it as an additional piece of evidence pointing towards the importance of the mineral resource discoveries in Early Modern Spain.

7. Conclusions

Soon after completing its reunification under Ferdinand and Isabella in 1492, Spain embarked on a thoroughly expansionist program, as reflected in the ever increasing size of the Spanish government under Charles V and Philip II, and its pervasiveness through all aspects of economic life.[51] The already indebted crown resorted to creative finance, leveraging the expected revenues from the Indies to assemble powerful armies and fleets with which to project its power over the known world and be the first to reach the yet unknown. Fueled by American treasure, this drive dwarfed any other factors that might explain the movements of the real exchange rate in the second half of the 16th century, which confirm that both Crown and private individuals expected increasing revenues, either from American mines or from military conquest. Large demographic changes or monetary disturbances, the main contenders when it comes to persistent changes in the real exchange rate, came too late to have any possible impact.

Spain's rosy expectations were not to be. Military defeats and dwindling profitability in the colonies soon put the government's budget on an unsustainable deficit spiral; when the Crown was first forced to default on domestically held debt in 1575, it became clear that the resources available to Spain would not suffice to sustain her expansion in any case. Individual income dropped sharply, causing a corresponding depreciation in the real exchange rate. The synchronization between imports of bullion, bankruptcies, and the persistent increase in the relative price of non-traded goods strongly support the Dutch disease hypothesis.

Although the real exchange rate series appear to reflect strong changes in the value of treasure flows, two fundamental questions remain unanswered. What was the magnitude of the effect of the Dutch disease on Spanish trade? And how did it impact the Spanish economy as a whole?

The price indexes can only reveal the presence of Dutch disease; one would need detailed trade statistics to quantify its impact on trade both during and after the silver boom. We do have two crucial pieces of evidence, however. The first one is the actual size of the real exchange rate movements. The 11% appreciation in New Castile and 14.2% appreciation in Valencia, while not enormous, are both substantial magnitudes and, crucially, they are persistent enough to rule out the possibility of a statistical artifact. The second piece of evidence, the reversal in the direction of the flow of traded goods, buttresses the case for a loss of competitiveness in those industries which were once the pride of Spanish trade. In the early 17th century, for example, as part of a pervasive decline in many traded goods sectors, Spain lost

[51] Ulloa (1977), the classic account on the finances of Philip II, is an excellent source on the impact of taxes and public debt on the economy of the kingdom.

its iron exports to Scandinavia and its textile exports to England; both these regions held onto their newly found comparative advantages, and eventually capitalized on them during their industrializations.

Assessing the overall impact of the Dutch disease on the Spanish economy is a subtler task. One could argue that trade represented a sufficiently small part of Spain's national income and that its effects on the economy as a whole can safely be ignored. While this may be true from a static perspective, it ignores the dynamic effects of specialization on economic growth. In the early modern age, what little growth economies experienced was probably coming from their expanding trade. Traded goods industries (and trade itself) fostered the specialization and division of labor that could lead to productivity increases and human capital accumulation, as the rise to prominence of the Low Countries exemplifies. The calibration of the model suggests that traded goods output could have been reduced by between 10 and 20% for a period of over 25 years; such a shift in production could hardly have been beneficial once the economy had to adjust to its post-boom reality.

It is worth remembering that the Dutch disease is not the only mechanism through which American silver might have become a curse for Spain. Natural resource windfalls have been shown to encourage rent seeking, and to discourage the accumulation of human capital. Both these phenomena can persist long after the natural resources are exhausted, becoming a lasting negative legacy spurred by a short-term blessing. While here I have focused exclusively on the trade and exchange rate effects of the natural resource windfall, there is surely a much richer picture to be painted on the subject of fiscal and institutional consequences of the silver discoveries.

