Série des Documents de Travail

n° 2019-14

The Primary Cause of European Inflation in 1500-1700: Precious Metals or Population? The English Evidence

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The Primary Cause of European Inflation in 1500-1700: Precious Metals or Population? The English Evidence[a]

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September 2019

Abstract

We perform the first econometric test to date of the influences of inflows of precious metals and population growth on the *"Great Inflation"* in Europe following the discovery of the New World. The English evidence strongly supports the near-equivalent importance of both influences. For 1500-1700, silver is the only relevant precious metal in the estimates. The study controls for urbanization, government spending, mortality crises and climatic changes. The series for inflows of the precious metals into Europe from America and European mining are newly constructed based on the secondary sources.

JEL classification: *E31, F00, J10, N13, N33*

Keywords: *The "Great Inflation," Demography, Precious metals, European economic history 1500-1700*

[a] Warm thanks to Enzo Dia, Michel Fouquin, Valerie Mignon, and Farid Toubal for valuable comments.
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1. Introduction

There is an enduring controversy about the causes of the European inflation following the discovery of the Americas. Was the inflation primarily the result of the inflow of precious metals or population growth (e.g., Mayhew 1995, p. 238)? To economists and a good many historians, the primary importance of the inflows of precious metals from the New World seems almost obvious. But the main tendency among historians is to favor the alternative explanation: population growth. The leading argument is that the emphasis on precious metals poses a fundamental problem of timing. European inflation began in the 1530s or 1540s while the inflows of the metals from the New World became heavy only in the 1550s. In addition, the inflows of the metals continued to climb rapidly from 1550 to 1700, whereas European inflation abated and ceased in 1660-1700. On the other hand, population growth moved in sync with inflation throughout 1500-1700. Exogenous factors like absence of epidemics and long spells of good weather led to growth of population beyond the ability of agricultural output to keep pace during the inflationary period, 1530-1660. Consequently, agricultural prices rose and inflation followed as people sacrificed real money stocks in order to limit the reduction of their consumption of the necessities and conveniences of life (e.g., Brenner 1961, 1962, pp. 281-4; Goldstone 1984, pp. 1152-3, 1988, pp. 107-10; 1991a, pp. 84-85; Fischer 1996, pp. 18-9, 75, 109). As early as 1972, Chambers wrote: "the price revolution of the 16th century, which used to be fathered on the import of bullion to Spanish ports, is now firmly placed on the doorstep of a demographic boom" (p. 27). The economic historians who nevertheless retain one foot firmly planted in the monetarist camp repost that it is wrong to focus exclusively on the arrivals of precious metals from the Americas. There was also a sharp rise in silver mining in Europe in the 1470s that only trailed off once the inflows from the New World began to swamp the market in the first half of the sixteenth century. In view of this proper chronology, one prominent economic historian, Munro (1999, p. 5), writes: "The interesting question [is] not why did it [the Price Revolution] occur so early… but rather why so late." This stalemate will never be resolved without some multivariate statistical analysis, which only became possible recently.

The opportunity for such analysis came with the publication of Broadberry et al.'s (2015) *British Economic Growth 1270-1870*, the fruit of a long labor of research, building on predecessors' and the authors' own earlier work. We now dispose annual series for England for population, gross domestic output, and the price level of output, going from

1270 to 1870. The only critical series missing from the database (which is now available computer-ready on the Bank of England website) to go forward with an investigation concerns aggregate inflows of the precious metals into Europe. We do have annual averages for the 8 quarter-centuries in 1500-1700 for the part of these inflows coming from the New World owing to Barrett (1990). His adjusted numbers receive repeated mention and command wide respect. As regards the rest of the inflow, coming from European mining, we also have a quinquennial series from Munro (2003, Table 1.3, pp. 8-9) for silver production from the major mines from 1470 to 1550 (except for the Serbian contribution), that is, the outstanding period of silver mining in Europe since the early middle ages and even before. But we lack a continuous series for the silver and gold extracted from European mines for the whole of 1500-1700. Notwithstanding, one can piece together such a series with some interpolation from Blanchard (1989, 2001, 2005) and the use of others' work, at least for comparison. Thus, it is now possible to construct the needed series for precious metals to investigate the role played by population and precious metals in shaping price formation in England. Few would doubt the relevance for the rest of Europe.

The results are striking. Precious metals and population both matter separately and jointly. Their effects on inflation follow after controlling for joint effects of output, urbanization, government spending, unusually high death rates, and climatic changes. With the exception of output, these other factors do not even much alter the positive effects of precious metals and population. At least two of these four additional controls besides output – urbanization and government spending – are also jointly significant with the right signs – right on the basis of the leanings of historians in the case of urbanization, on the basis of theory in the case of government spending.

For the 1500-1700 period in question, these conclusions apply to the inflow of silver alone. The inflow of gold is insignificant and adding gold to silver yields an aggregate for inflows of precious metals whose significance depends entirely on the silver component. It seems therefore that the superior ability of silver to deal with small transactions if sufficiently alloyed with base metals is essential in analyzing inflation for the period. Gold's advantage over silver is too limited to large transactions. This important result harmonizes with the predominant stress on silver in the literature on the 16th century "Great Inflation". But we will come back to the issue in the closing section, where gold will emerge as jointly significant with silver if the study period starts earlier, for reasons we will explore. Another arresting result is that while the flow of silver from the New World is highly significant by itself, in accordance with the views of many, the aggregate inflow of silver inclusive of the European contribution is unambiguously superior. This evidently supports Munro's preceding observation about the timing of the effects of inflows of silver on the price level and inflation. The newly constructed series for inflows of gold and silver into Europe from the Americas and its own mines is itself a contribution.

We will begin with a theoretical model of inflation containing no other influences but the precious metals and population. Soon we will add output as a third influence. Next, we will explain the construction of the precious metal series. Following, we will discuss the profile of the major time series. Then we will proceed to the tests and test results. There will follow a section incorporating other variables or controls into the tests. A general discussion, containing some added evidence, will close the paper.

2. The core model

Historians typically open the discussion with the Fisher equation, $MV = PT$, where M is the money stock expressed in the unit of account, V is the transactions velocity of money, P is the price level and T is the level of real transactions. Alternatively, they start with a different form of the Fisher equation, $MV_Y = PO$, where V_Y is the income velocity of money and O is real output. However, in both forms, the equation is an identity. In the first one, V and T are defined jointly to assure the equality, and in the second, V_Y must simply equal PO/M. Yet we find it difficult to reason about empirical behavior based on an identity,[1] and therefore prefer to begin with the related Cambridge equation:

$$M = kPO \qquad (1)$$

which is an equilibrium condition. k is the desired ratio of M to PO and M can be greater or less than kPO since excess demand or supply of money is possible.

Let us restate equation (1) with the P term on the left and next in logs:

[1] This is not to contest the contribution of earlier studies of the circulation of money to knowledge. Not at all; they provide much valuable information about the market uses of money. Yet they cannot yield the V or V_Y of the Fisher equation and therefore cannot serve to determine P.

$$P = M/kO \tag{2}$$

$$lP = lM - lk - lO \tag{3}$$

In terms of growth rates, equation (3) is

$$\frac{dlP}{dt} = \frac{dlM}{dt} - \frac{dlk}{dt} - \frac{dlO}{dt} \tag{4}$$

M in these equations depends partly upon P, since money, however defined, was not under official control at the times, and the various producers of the nominal money stock, including the political powers, responded to an exogenous change in its value, $1/P$, based on their own budgetary or private concerns. In addition, any anticipated inflation lowered desired real money balances, then as now. Thus, it would lower k too. Suppose next, if only for the moment, that both population and precious metals are truly exogenous influences on P. If so, according to the model, they must affect M, k or O or a combination of the three. Let us then rewrite equations (3) and (4) as (5) and (6):

$$lP = f(lpop, lpm) \tag{5}$$

$$\frac{dlP}{dt} = f\left(\frac{dlpop}{dt}, \frac{dlpm}{dt}\right) \tag{6}$$

$lpop$ for log of population, lpm for log of precious metals, both silver and gold arriving in Europe stated in silver equivalents, $dlpop/dt$ and $dlpm/dt$ for the respective growth rates of population and precious metals.

Next, we will consider the justification for equation (5). Once this is done, equation (6) will follow. Previous discussion has never proceeded beyond equation (5) despite concern with inflation. This is understandable since price levels rose around 4-fold or more everywhere in Europe in 1530-1660, an impressive number, whereas annual rates of inflation were no higher than, say, around 1.25 percent (about 1.1 percent in England) and therefore difficult to analyze. Quite relevantly too, despite the low annual rates of inflation ("creeping inflation," we would say today), contemporaries clearly felt themselves to be living in inflationary times. The famed Bodin-Malesdroit controversy of the late 1560's over the sources of the European inflation is ample testimony (see also, e. g., Ramsey 1971, pp. 3-5).

The justification for equation (5) raises a number of fundamental questions: Why are population and precious metals both causal influences on *P*? What are their effects on inflation? Why is it plausible to assume they are exogenous? And in so far as exogeneity is disputable, what can be done about it?