Scholars and conventional wisdom alike have long set the death of Philip II in 1598 as the beginning of Spain's long decline. Contemporary writers, however, were well aware that something in the inner workings of the empire had been wrong since much earlier. Writing in 1600, Gonzalez de Cellorigo looked at what he saw as the main reason for the already apparent downturn in the fate of the kingdom: "Our Spain has set her eyes so strongly on the business of the Indies, from where she obtains gold and silver, that she has forsaken the care of her own kingdoms; and if she could indeed command all the gold and silver that her nationals keep discovering in the new world, this would not render her as rich and powerful as she would have otherwise been."[52]

Appendix. Calibrating the model

The general equilibrium model presented in the text can be written as the following system of eight equations:

$$\frac{1-\gamma}{\gamma}\frac{C^{\mathrm{T}}}{C^{\mathrm{NT}}}-p=0, \tag{A.1}$$

[52] Gonzalez de Cellorigo (1991, p. 50). The translation is my own.

$$N^{\mathrm{T}} + N^{\mathrm{NT}} - \left(\bar{N} - N^{G}\right) = 0, \tag{A.2}$$

$$Y^{\mathrm{NT}} - C^{\mathrm{NT}} = 0, \tag{A.3}$$

$$Y^{\mathrm{T}} + pY^{\mathrm{NT}} + wN^{G} + (1-\tau)s - C^{\mathrm{T}} - pC^{\mathrm{NT}} = 0, \tag{A.4}$$

$$p\eta Z^{\mathrm{NT}}(K^{\mathrm{NT}})^{1-\eta}(N^{\mathrm{NT}})^{\eta-1} - w = 0, \tag{A.5}$$

$$Z^{\mathrm{NT}}(K^{\mathrm{NT}})^{1-\eta}(N^{\mathrm{NT}})^{\eta} - Y^{\mathrm{NT}} = 0, \tag{A.6}$$

$$\alpha Z^{\mathrm{T}}(K^{\mathrm{T}})^{1-\alpha}(N^{\mathrm{T}})^{\alpha-1} - w = 0, \tag{A.7}$$

$$Z^{\mathrm{T}}(K^{\mathrm{T}})^{1-\alpha}(N^{\mathrm{T}})^{\alpha} - Y^{\mathrm{T}} = 0. \tag{A.8}$$

The first step is to determine which of the magnitudes involved in the model will be used as the eight endogenous variables, and which ones will be treated as parameters. I will treat C^{T}, C^{NT}, N^{T}, N^{NT}, Y^{T}, Y^{NT}, p, and w as variables, while α, η, γ, Z^{T}, Z^{NT}, K^{T}, K^{NT}, $\bar{N}$, N^{G}, and $(1-\tau)s$ will be the parameters. The next step is to manipulate Eqs. (A.1)–(A.8) into a form that will allow for solving the model numerically in terms of the parameters. Dividing (A.5) by (A.6) yields

$$w = p\eta \frac{Y^{\mathrm{NT}}}{N^{\mathrm{NT}}}. \tag{A.9}$$

Similarly, dividing (A.7) by (A.8)

$$w = \alpha \frac{Y^{\mathrm{T}}}{N^{\mathrm{T}}}. \tag{A.10}$$

And combining (A.9) and (A.10)

$$pY^{\mathrm{NT}} = \frac{\alpha}{\eta}\frac{Y^{\mathrm{T}}}{N^{\mathrm{T}}}N^{\mathrm{NT}}. \tag{A.11}$$

Using Eqs. (A.1)–(A.3), (A.10), and (A.11) to replace the appropriate variables into the budget constraint (A.4) yields, after some straightforward manipulation

$$\begin{aligned}&(N^{\mathrm{T}})^{\alpha}Z^{\mathrm{T}}(K^{\mathrm{T}})^{1-\alpha}\left[1 + \frac{\gamma}{1-\gamma}\frac{\alpha}{\eta}\right]\\ &\quad + (N^{\mathrm{T}})^{\alpha-1}Z^{\mathrm{T}}(K^{\mathrm{T}})^{1-\alpha}\left[\alpha N^{G} - \frac{\gamma}{1-\gamma}\frac{\alpha}{\eta}(\bar{N} - N^{G})\right] + (1-\tau)s = 0.\end{aligned} \tag{A.12}$$

Eq. (A.12) is a polynomial in N^{T}, all the other magnitudes being parameters. The roots of the polynomial that belong in the interval $[0, (\bar{N} - N^{G})]$ are the equilibrium values of N^{T}. The roots of Eq. (A.12) can be found by numerical methods and used in conjunction with Eqs. (A.1), (A.2), (A.5)–(A.8) to find the equilibrium values for the remaining variables.