Let us consider population first. In its case, the sign of the causal effect and the issue of exogeneity (or reciprocal influence) are intimately related. If population rises predominantly from exogenous sources, that is, independently of the state of the economy, then the rises will tend to increase the demand and, via the production function, the supply of agricultural goods. Suppose also, as historians maintain, that in 1500-1700, the demand usually outpaced the supply and therefore agricultural prices rose. Given inelastic demand for food and the importance of food in family budgets, the general price level, inclusive of all goods, would go up, since people would sacrifice some liquidity in order to maintain consumption. In terms of the Cambridge equations (1) and (3), *k* would fall and *P* would rise. On the other hand, if, as current population theory would say, population depends on the economy and changes in population come essentially from economic forces, the situation differs substantially. Money wages tend to lag behind money prices. Thus, a rise in *P* stemming from economic forces outside the labor market would lower real wages and, for the well-known Malthusian reasons, lower population in sufficient time. Population would then be negatively related to *P*. As Lee (1973, 1985) had emphasized before us, the issue turns on the sources of the shocks affecting population (see also Chambers 1972).

On this matter, the historians' stress on demographic shocks coming from outside the economic system has considerable conviction. The evidence shows a high positive correlation between population and *P*, which agrees with exogenous rather than endogenous population on previous reasoning. Very significantly too, the exogeneity has important foundations. Before 19th century advances in medicine, strong forces impinged on population size via death rates and even birth rates stemming from epidemics and weather conditions (see Hatcher 1977, pp. 68-73; Wrigley and Schofield 1989, pp. 353-5). Higher temperatures favor agricultural output under European climates, and therefore population growth. A long secular trend of favorable weather and low epidemics would then lead to excess demand for goods on previous grounds. The argument for a positive sign of *lpop* in equation (5) thus looks reasonable. Notwithstanding, we cannot simply assume away the market forces acting on population as well. The simplest way to control for reverse influence or endogeneity in time series analysis is to introduce lags. Earlier population levels will depend less on current P than the current population level. In the case at hand, the relevant theoretical reasoning would also justify lags independently: diseases and weather conditions need time to affect death and birth rates and further time before population changes can affect agricultural prices and P. On both counts, we will lag population in subsequent estimating equations.

Consider the precious metals next. In this case, the sign of influence is clearly positive. There are two channels through which inflows into Europe would raise the supply relative to the demand for money in England, or the ratio M/k, and thereby have a negative effect on the value of English money or a positive one on P. One is the balance of payments. Inflows of precious metals into Europe would raise prices near the points of entry (as well documented by Hamilton 1934 for early-16th-century Spain), spread out from there, and thereby afford England a competitive advantage, leading to a balance-of-payments surplus and an inflow of precious metals into the country. The other channel is commodity market integration. Such integration would cause English commodity prices to respond directly to changes in continental European ones without any movement of precious metals. In this last case, P times O would rise in England in response to the rise in continental European prices, lower the ratio of M/PO below the equilibrium value k and thus raise the required ratio M/k in equilibrium. The decomposition of the rise between M and k would depend partly on the definition of M and matter little. The early discussion in the literature focused largely on the Ricardian channel of influence (see, e.g., Ramsey 1971, p. 7; Hammarström 1957, p. 49; Brenner 1962, pp. 273-4). But there has been mounting attention, if indirect, to the channel of price integration in markets for exported and import-competitive goods in recent decades (typically under the heading of the "monetary approach to the balance of payments," a model that combines both channels (see Flynn 1978 and Fisher 1989)).

The fact that England was a small country of 2.2 million people on the periphery of Europe in the early 16th century ("an agrarian periphery," says Allen 2003, p. 403) should cast no doubt on the possible significance of the two previous channels of influence. After all, England was already the major exporter of quality wool to the rest of Europe in the preceding century and correspondingly a large importer of gold and silver coins from the rest of Europe at that time (Lane 1984, p 39; Spufford 1988, pp. 388-9). Already in the second half of the 12th century the region of Carlisle, near the Scottish border, was the single biggest mining center in all of Europe. Its annual output reached a peak of 25 tonnes around 1165 (Blanchard 2005, p. 923; 2001, chapter 2), a level never exceeded in Europe as a whole for around three centuries, or until the mid-1400s. Plainly the bulk of this English silver spread out to the rest of Europe and further east, proof of significant market integration. Blanchard (2001, p. 904) provides an interesting world map of flows of tin in Eurasia in the 13th century, showing that the markets for the metal were surprisingly integrated from the English coast as far east as China and Southeast Asia.[2]

As regards the issue of exogeneity, this is precisely the concern that led us to choose the arrival of precious metals from the Americas in Spain or from European mines as the basic monetary influence and to stick to this choice rather than try to draw closer to some measure of English money. As already underlined, English money M, the English price level P, and English output O, were all reciprocally related at the time. Yet the arrival of precious metals into Europe was essentially independent of all three. Given our choice of monetary influence, exogeneity is not the issue so much as the *measure* of the exogenous inflows. One question is whether to include the part of the inflows that flowed right out of Europe to the East. We believe that including this part is correct. The part that transited through Europe out East would have stayed in Europe under the right European conditions, to which England contributed. On parallel reasoning, we exclude the inflow of African gold as irrelevant. Europe would often turn to Africa for gold when it had an excess demand for gold and otherwise would reduce its imports from Africa (i.e., Spufford 1987, pp. 826-7, 1988, pp. 163-86). There were also no major supply shocks in African mining. It would thus seem difficult to treat the African gold inflow as exogenous.

These assumptions about the measure of the exogenous inflows are admittedly imperfect. When Portugal established itself on the Gold Coast in the second half of the 15th century and progressively disrupted the flow of African gold via the desert route toward Europe and the Levant, it probably produced an exogenous shock on the gold flow into Europe operating well into the 16th century (see Vilar 1974, p. 62; Day 1978, pp. 36-

[2] While the English silver mines were exhausted by the middle of the 13th century, Blanchard (1978) points out that England remained a leading factor in the European metallurgical industry up through the year 1800 in the production of a variety of other metals: iron, lead, tin, zinc and copper.

39; Bakewell 1997, pp. XIII-XIV; Munro 2003, pp. 6-7). Note, however, on this score, that the total flow of African gold via Portuguese hands was never large. Estimates range to a maximum of one tonne annually at the peak in the late 15th century (Garrard 1980, chs. 1-5, Curtin 1983, Wilks 1997, pp. 4-5, 25, Munro 2003, p. 6). As concerns the inflows of precious metals into Europe stemming from its own mines, doubts may also arise. The extraction from known mines varied with profit opportunities. Poorer ores would be mined and abandoned mines would be reopened when profitable. In this next regard, we take comfort in the fact that England mined no gold or silver during the relevant period (though it did mine other metals, as mentioned in note 2) despite intense prospecting at times. We would be less prone to assume exogeneity for all of mining output of precious metals for Germany, Hungary or Serbia.[3]

Two basic points remain. First, arrivals of precious metals from the Americas into Spain and from mining within Europe could only affect the English price level with a time lag, regardless whether the impact came via the Ricardian channel or via price integration in European markets. Thus, we will introduce such a lag in our estimating equations (quite apart from any concern with endogeneity, as in the case of population). Next, it seems right to admit current English output, O, as an influence on P, from the start. As matters stand in equations (5) and (6), the only influence of O on P comes via population and thus labor. But capital accumulation and the reallocation of land from unexploited to productive or more productive uses based on relative prices also took place. Technological improvements mattered too over 1500-1700.

The theoretical sign for the impact of exogenous changes in output on the price level, which comes from the supply side, is clearly negative: Higher O leads to lower P. But since it also breeds population (with a considerable lag), in O's presence, the effect of population on output prices is more clearly a demand one and raises P. As regards the timing of the impact of O, we expect no annual lag. Our proposed estimation forms for

[3] To go further, since the prospecting for precious metals in Europe was also endogenous, the probability of discoveries was likely to be so too. Of some note as well, Lindert (1985) objects to any treatment of the inflows of precious metals, like ours, as a solution to the problem of the endogeneity of money on the ground that "not all gold and silver became money; and the outflow of silver to the east was also probably large" (p. 629). Evidently, this objection assumes that the problem is to identify an exogenous *component* of the money stock in England rather than an exogenous influence on it. On the other hand, Lindert has a valid point when he objects (same passage) that "European profiteers also imported large volumes of precious metals." The illegal inflows from the New World by "profiteers" to avoid taxes do belong in any proper measure of the exogenous variable and they will do so in ours, as became possible since Morineau's (1985) contribution appearing the same year as Lindert's article.

equations (5) and (6) (revised to include O) follow:

$$lP_t = \alpha_0 + \alpha_1 lpop_{t-n} + \alpha_2 lpm_{t-n} + \alpha_3 lO_t + \varepsilon_t \tag{7}$$

$$\frac{dP_t}{P_t} = \beta_0 + \beta_1 \frac{dpop_{t-n}}{pop_{t-n}} + \beta_2 \frac{dpm_{t-n}}{pm_{t-n}} + \beta_3 \frac{dO_t}{O_t} + \mu_t \tag{8}$$

The α and β terms are coefficients; α_1 and β_1 are expected to be positive, α_2 and β_2 are expected to be positive, and α_3 and β_3 are expected to be negative; the subscripts t are time indices; the t-n subscript denotes a time lag of n duration; the assumption that this lag is equal for population and precious metals (same n) is a simplification. μ_t and ε_t are disturbance terms with the usual statistical properties: zero average, constant variance, and no autocorrelation in time.

Before proceeding, further clarification of the reasons for our choice of specification is probably desirable. M today consists of assets of constant nominal price, so that as long as we identify the monetary assets (coin, bills, and specific sorts of deposits) we can sum up an aggregate for money without attention to relative values or weights. The rate of inflation or deflation of our general index of goods prices will apply equally to our money aggregate, however defined. None of this is true for the relevant times. The relative prices of coins varied with wear, clipping, weight, metallic composition, variations in the prices of the composite metals and government recoinages and revaluations. Uncoined bars and ingots of precious metals in various shapes and weights and various promissory notes also frequently served as media of exchange.[4] Nonetheless, the price level P can be defined for the period in the same way as it is today, independently of any changes in relative prices of different monetary assets: namely, as the accounting value of an array of agricultural and manufacturing goods and services relative to the accounting value of the array in a base year (1700). Broadberry et al. (2015) made this possible, which necessarily required them to take into consideration variations in the unit of account over the period, the pound. Therefore, the rate of inflation or devaluation of money, as drawn from them, applies correctly only to an aggregate of monetary assets with

[4] There is notwithstanding a long line of efforts to construct time series for English money, in full cognizance of these issues. For the latest such effort and bibliography, see Palma (2018).

different weights at all dates and varying with the types of assets included.[5]

On the other hand, inflows of precious metals are measurable in tonnes. The only element of price that intrudes in their measure comes when silver and gold are mixed together and we must employ the exchange rate between the two metals to define a sum of silver-equivalent tonnes. Furthermore, using these inflows as the basic monetary influence does not require any choice of one definition of money or another. All inflows of precious metals into Europe will affect the respective prices of silver and gold in terms of other goods on the continent to a similar extent in the same direction whatever the respective composition of the two metals between jewelry, silverware (gold ware), building ornaments, bullion and coin. Accordingly, the impact of the influence on P in England could be the same regardless of the composition of the inflow of the precious metals into the country, and assuming the independence of English O, the Cambridge equation will yield the associated level of M/k in equilibrium (with the separate influence on M or k or both depending partly on the choice of definition of money). Thus, the extent of coinage of gold and silver and the devaluations of specific coins in England need not be crucial in determining P. These considerations underlie our preference for precious metals over M apart from issues of endogeneity. Yet if there are exogenous influences on the excess supply of English money affecting P independently of *lpop*, *lpm* and O, there are some missing variables in the core model and we will need to repair the problem subsequently.

3. Data and Descriptive Statistics

3.1 The series for precious metals

Our construction of the time series for silver and gold inflows needs special attention next. Concerning the inflows from the Americas, we rely on Barrett (1990). After examining previous sources closely, Barrett chose Humboldt's (1811) numbers for his 8 quarter-century annual-average figures for production from American mines. As concerns arrivals of this output in Europe, his preferred source was Morineau (1985). However, Morineau's figures only begin in the 1560s, and therefore he needed to rest his 3 figures for 1501-1575 differently. In this case, he decided to return to Humboldt's production figures and simply deduct a certain percentage for "retentions and losses". His chosen percentage deduction was 15%, on the lower end of his estimate range. However,

[5] The alternative would have been to start from a set composition of money and then allow the rate of inflation to vary depending on the definition of money. See a related passage in Gould 1964, pp. 257-9.

the deduction is too small since it yields a figure for arrivals in 1551-1575 that is no lower than the one in 1576-1600, which would imply no rise from the third to the fourth quarter whereas Humboldt shows output rising by 17% from l551-1575 to 1576-1600. We also know independently that inflows rose in 1576-1600. In addition, Morineau's figures for arrivals in the 5 succeeding quarter-centuries, for 1576-1700, are never as little as 15% lower than Humboldt's production figures but steadily 25-30% so. Conservatively, therefore, we retained 20% for "retention and losses" for the first 3 quarter-centuries, 1501-1575 (well within Barrett's guesstimates),[6] which resolves the problem.

In addition, Humboldt's production figures omit the arrival of booty into Spain from the successive Aztec and Incan conquests in the first half-century. For this booty, which consisted essentially of gold, estimates come from Bakewell (1984, pp. 141-3, and 1997, pp. XIII-XV). Bakewell provides figures for 1531-1550, which we extrapolated back to 1500-1530.

All of Barrett's numbers (Table 3, pp. 242-43) combine gold in units of silver with silver as such. For our purposes, we needed separate estimates for the two metals. In this case, we turned to Table 2 in Barrett (pp. 228-29) providing figures extracted from Morineau for annual-average percentage gold inflows into Spain over the 16th and 17th centuries. For the 16th century, the figure is 18%; for the 17th it is 8%. Yet we could not simply assign these two figures evenly to each quarter in the two respective centuries. As regards the 16th century, facts show that the early entries from the New World until the late 30's consisted predominantly of gold; silver only took over later. Therefore we must start with high figures for the gold inflows in the first two quarters and let the inflows fall off sharply in the last two. Still the early figures for gold cannot exceed the preset quarter-century sums for gold plus silver in the 16th century while they also need to add up to 18% for the century as a whole. The 18% figure turns out to be high because the inflows of silver tripled from the second quarter to the fourth one while the gold arrivals fell off from their mid-16th century levels. Consequently, we had remarkably little room for discretion.

For the 17th century, the problem is different, less important, but more stubborn. The first quarter of the 17th century saw an upward jump in the arrivals of gold because of a revival of production in the Americas, especially in New Granada (Blanchard 1989, pp. 25, 53). Significantly too, the price of gold rose in this quarter-century relative to

[6] These "retentions and losses" notably contain shipments to the Indies, the Far East and China via the Pacific and, specifically, via Manilla after 1571.

silver. By contrast, in the last 3 quarters of the century, American mines yielded declining outputs of gold while the rise in its price progressively weakened. The result was a continuous fall in gold imports until the final years of the century, when the efforts to find new gold mines finally gave fruit, as important mines of gold were found in Brazil. The Brazilian gold also started arriving in Europe early, within the century. The difficulty is that obeying the required profile of gold arrivals implies a steady upward rise in silver arrivals. This upward trend for the century as a whole agrees well with Garner (1997), the best source of production figures for silver in the Americas, but the steadiness of the rise does not (see Garner, p. 227). The alternative would have been to start with Garner's production figures, infer the arrivals in Europe and deduce the numbers for gold, but we judged this alternative worse.

Table 1 displays our 8 quarter-century values for arrivals of gold and silver in silver equivalents in the second column and our division between gold and silver in the third and fourth columns. All values are in tonnes (not tons).

— Insert Table 1 —

The values in the first column and the last five in the second column come right out of Barrett. The first three values in the second column are our revised Barrett ones, as explained. The third and fourth columns are the ones we constructed for gold and silver separately based on Barrett (indirectly Morineau) and the additional factual considerations we raised. The numbers in columns 2, 3, and 4 of this table are the basic ones that will serve in our work. For this work, we also needed to annualize the quarter-century averages. In doing so, we could have attributed the same number to each year in every quarter, or alternatively, smoothed the annual series, while making sure that the averages are right. The latter procedure would avoid the artificial jumps every 25th year. Since we later adopt long lags of 20 years for the silver and gold series in our tests (starting with zero in all years prior to 1500), it turns out eventually to make no difference which method we use. We prefer the smoothed series.

As concerns European production, we may start with silver. Munro (2003, Table 3, pp. 8-9) provides quinquennial averages for production from the major South German and Central European mines for 1471-75 to 1546-50. As indicated before, this period is also the one of principal interest regarding European silver. It is at this time that

European production surged ahead, most prominently in Schwaz in the Tyrol, South Germany, Joachimsthal in Bohemia, Hungary, other parts of Central Europe and the Balkans. For Europe as a whole, production went up from levels of 2.5 to 7 tonnes a year in the 1460s to levels of over 60 tonnes by the 1540s. As a result, inflows from the New World did not even match the European production until about 1540. We will confine discussion of the construction of our series for European silver production to the period post-1425, though we collected figures going back to 1300. As regards 1425 to 1470, Blanchard (2005, especially pp. 1020-23, 1028-29, and 1035) is the primary source; Spufford (1988, p. 363) is useful too. For 1470-1550, we relied on Munro's estimates (which are on the low side, in his view) for South German and Central European mines and made an upward adjustment for the Balkans (which Munro omitted) based on Blanchard (2005, pp. 1022-24). For 1550-1700 as a whole, we relied essentially on Blanchard (1989, pp. XIV, 49-52).

As for gold, there was significant production in Kremnica in Hungary and the Rhenish region of Germany from the 1420s to the 1550s yielding annual levels of 4.5 to 7 tonnes, thus amounting to impressive figures in silver equivalents 11 to 12 times higher. But in the middle 1560s the production fell to almost nothing all the way up to 1700 (Blanchard 2005, pp. 1020-36, 1112).

Following the estimates of the inflows of the two metals from both geographical areas, we faced a problem of aggregation since Barrett's figures for gold were in silver equivalents and therefore we could not simply add them to the European ones, in tonnes. It was necessary first to convert his gold figures back into tonnes. To do so, we used the same exchange rate figures he reported using himself (Barrett, 1990, note 19): 11.3:1 for gold to silver in the 16th century and 13.9:1 for the 17th century. This made it possible to sum the arrivals of gold from both geographical areas.

The last problem was to produce a grand total for both precious metals together. In this case, we needed a common silver/gold exchange rate. To obtain one, we looked for the most detailed series for the exchanges rates in Europe we could find. The best two we found cover 1285 to 1700: one is from Soetbeer (1879, pp. 118-25) for Germany, the other is from Blanchet and Dieudonné (1916) for France. The correlation between the two for 1500-1700 is 0.84. Thus, either series could have served us but we favored the German one since it is more likely to be independent of English events.