To calibrate the model, it is necessary to introduce the equations for the rental rate of capital in each sector:

$$(1-\alpha)Z^{\mathrm{T}}(K^{\mathrm{T}})^{-\alpha}(N^{\mathrm{T}})^{\alpha} = r^{\mathrm{T}}, \tag{A.13}$$

$$p(1-\eta)Z^{\mathrm{NT}}(K^{\mathrm{NT}})^{-\eta}(N^{\mathrm{NT}})^{\eta} = r^{\mathrm{NT}}. \tag{A.14}$$

Combining (A.13) and (A.14) with (A.5) and (A.7) yields:

$$K^{\mathrm{T}} = \frac{1-\alpha}{\alpha}\frac{w}{r^{\mathrm{T}}}N^{\mathrm{T}}, \tag{A.15}$$

$$K^{\mathrm{NT}} = \frac{1-\eta}{\eta}\frac{w}{r^{\mathrm{NT}}}N^{\mathrm{NT}}. \tag{A.16}$$

The calibration procedure involves the following steps:

(i) Set the initial value of p to 1; use the ratio $C^{\mathrm{T}}/C^{\mathrm{NT}} = 1.9897$ obtained from the consumption baskets to calculate the value $\gamma = .666$ from Eq. (A.1). Set the tax rate τ to 0.2 (the "royal fifth"). Normalize $\bar{N}$ to 1, and set N^{G} to .2 following Nadal's estimate of 12% for the number of idle *hidalgos* and augmenting it for members of the military and clergy.[53]

(ii) The only parameter values that remain undetermined are the shares of labor; to calibrate them, evaluate the expressions for the rental rate of capital and focus on those values of α and η that imply rental rates in the neighborhood of prevailing interest rates. A consistent feature of the model is that the share of labor in production needs to be set fairly high (in the neighborhood of .8) in both sectors, as lower labor shares result in rental rates of capital too elevated to be plausible. The results reported in Table 5, which are typical of the parameter range that yields plausible rental rates, use $\alpha = \eta = .8$ and imply a rental rate of capital of 11%, which lies between the typical rates of 7 and 14% used in most forms of government financing.

(iii) Assume that in the initial equilibrium $r^{\mathrm{T}} = r^{\mathrm{NT}}$ and set guesses of $w/r = 1$ and $N^{\mathrm{T}}/N^{\mathrm{NT}} = C^{\mathrm{T}}/C^{\mathrm{NT}}$. Eqs. (A.15) and (A.16) can then be used to calculate K^{T} and K^{NT}.[54]

(iv) Normalize $Z^{\mathrm{T}} = 1$. Recalling that $p = 1$, use Eqs. (A.13) and (A.14) to calculate the value of Z^{NT}.

(v) Using the initial guesses and the calibrated parameter values, calculate the equilibrium values of the model variables by solving Eqs. (A.1), (A.2), (A.5)–(A.8), (A.12). Use the resulting values of w, r, N^{T}, and N^{NT} as new initial guesses for w/r and N^{T}/N^{NT}. Iterate steps (iii) through (v) until convergence.

[53] Nadal (2001, pp. 37–43).

[54] The assumption $r^{\mathrm{T}} = r^{\mathrm{NT}}$ can be rationalized by thinking of capital as being difficult to move across sector rather than strictly sector-specific. In a long-run equilibrium, therefore, the rental rates of capital will be equal, but in the short-run they may well differ.

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