3.2 The time profiles of the main series

Before proceeding to the tests, we must pause on the time profiles of the principal time series. We will present these profiles as they stand prior to conversion into logs. Since the annual series for P is choppy, we smoothed it in preparation for testing. We did so by taking 15-year averages at every point, the year itself, 7 years prior and 7 years after. Consequently, 1693 is our latest observation. Figures 1A and 1B respectively show the smoothed time series for the price level and inflation. We go back to 1300 for better perspective. It is clear from Figure 1A that from 1300 to around 1530, there was no secular inflation to speak of whereas a roughly four-fold rise in *P* took place from the 1530s to the 1660s. One might have feared that because of the smoothing of *P*, little variation in inflation rates would follow. But Figure 1B shows differently. The two horizontal lines in Part B of the figure indicate that inflation was roughly stationary around zero in 1300-1500 and around some fraction (about 0.75) of 1 percent in 1500-1700.

— Insert Figures 1A and 1B —

In the case of population, the original series are smooth enough to demand no further smoothing. As seen from Figure 2A, there was a steep rise in the population (in millions) from about 1450 to the mid-17th century, bringing the English population back up in the 1620s to the level it had attained prior to the Black Plague in 1348, that is, close to 5 million. As inferable from the graph, the population data is much spottier before 1540 than afterwards, which may raise doubts about the ability to capture variation in the growth rate in the earlier part of our study period. Even for the later stretch of the series there may be similar doubts, since the series rises almost steadily until the mid-1600's. Figure 2B is there to calm these doubts. It shows the growth rate of population, in each year from the previous one for 1500-1700. As seen, many peaks and troughs in population growth appear in 1520-1630 and still greater peaks and troughs in 1630-1700.

— Insert Figures 2A and 2B —

Figures 3A and 3B concern the precious metals but center on silver, the crucial metal for English inflation in the period, as we will see. Figure 3A provides separate time profiles of the annual inflows of silver from European mines beginning in 1300 (our starting year in the construction) and those from the Americas beginning in 1500, both in tonnes. As is visible, the inflows from Europe itself rose sharply before 1500 and attained over 60 tonnes annually in the late 1530s, while the American inflows, which start from zero in 1500, caught up with the European ones around 1540 before zooming ahead. In the 1560s, the *growth* of the inflows from the Americas notably decelerated while the European contribution took a precipitous dive because of mine depletion and the stiff competition from the American silver.

The outcome, shown in Figure 3B by the lower line, is an aggregate of inflow of silver from the Americas and European mines with a substantially different profile than is usually contemplated. The year 1500 merely sees a continuation of an upward trend that began decades earlier,[7] which then accelerates in the 1530s and 1540s and later flattens in the 1560s, not to rise sharply again until the 1650s. The upper (broken) line in Figure 3B shows the same profile of inflows of precious metals once the inflows of gold in silver-equivalent tonnes are added to those in silver. The upper line is choppier than the lower one, especially around 1550, when the American production switches heavily from gold to silver.

— Insert Figures 3A and 3B —

Next, Figure 4A shows the profile of O (real GDP) after using a 15-year moving average to smooth the time series. The line slopes upward in 1500-1700 (with some acceleration in 1600-1700), as we might expect since population increases from roughly 2 million to more than 5 over the period. In total, O rises by a multiple of about 3 from 1500 to 1700. As both O and P therefore rise significantly in the study period, 1500-1700, we also show the behavior of output per capita in Figure 4B. Significantly, this series displays considerable downward as well as upward movement. From 1500 to 1650, output per capita moves up and down sharply around a (modestly) downward trend. Following, a sharp upward trend takes hold in 1650-1700 while population growth ceases. Since P was on a nearly continuous upward path in the early part 1500-1650 (Figure 1A), it is important to note that it is the downturns in output per head that fit well with our earlier justification for a positive sign for population in equation (5). Population growth in these sub-periods, if exogenous, would have caused output to grow but more slowly than

[7] To be sure, historians have been well aware of this upward trend in the late 15th century resulting from European mining for a long time. Hamilton (1934, p. 301) recognized it. Nef (1941) wrote a widely read article on the subject. But the European contribution was not properly quantified before Munro (2003) and has never since been properly integrated.

population (in conformity with the fall in output per head), and as demand for goods would have exceeded supply, *P* would have risen along with the rise in population, as it did. By the same token however, the upturns of output per head during this time stretch cannot rest on exogenous growth of population but must stem from other forces instead. This feature strongly reinforces our decision to introduce *O* as an independent variable in the elementary model right from the start (*O* not *O* per capita since population enters separately in the equation).

— Insert Figures 4A and 4B —

4. Main Econometric Results

We now turn to the tests of estimation equations (7) and (8). The test of equation (7) addresses the literature directly since it deals with the question in levels. The test of equation (8), in growth rates, goes beyond the literature. It also has the advantage of eliminating the strong common statistical trends that are evident in the data (of which historians are well aware) and to address the issue of non-stationarity.

To clear the ground first, the initial test of equation (7) in the first column of Table 2 shows the outcome of regressing the log of the price level, *lP*, strictly on *lpop*, the log of population. The test significance of *lpop* is staggeringly high with the right positive sign. Standard errors, here and later, are "robust," that is, they are corrected for heteroscedasticity (using the White method). The second column shows the outcome of regressing *lP* on *lsilv* instead, the log of the silver inflows from mining coming from Europe and the New World combined. The test significance once again is staggeringly high, even if the *t*-statistic is four times lower than the earlier one for *lpop*, and the positive sign is right. The third row considers *lpop* and *lsilv* together. Both of the variables continue to be extremely significant, though the coefficient of *lsilv* comes down considerably in size and significance. These estimates have the simple, important merit of showing that it was wrong all along to take strong positions about the main cause of the "Great Inflation" based on visual evidence of *bilateral* correlations. However, the causal interpretation of these first three equations is more than doubtful. Apart from concern with omitted variables and common trends, it is difficult to imagine that either explanatory variable would have borne its impact within a year.

— Insert Table 2 —

Suppose then, in accordance with equation (7), that we lag both *lpop* and *lsilv*, and subsequently repeat the same three estimates as before. Preliminary work with lags at 5-, 10-, 15- and 20-year intervals showed major improvements in the performance of precious metals as lags went up to 20 years and, in case of 5-year lags or longer, some smaller advantage for population as well. We thus adopted 20-year lags, which appear plausible to us for 1500-1700. In the subsequent tests, columns 4 and 5 correspond exactly to 1 and 2. Both *lpop* and *lsilv* remain highly significant in these next two columns, though the coefficients of both variables drop modestly as compared to the earlier ones. Yet the *t*-statistic of *lsilv* nearly doubles. Comparing columns 6 and 3 yields our first probing result thus far. When both *lpop* and *lsilv* enter together with respective 20-year lags, the coefficient of *lpop* drops while that of lsilv rises, both in a notable way. In addition, the level of significance of *lsilv* rises enough to become only negligibly smaller than that of *lpop*. Notwithstanding, the elasticity of influence of *lpop* remains much higher than that of *lsilv*, 0.95 as opposed to 0.31. We shall have more to say later, on that score.

The interpretation of *lpop* in all these tests remains marred by the absence of any other consideration of output except the impact of population itself on labor. The seventh column does something to repair this defect. In accordance with earlier discussion, the equation adds the log of output, *lO* without any lag. Interestingly, *lO* proves both highly significant and with the expected negative sign. Its elasticity of influence is considerable too, 0.72, and in its presence the significance of both *lpop* and *lsilv* remains the same, but the coefficient of *lpop* rises markedly, attaining 1.56, near the levels it had exhibited before when it was entered by itself alone in columns 1 and 4. In fact, this change agrees with theory: As indicated before, in the absence of *O*, the coefficient of population should have incorporated the restraining effect on inflation of the positive effect on *O*. With *O* present, the inflationary effect of population comes dominantly from the demand side and is higher.

The last three columns of Table 2, turn to the issue of the choice of *lsilv* as measure of the inflow of precious metals. In column 8, we restrict the measure of the silver inflows strictly to those coming from the Americas. This focus corresponds to the literature. The equation is highly satisfactory and important but the precision of the estimates of all three explanatory variables drops, especially that of silver inflows whose coefficient goes down by two-thirds and whose t-value falls by more than half. Clearly, then, limiting the study of the impact of silver to the part coming from the New World yields poorer results. In column 9, we turn to gold and show the results of substituting it for silver as the measure of inflows of precious metals. The deterioration is massive. Not only are the inflows of gold insignificant but the significance of *lO* disappears too. In column 10, we take the more reasonable step of combining gold and silver to measure the impact of the inflow of precious metals. The equation performs well but notably less so than the earlier one in column 7, based on silver alone. The coefficient of the log of precious metals is around 20% below the earlier level of *lsilv* and its t-value drops by almost two-thirds. It is clear from columns 8, 9, and 10 together that the good performance of the precious metals in column 10 comes from silver alone.

Next we turn to tests of equation (8), concerning the percentage changes, or more precisely, growth rates. The rate of inflation becomes the dependent variable and the joint positive trends of all three major variables, price level, population and precious metals drop out. As we saw in the time profiles, the series for prices and population both become essentially stationary around a single value or at most two (inflation) over two successive stretches. Though not shown, the same is true for silver as well. The definition of inflation is the percentage change in P from the preceding period t-1 to the current one t. This definition is evident, but that of the change in the 20-year lags of population and silver in equation (8) at time t is not. We could interpret these two lagged growth rates as the percentage changes from the 21st year earlier to the 20th one. But we could also interpret them as the percentage changes from the 22d to the 20th year earlier or, perhaps better still, from the 22d to the 18th one. The last possibility of centering on the growth rate around the 20th year is our choice. We opted for a 10-year band. Thus, for 1500 for example, the relevant growth rate is from 1475 to 1485, for 1550 it is from 1525 to 1535, etc. Later we discovered that a shorter band around the 20th year would have done moderately better but we stuck to our initial choice.[8]

In Table 3, we proceed directly to testing for population and silver together instead of presenting separate tests for them first. Column 1 corresponds to column 6 in Table 2. The R^2 drops markedly from the earlier 99% level to 35%, still a respectable level for first

[8] We also checked with augmented Dickey-Fuller tests about the stationarity of all our variables – prices, population, silver alone or silver and gold combined, and real GDP. They are indeed non-stationary in levels and stationary in growth rates. There is also no cointegrating relationship between prices and the other variables in levels.

differences or growth rates. Except on this point, the equation does nearly as well as the earlier one. Both major explanatory variables still enter highly significantly with the right positive sign while their *t*-values are more comparable to one another than before (though population retains a much higher coefficient than silver). Next, we add the impact of growth in output from the previous year. Again the results agree well with the earlier one, in column 7 of Table 2. All three explanatory variables are highly significant with the right signs and the R^2 rises to 49%. As a significant difference, though, the coefficient of the (lagged) population variable is no longer seriously affected by the presence of the (unlagged) output one, as it was before.[9, 10]

The next three equations simply check on the earlier results about alternative measures of the precious metals. As regards imports of silver from the Americas alone, column 3 (as compared with column 2) yields basically the same result as before in column 8 in Table 2 (as compared with column 7). Specifically, growth in silver from the Americas is still highly significant but much less so than the growth of silver from the Americas and Europe combined. Both the coefficient and the *t*-value of silver from the Americas in column 3 drop markedly in relation to column 2, the one for the *t*-value by about half. Next, the equation in column 4 confirms the earlier insignificance of gold (though without any of the attendant damage to the output variable that occurred before). Finally, column 5 once again displays the better results of sticking to silver alone rather than adding gold. All in all, there can be little question that the results favor measuring the total inflow of precious metals as the sum of the flows of silver and silver alone from both geographical areas.[11]

[9] It is interesting to compare these results with those of Findlay and Lundahl (2002) in a much-neglected thought experiment with a simple general-equilibrium model that attempts to explain the same historical events starting as early as the Black Plague in 1348, yet without any empirical testing. Among the fundamental points of divergence, these authors treat population as entirely endogenous in 1500-1700 and they treat the upsurge of silver production in Europe starting around 1470 the same way. Unsurprisingly, they come to different conclusions.

[10] Of note, there is a nearly concurrent work, by Palma (2019), that uses an impulse-response methodology to test the impact of precious metals on inflation. Palma's results harmonize with ours. He finds that a shock to precious metals of American origin yields inflation in Europe in 1531-1790 after about 7 years and that it continues to do so increasingly over the rest of his 12-year horizon. Yet Palma's measure of precious metals differs notably from ours. He relies essentially on TePaske (2010), whose data - the most detailed thus far - concerns officially registered production in the different mines in the Americas. But as Palma recognizes (*passim*, see p. 17 and note 40 in particular), TePaske makes no attempt to estimate unregistered production, smuggling across the oceans and output that remained in the Americas, whereas these parts of the production are large and a central preoccupation of the literature, including Barrett (1990), on whose judgment we rely. In other regards, Palma's principal focus diverges from ours. He is mainly concerned with the effect of precious metals on real output, that is, the effect of one influence on the price level on another in our work, and he is not concerned with the populationist thesis.

[11] We have handled the issue of possible autocorrelation in the residuals thus far by passing from levels to growth rates and first differences. A stronger test would be to go on to include the lagged value of the dependent variable, inflation, as an additional regressor. However, this would put heavier stress on the accuracy of the original series

— Insert Table 3 —

5. Robustness Tests

5.1 Adding urbanization

We shall next enlarge the model to allow for missing influences and thereby explore the robustness of the core model. The missing variable in the core model that the literature suggests mostly is urbanization (Goldstone 1984; Spufford 1994, pp. 367-78). Common sense tells us that urbanization increases money trade relative to barter. But what about the sign of the effect of monetization on the value of money?

At first blush, it may seem that an increase in the demand for money, like anything else, should lead to a rise in its value, thus meaning a fall in the price level. But on further thought, if money is already present, urbanization might encourage the development of financial substitutes for it and perhaps also an increase in the supply of money itself (always a subject of definition). Perhaps therefore the net effect is an excess supply of money and inflationary. Apart from this last possibility, Goldstone (1984, pp. 1141-8) provides an important argument for a positive effect of urbanization on inflation, which finds many echoes in the historical literature. Goldstone argues that with urbanization, the existing stock of money can turn over more rapidly so that a lower stock of money will now do as well as before. To show the good sense of this argument, suppose that the individual household is able to replace its stock of money in rural areas only once a year at harvest time. With the development of urbanization, the opportunities for profitable sales of rural output – not only crops but a variety of home-made goods – occur more often (see Spufford 1988, pp. 382-7). Cities also provide more frequent opportunities for profitable trades among residents than rural areas do within the rural population. It thus becomes possible to finance the same level of aggregate spending over the year with lower average holdings of money stocks (as illustrated in the Baumol-Tobin inventory model by a change from annual to monthly income receipts). From the individual perspective, money simply rolls over more frequently in and out of a person's hands. Yet if the aggregate

for the price level than we do already by converting them to inflation rates. We performed the test nonetheless. All three principal causal variables remain statistically significant at the 1% confidence level, while the absolute values of their coefficients drop greatly. Errors in variables are known to lead to underestimates of coefficients. Therefore we conclude, first, that there is no problem of autocorrelation in the residuals in the estimates of Table 3 and second, that those estimates yield more reliable coefficients than the ones in the later and more exacting test.

nominal stock of money and the price level stay the same, then on the aggregate level the Fisher equation ($MV = PT$) says that V and T must go up. Furthermore, the rise in desired total real spending most likely means a rise in the demand for currently produced goods as well. Thus, in terms of the Cambridge equation, at given M, O and P, there will be an equilibrium fall in k. Quite notably, this fall does not signify a rise in money substitutes nor a loss in the appeal of money relative to other goods but the mere fact that the existing stock of money acquires more uses. A lower average stock of money simply serves as well as before in reducing transaction costs both for the individual and in the aggregate. kPO falls relative to M, there is an excess supply of money, and the price level must rise in order to restore equilibrium. As applied to earlier periods when the rural/urban distinction was much sharper and when monetization was only partial, this reasoning seems compelling.[12] It has been well received by historians overall (despite some criticism by Mayhew 1995).

On the empirical level, the measure of urbanization is a separate issue. The most frequent measure is the fraction of the national population living in towns of more than 10,000 (De Vries 1984). But Bairoch et al. (1988, pp. 253-61) propose a lower benchmark, of 5,000 or even 2,000. This issue matters for England. For a European country with around 2 million inhabitants at the opening of the 16th century the country had an unusually low number of cities with a larger population than 10,000 besides London but a more comparable number with a population of over 5,000 (see Wrigley 1985, pp. 684-8, 707-8). In testing, we therefore tried two alternative measures of urbanization, one from Broadberry et al. (2015, p. 153) based on the 10,000 criterion, the other from Bairoch et al. (1988, p. 259) based on the 5,000 criterion. Table 4 shows the two sets of figures. We also linearized both series before testing. Early experiments called for a growth rate of urbanization over more than a one-year span in the past. We chose the growth rate since time t-5. Thus, the relevant urbanization data start in 1495. As a result, the estimates with the 10,000 criterion rest on 6 observations and those with the 5,000 criterion rest on 4 (see Table 4).[13]

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[12] Cf. Lindert (1985), pp. 621-2. Goldstone (1984, pp. 1141-8) himself formulates the argument differently with an accent on network effects and a general sociological interpretation. But the two formulations come to the same in our view (despite Goldstone's reasoning in terms of V and T instead of V_Y and O).

[13] Note that the Broadberry et al (2015) and Bairoch et al (1988) figures for 1700 conflict. If the former is right, the latter is too low; if the latter is right, the former is too high. However, both sets of authors agree about a sizable rise from 1600 to 1700. (Wrigley's figures for 1520 to 1700 (1985, p. 707), based on the 10,000 criterion, agree closely with Broadberry et al.) There is a second difference of note: Broadberry et

— Insert Table 4 —

Table 5, column 1 displays the result of adding growth of urbanization to the core model based on the 5,000 criterion because the 10,000 criterion, not shown, performs decidedly worse. As seen, urbanization enters with the expected positive sign, but with a *t*-value of only 1.54, a little below the 10% significance level. The performances of population, precious metals, and real output are virtually the same as those before in Table 3, column 2.

— Insert Table 5 —

5.2 Adding government spending

As a second control, we turn to government spending, which if financed through money creation or borrowing should be inflationary. Broadberry et al. (2015) provide an annual series for real government services as a fraction of the 1700 level, which starts in 1270, and goes on to 1870. Government services in the 1270-1700 time spell refer predominantly to spending on defense and war. In principle, we should separate the part of this spending that was financed through taxes and income on royal property from the part that was financed through the issue of money, debasement, and borrowing, as the latter part is more inflationary. But the distinction is one we are not able to quantify. Doing so would be a subject for a large separate study. Here we will satisfy ourselves with examining the inflationary influence of the aggregate government spending on services regardless of the source of financing. The series for this spending displays considerable movement but no secular trend from 1500 to 1626. Its level remains 14-15% both at the opening and the closing. From 1626 on, however, a major rise in the spending took place, particularly during the two successive civil wars in 1642-1654, and during the 9-years war in 1688-1697 following the "Glorious Revolution" of 1688.

al imply a rise in urbanization in the 15th century while Bairoch et al show a fall. On this last point, both could be right and the difference could lie in the difference in measure of urbanization. But the population literature tends to agree with Bairoch et al about a fall of urbanization in the 15th (see, for example, Lopez and Miskimin 1961, pp. 415-6, Goldstone 1984, p. 1148, and Allen 2003, p. 437). Perhaps this position reflects a general preference for the 5,000 criterion or lower.

As in the case of urbanization, it proves useful to measure the growth rate of government services since time t-5. Following, Table 5, column 2, shows that the growth rate of government services enters with a positive sign and significant at the 10% level. Urbanization now also rises to significance near the 5% level. The coefficients and significance of the three fundamental variables barely move.

5.3 Adding mortality crises and climate changes

The next control we consider is mortality crises. These crises are typically of short duration and sometimes supposed to yield upward spikes in food prices and inflationary pressure during their persistence as output drops more than demand (e.g., Malanima 2009, p. 52). To measure such crises, we turn to Wrigley and Schofield (1989, pp. 333-7), who define them as years of death rates 10% above trend. Such death rates are likely to indicate extremely unfavorable natural conditions, like the outbreak of disease or extremely bad weather. Because the parish data on which Wrigley and Schofield rely does not go back earlier, their series only begins in 1541. Historians also consider it doubtful that reliable data for a pre-1541 mortality time series will ever arise. Yet we quote Loschky and Childers (1993, p. 85): "All available materials indicate that a substantial fall in mortality occurred in the fifteenth or early sixteenth century." On this basis, we set mortality crises at zero for 1500-1540, and next followed Wrigley and Schofield (1989, Table 8.11, p.333) for 1541-1700. In one effort, we retained Wrigley and Schofield's figures, which meant assigning separate weights to individual years of mortality crisis but a common zero to all of the "non-crisis" years. However, poor results followed. In another experiment, we applied a 0-1 dummy variable to distinguish between Wrigley and Schofield's years of mortality crises and the rest. This gave better results. Table 5, column 3, shows the outcome of this latter experiment. Though mortality crises enters with the expected positive sign, its coefficient is below conventional significance levels. Unsurprisingly, the rest of the equation is unaffected.

Our last control pertains to changes in climate. Lamb (1984, p.248) furnishes graphs for temperatures in central England for 900-1900 after smoothing, well adapted for discussing climate rather than weather. He also mentions strong evidence that lower temperatures over long periods are associated with poorer harvests in the English climate zone (see also Goldstone 1991, pp. 64-68). If so lower temperatures would lead to higher agricultural prices. Supplies of goods would drop, even in the aggregate, while aggregate demand would likely rise as colder climates also require higher energy consumption. To test we tried a number of alternative measures of climate changes. The signs are negative and correct, but the coefficients are generally insignificant. In Table 5, column 4, we show the results with one reasonable measure, the percentage change of temperature relative to the average temperature in Lamb's series (profile A).

5.4 The comparative influence of population and precious metals

As a final word about the tests, let us come back to the important issue of the relative orders of influence of population and precious metals on inflation. As a preliminary, we may reconsider our preferred estimate, Table 5, column 2, after dropping the output variable. The subsequent estimate, Table 5, column 5, confirms the earlier result in our core model (Table 3, columns 1 and 2) that dropping output leaves the coefficient of population essentially the same. This is important. Had output growth significantly altered the coefficient of population, as was true in levels (Table 2), identifying the relative influences of population and precious metals would have been difficult since the coefficient of population in Table 5, column 2, must refer to the impact of population growth on inflation *at a given level of output growth*. As things are, the presence or absence of output growth makes no difference.

As we see from Table 5, columns 1 through 4, the coefficient of population growth is on the order of 5 to 6 times larger than that of the growth of silver, as was generally true in the estimates of the core model in Table 3. What do we make of that? Population was around 2.2 million in 1500 while total silver inflows represented around 31 tonnes a year. A rise of one percent of population meant 22,000 more people in England and a rise of one percent in silver meant an extra 0.31 of a tonne of added silver in Europe. To many an eye, 22,000 more residents counts much more for England than an extra 0.31 of a tonne of silver a year for all of Europe. But impressions can mislead. The soundest basis for comparison, we think, is between the relative contributions of population and silver to English inflation for the entire period 1500 to 1700. The price level during this time rose from 19.9 to 100, or by 80.1 percentage-points. Population went from 2.2 to 5.2 million, a rise of a multiple of 2.36, or by 136 percent. Silver inflows went up from 31 tonnes to 352 tonnes, a rise of a multiple of 11.35 or by 1035 percent. The respective coefficients of the two variables in Table 5, column 2, for the annual growth rates, are 0.12 for population, 0.02 for silver. 0.12 times 136 means that population contributed 16.3 percentage points to the 80.1 percentage-point rise in inflation while 0.02 times 1035 means that silver contributed 20.7 percentage points to it. Thus, the contribution of silver was moderately higher. Since the respective *t*-values of the two coefficients are 7.62 for population and 4.4 for silver, the uncertainty bands around the values of 16.3 (population) and 20.7 (silver) are negligible.

6. Discussion

From the second quarter of the 16th century to the middle of the 17th century, the price levels in most parts of Europe, including Spain, the Italian city-states, Germany, central Europe, France, Flanders/Burgundy, the Netherlands, and England, rose by a factor of 4 to 6 or 7. This can only be the result of common causes. Economic historians have championed two such causes: the European-wide population growth and the massive inflows of precious metals from American and European mines. Both arguments have been challenged and confirmation of either was never possible until recently because of inadequate data. Broadberry et al. (2015) provided the needed data for England. This data does not yet permit a test based on contemporary theory, since that would require still-absent data for stocks of precious metals and opportunity costs of holding the metals in various forms. But their data does make it possible to base a test on a simple old-fashioned model that has served to organize thought all along by a mere extension (from equations 3-4 to equations 5-6). As this test is the first of its kind, there was no way to predict the outcome beforehand. The results are remarkably good. They tend to vindicate those many economic historians who always considered both principal arguments correct, prominently the late Van Bath (1963, pp. 98-131), Miskimin and the late Munro among others (see, e.g., Miskimin 1975a and Munro 1984), but they tend to contradict the partisans of one explanation to the near-exclusion of the other. In light of the results, let us examine the problems with the extreme positions.

Economists as a group have never been comfortable with the “populationist” thesis, so far as they have even been aware of it, though they are mainly guilty of slight. In defending this slight, much has been made of the fact that a rise in agricultural prices does not imply a rise in the general price level but could simply mean a rise in the price of agricultural goods relative to the rest (McCloskey 1971 and Bordo 1984, p. 373). Yet there has never been any effort to explain why under conditions of dearth of agricultural goods in a low-income country people would plausibly try to maintain their food consumption strictly at the expense of manufactured goods and other services without touching their real money balances. In any event, the results of the tests are clear. The price of aggregate output, as measured by Broadberry et al. (2015) based on a detailed decomposition of output, goes up with higher population.[14] Another criticism of the "populationist" thesis, far more negative, goes on to say that the thesis defies basic economic theory. In her short review of a collection articles containing populationist ideas, McCloskey (1971) takes this position and argues, to considerable effect, that higher population means more demand for money, which should have a deflationary not an inflationary impact. Yet higher population also means more aggregate demand for goods. Short of borrowing abroad or reducing initial capital (like livestock), at given levels of money and output, a national population cannot have more of both. They must choose between the two. People in this quandary might well keep up their consumption at the sacrifice of some liquidity, as historians predominantly think and as the English evidence says. It is difficult to see any conflict with economic theory.

The arguments of the critics of the "monetarist" position, on the other side, are two-pronged. In one part, the critics argue that the increases in coinage in European countries were too small to explain the observed rises in price levels. Yet the impact of the inflow of precious metals into Europe on, say, English prices need not come through a rise in English money but can come through market competition in commodities markets. If English prices rise because of a rise in the prices of European competitors, the English real money stock may even go short for a time since its real value may fall. More generally, if we step back, clearly any inflow of precious metals from American and European mines must serve not only to satisfy the demand for coins, but also the demand for silverware, jewelry and ornaments, hoards, and foreign goods all at once. If we suppose set relative prices of silver in different forms, the rise in the supply of silver will cause the prices of silver in all forms to fall relative to other goods, which would mean a rise in the general price level. A rise in the supply of silver going heavily into silverware will tend to

[14] By curiosity, we also experimented with the consumer price index (CPI) as a measure of *P* instead of the price of output, although the price of output is the right measure in the V_Y version of the Fisher equation, and as long as the Cambridge equation is a parallel (O in the equation meaning total output), right there too. However, since the correlation between the two series for the growth rates of P (inflation rates) is 0.94 little difference might be expected. Indeed that is the case. In testing the model in our preferred form, Table 5, column 2, with the CPI instead of the price of output as the measure of inflation, the performances of population and silver stay the same. That of output is as good as before though there is a sizeable change in its coefficient (-0.73 rather than -0.54). The R-square of the equation also falls by about 3 percentage points.

lower the price of silver just as would a rise in the supply going into coins. Under a silver standard, there was thus never any sound reason to expect the impact of silver on the price level to come strictly through coinage. In the absence of a perfectly integrated world market, only the outflow of silver to the east of Europe would mitigate the tendency of the inflow to raise the European price level. Quite significantly too, whatever happens will be consistent with the Fisher equation, which is a tautology. Notwithstanding, shortages of money in England in 1500-1700, evidence that the inflows of the precious metals go partly into silverware, jewelry and ornaments, partly disappear into stocks, and partly move out of Europe to the east, are all presented as so many arguments against the monetarist position.[15]

The other and more compelling part of the argument against the monetarist position concerns timing. We have already dealt with this argument regarding the 1500-1550 period. But Goldstone (1984, pp. 1152-4, 1988, p.109) advances it too for 1660-1700. At that time, inflows of silver accelerated but the price level remained essentially flat, in seeming contradiction with the monetarist position. Yet looking back at Figure 5A, we can see a possible simple answer. Output growth in the second half of the 17th century was exceptionally high. Thus, the positive impact of precious metals on inflation (without any reinforcement from population, which hardly rose) would have met special resistance from output growth. It is interesting, in this light, that the role of output growth in mitigating inflation has been virtually absent in the discussion of the "Great inflation." Goldstone (1984, p. 1125, 1135-41, 1154-5; 1991a, pp. 62, 73-81; 1991b) stands out among detractors of the monetarist argument as an advocate every last one of the foregoing criticisms.

Next, the exclusive importance of silver, not gold, deserves special attention. It was not possible to anticipate this result. Yet it emerges clearly from the tests: in the relevant period silver by itself was able to satisfy the demand for high as well as low denominations and for money in small and large transactions without any help from gold, even though gold provided complementary services as a medium of exchange in international

[15] Supporters of the monetarist position are not necessarily innocent of these mistakes. For example, in his innovative use of impulse-response functions to study the impact of the discovery of precious metals in the Americas on output and the price level in Europe for the next few hundred years, Palma (2019) treats the production of the precious metals in the Americas as an instrument for European coinage. This obviously disregards the effects of inflows of the precious metals on European price levels independently of coinage (and "money" in the broadest sense).

transactions (both in the form of bullion and coin). Some probing on this issue is useful.

Prior to the adoption of an improved method of exploiting the silver mines in Europe around 1470 (the *saigerprozess*), there had been a long so-called "silver famine" in Europe. The scarcity of silver began to be felt around 1340-1360 after centuries of monetary dominance of silver in the early Middle Ages. In consequence, gold coinage increased in Europe. A strong factor in this development was a spurt in European gold production beginning in the early 14th century, peaking in the middle of the 15th and remaining heavy until the mid-16th. The outstanding source of the new gold was Kremnica in Hungary, but there was major contribution from the mines in the Rhenish region of Germany too. African gold also complemented the European stock significantly in response to European demand. Spufford (1988) entitles a whole chapter on the mid- and late-14th century "The victory of gold." Munro (1984, p. 32) maintains that England consistently favored gold in 1351-1520. Further, the fineness of silver in European coins, especially in lower denominations, dropped greatly during this long period (see Spufford 1988, pp. 289-318, Day 1978 and the summary table in Malanima 2009, p. 198). Silver coins made up predominantly of lesser metals ("*monnaie noire*") circulated widely in France in the 15th century and elsewhere on the continent. Correspondingly, Figure 3B shows that silver arrivals constituted only a modest fraction of silver plus gold in silver equivalents in this century. Could it be then that despite gold's high value even in the form of tiny coins (had there been any), it managed to displace silver as the primary monetary influence on the price level? Or is it instead that the silver inflow into Europe remained fundamental but the gold inflow joined it as a monetary influence on inflation?

Table 6 responds to these questions. The tests rest on our favored equation form, inclusive of urbanization and government services, but they stretch the study period backward to 1450. As a result, the tests depend on information going back to 1425 given our lags. In the first column, we see that for the longer period, 1450-1700, silver alone does indeed lose all significance. In the second column, we see also that gold remains just as insignificant as before. Finally, however, when we add the two metals together in terms of market-equivalent tonnes of silver in the third column, we find that the aggregate is highly significant, with a *t*-statistic of 3. Silver, therefore, retains its importance as an influence on the price level prior to 1500 but only if we add gold to it. This result sits well with the views of the experts who refer to 1300-1500 broadly as a period of "bimetallism" in England: see Day (1984, p.20), Mayhew (1992, pp. 143-9), and Miskimin (1975b, pp.

120-1). Later, when silver became abundant after the 1530s and chased gold away as a partner in monetary influence on the price level,[16] the fineness of silver coins stabilized and ceased to fall in Europe (Malanima 1969, p. 198, and Spufford 1988, pp. 365-6).

— Insert Table 6 —

The changes in the performances of urbanization and government services in Table 6 deserve attention too. Interestingly, the separate significance of urbanization, previously marginal, becomes unmistakable for 1450-1700. This change also makes sense. In 1500-1700 urbanization was on a continuous upward course. But in the preceding century urbanization had retreated from earlier levels (see Table 5). Thus, the addition of a 15th century observation to the earlier ones permits a clearer distinction of the impact of urbanization from that of the other variables, notably population. In company with other authors, Britnell (1995, p. 25) says that "England was probably as urbanized in 1300 as it was in 1600" (cf. note 13 and Rigby 2010). If so, we can easily see that the role of urbanization would become more visible if we start early enough to capture a turnabout.

On the other hand, for 1450-1700 government services becomes less significant, indeed insignificant. This too can be explained but with less confidence. The ability of royalty to tax regularly rather than occasionally for financing defense and war and otherwise to live on revenues from its own properties, only came about progressively in Europe after the Middle Ages (Ormrod 1999, Schultze 1999). Hart (1999) writes of a movement from a "domain state" to a "tax state" during the Renaissance. With greater tax abilities also came greater ability to borrow. Thus, it could be that up to the Renaissance, European political powers remained unable to influence the general price level through their monetary/fiscal actions and only became able to do so subsequently. Yet it would be premature to embrace this conclusion.

The last column in Table 6 responds to a concern about silver/gold exchange rates. In all the tests with silver and gold together, the silver/gold exchange rates are a factor. We mentioned earlier a high positive correlation between our two long series for these exchange rates (0.84). In view of this fact, we simply picked the series agreeing better with the required exogeneity with respect to England. For 1450-1500, however, the

[16] Notwithstanding, gold coins continued to constitute about 25% of the value of total coins in England in 1643 according to Mayhew (1995, p. 245).

French and German exchange rates are even negatively correlated (-0.24) though they remain positively correlated for the 15th century as a whole (0.66). It is indeed the case that in 1400-1500 the French exchange rate was especially unstable. More broadly still, in 1300-1500 the silver-gold exchange rates varied by orders of 20-30% within Europe (see, e.g., Watson 1967, Spufford 1988, pp. 272, 370-1). Only in the 16th century did the arbitrage points between silver and gold stabilize within Europe and narrow substantially. The final column of Table 6 shows the result of substituting the French for the German silver-gold exchange rate in order to provide a sum of both precious metals in terms of market-equivalent tonnes of silver over 1450-1700. Surprisingly or not, the significance of the variable rises. Of course, the reason could be some element of reciprocal English influence on the French exchange rate, which is precisely what we wish to avoid. We stick to our earlier choice.

Let us close with the big question: Is it reasonable to expect similar results to hold for the rest of Europe in 1500-1700? The answer is emphatically yes. We see every reason why the excellent results for silver for England would apply to the rest of Europe, including Scandinavia and the east. Evidently, the lags in the influence of silver would vary depending upon distance, geography, and the routes of travel in trade. In particular, the lags would be expected to be especially short in Spain, as Hamilton (1934) has amply shown to be the case. In addition, the proper measure of an exogenous aggregate of European silver would need further consideration for the countries where the mines are located. But in general the inflows of silver into Europe from the New World and Europe's own mines should bear their inflationary effect. As regards population, we would also expect the English results to hold everywhere on the important condition of no initial shortage of labor. This last condition matters since if violated, added population would relieve a labor shortage and the hypothesis of inflationary effects of population growth (because of inadequate output relative to demand) would not follow. On this ground, the hypothesis is dubious for Spain, where labor was probably still in short supply in the early 16th century (Broadberry et al. 2015, pp. 377-80). However, elsewhere the lags might differ, but the positive sign and significance of the impact of population growth on inflation should hold. Lastly, we would anticipate clearer inflationary effects of government spending in the case of the principal participants in the religious wars of the 16th and 17th centuries, Spain, Germany and France.

References Cited

Allen, Robert (2003). "Progress and poverty in early modern Europe," *Economic History Review*, 56 (3), pp. 403-443.

Bairoch, Paul, Jean Batou and Pierre Chèvre (1988). *La population des villes européennes de 800 à 1850*, Genève : Librairie Droz.

Bakewell, Peter (1984). "Mining in colonial Spanish America," in Leslie Bethell, ed., *Cambridge History of Latin America*, Part II, pp. 105-21.

Bakewell, Peter (1997). "Introduction" in Bakewell, ed., *An Expanding World: The European Impact on World History 1450-1800, vol. 19, Mines of Silver and Gold in the Americas*, Brookfield, Vt., USA: Variorum, pp. XII-XXIV.

Barrett, Ward (1990). "World bullion flows 1450-1800," in James D. Tracy, ed., *The Rise of Merchant Empires: Long Distance Trade in the Early Modern World*, Cambridge, Cambridge University Press, pp. 224-54.

Blanchard, Ian (1978). "Resource depletion in European mining and metallurgical industries, 1400-1800," in William Parker and Antoni Mączak, eds., *Natural Resources in European Industry*, New York: Routledge Revivals, pp. 85-113.

Blanchard, Ian (1989). *Russia's 'Age of Silver': Precious Metal Production and Economic Growth in the Eighteenth Century*, London and New York: Routledge.

Blanchard, Ian (2001). *Mining, Metallurgy and Mining in the Middle Ages, vol. 2, Afro-European Supremacy, 1125-1225*, Stuttgart: Franz Stein Verlag.

Blanchard, Ian (2005). *Mining, Metallurgy and Mining in the Middle Ages, vol. 3, Continuing Afro-European Supremacy, 1250-1450*, Stuttgart: Franz Stein Verlag.

Blanchet, Adolphe and J.-Adrien Dieudonné (1916), *Manuel de Numismatique française*, Tôme 2, Paris : Auguste Picard.

Bordo, Michael (1986) "Explorations in Monetary History: A Survey of the Literature," *Explorations in Economic History* 23, pp. 339-415.

Brenner, Y. S. (1961). "The inflation of prices in early sixteenth-century England," *Economic History Review*, XIV (1), pp. 225-39.

Brenner, Y. S. (1962). "The inflation of prices in England, 1551-1650," *Economic History Review*, XV (1), pp. 266-84.

Britnell, Richard (1995). "Commercialization and economic development in England, 1000-1300," in Britnell and Bruce Campbell, eds., *A Commercializing Economy: England 1086 to c. 1300*, Manchester: Manchester University Press, pp. 7-26.

Broadberry, Stephen, Bruce Campbell, Alexander Klein, Mark Overton and Bas van Leuven (2015). *British Economic Growth 1270-1870*, Cambridge: Cambridge University Press.

Chambers, J. D. (1972). *Population, Economy and Society in Pre-Industrial England*, London: Oxford University Press.

Curtin, Philip (1983). "Africa and the wider monetary world, 1250-1850," in J. F. Richards, ed., *Precious Metals in the Later Medieval and Early Modern Worlds*, Durham, Carolina Academic Press, pp. 231-68.

Day, John (1978) "The great bullion famine of the fifteenth century," *Past and Present*, 79 (1), pp. 3-54.

Day, John (1984). "Introduction," in John Day, ed., *Études d'Histoire Monétaire*, Lille : Presses Universitaires de Lille, pp. 9-25.

De Vries, Jan (1984). *European Urbanization 1500-1800*, London: Methuen.

Findlay, Ronald and Mats Lundahl (2002). "Towards a factor proportions approach to economic history: Population, precious metals, and prices from the Black Death to the price revolution," in Findlay, Lars Jonung and Lundahl, eds*., Bertihl Ohlin: A centennial celebration (1899-1999)*, Cambridge, MA.: MIT Press, pp. 495-528.

Fischer, David Hackett (1996). *The Great Wave and the Rhythm of History*, Oxford: Oxford University Press.

Fisher, Douglas (1989). "The price revolution: A monetary interpretation." *Journal of Economic History*, XLIV (4), pp. 883-902.

Flynn, Dennis (1978). "A new perspective on the Spanish price revolution: The monetary approach to the balance of payments," *Explorations in Economic History*, 15, pp. 388-406.

Garner, Richard (1988). "Long-term silver mining trends in Spanish America: A comparative analysis of Peru and Mexico," *American Historical Review* 93 (4), pp. 898-935.

Garrard, Timothy (1980). *Akan Weights and the Gold Trade*, Cambridge: Cambridge University Press.

Goldstone, Jack (1984). "Urbanization and Inflation: Lessons from the English Price Revolution of the Sixteenth and Seventeenth Centuries," *American Journal of Sociology*, 89, pp.1122-60.

Goldstone, Jack (1988). "East and West in the seventeenth century: Political Crises in Stuart England, Ottoman Turkey, and Ming China," *Comparative Studies in Society and History*, 30 (1), Jan., pp. 103-42.

Goldstone, Jack (1991a). "The causes of long waves in early modern economic history," *Research in Economic History*, Supp. 6, pp. 51-92.

Goldstone, Jack (1991b). "Monetary vs. velocity explanations of the 'Price Revolution': A comment," *Journal of Economic History* 51, pp. 176-78.

Gould, J. D. (1964). "The price revolution reconsidered," *Economic History Review*, XVII (2), pp. 249-66.

Hamilton, Earl (1934). *American Treasure and the Price Revolution in Spain, 1501-1650*, Cambridge: Harvard University Press.

Hammarström, Ingrid (1957). *Scandinavian Economic Review*, V, as reprinted in Peter Ramsay, ed., *The Price Revolution in Sixteenth-Century England*, London: Methuen & Co., pp. 42-68.

Hart, Marjolein 't (1999). "The emergence and consolidation of the 'tax state': The seventeenth century," in Richard Bonney, ed., *The Rise of the Fiscal State in Europe, c. 1200-1815*, Oxford: Claridon Press, pp. 281-93.

Hatcher, John (1977). *Plague, Population and the English Economy1348-1530*, London: Macmillan Palgrave.

Humboldt, Alexander von (1811) *Political Essay on the Kingdom of New Spain*, trans. John Black, 4 vols. London.

Lamb, Hubert (1984). "Climate and history in Northern Europe and elsewhere," in N. A Mörner and W. Karlen, eds., *Climatic Changes on a Yearly to Annual Basis*, Dordrecht, Neth.: Kluwer Academic Publishers, pp.225-40.

Lane, Frederick (1984). "Exportations vénitiennes d'or et d'argent de 1200 à 1450," in John Day, ed., *Études d'Histoire Monétaire*, Lille : Presses Universitaires de Lille, pp. 30-48.

Lee, Ronald (1973). "Population in Preindustrial England: An Econometric Analysis," *Quarterly Journal of Economics*, 87 (4), pp. 581-607.

Lee, Ronald (1985). "Population homeostasis and English demographic history," *The Journal of Interdisciplinary History,* 15 (4), pp. 635-660.

Lindert, Peter (1985). "English, population, wages and prices: 1541-1913," *The Journal of Interdisciplinary History*, 15 (4), pp. 609-34.

Lopez, Roberto and Harry Miskimin (1961). "The economic depression of the Renaissance," *Economic History Review*, XIV (1), pp. 408-26.

Loschky, David and Ben Childers (1993). "Early English mortality," *The Journal of Interdisciplinary History*, 24 (1), pp. 95-97.

Malanima, Paolo (2009). *Pre-modern European Economy: One Thousand Years (10th-19th Centuries)*, Leiden: Brill.

Mayhew, N. J. (1992). "From regional to central minting 1158-1464," in Christopher Challis, ed., *A New History of the Royal Mint*, pp. 83-178.

Mayhew, N. J. (1995). "Money supply, and the velocity of circulation in England, 1300-1700," *Economic History Review*, 48 (2), pp. 238-57.

McCloskey, Deirdre (1971). "Book review of Peter Ramsey 'The price revolution in sixteenth-century England'," *Journal of Political Economy*, 80 (6), pp. 1333-5.

Miskimin, Harry (1975a). "Population growth and the price revolution in England," *Journal of European Economic History*, 4 (1), pp.179-86; reprinted in Miskimin (1989), *Cash, Credit and Crisis in Europe, 1300-1600*, London: Variorum Reprints.

Miskimin, Harry (1975b). *The Economy of Early Renaissance Europe 1300-1400*, Cambridge: Cambridge University Press.

Morineau, Michel (1985). *Incroyables gazettes et fabuleux métaux*, Cambridge : Cambridge University Press, and Paris : Éditions de la Maison des Sciences de l'Homme.

Munro, John (1984). "Mint outputs, money and prices in late Medieval England and the Low Countries," in Eddy van Cauwerbergue and Franz Irsilger, eds., *Munzprägung, Geldumlauf and Wechselkurse, Trier: Verga Trier Historische Forchungen,* pp. 31-122.

Munro, John (1996). "Review of David Hacker Fischer, The great wave and the rhythm of history," *H-Net Reviews in the Humanities and Social Sciences*, Feb., pp. 1-11.

Munro, John (2003). "The monetary origins of the 'Price Revolution': South German silver mining, merchant banking, and Venetian commerce," in Dennis Flynn, Arturo Giràldez and Richard Von Glahn, eds., *Global Connections and Monetary History, 1470-1800*, Aldershot, Eng.: Ashgate, pp. 1-34.

Nef, John (1941). “Silver production in Central Europe, 1450-1618,” *Journal of Political Economy*, 49 (4), pp. 575-91.

Ormrod, W. M. (1999). “The West European monarchies in the later Middle Ages,” in Richard Bonney, ed., *The Rise of the Fiscal State in Europe, c. 1200-1815*, pp. 123-60.

Palma, Nuno (2018). “Reconstruction of annual money supply over the long run: The case of England, 1279-1870,” *Economic History Review* 71(20), pp. 373-92.

Palma, Nuno (2019). “The existence and persistence of monetary non-neutrality: Evidence from a large-scale historical natural experiment,” *Manchester Economics Discussion Paper* EDP-1904.

Ramsey, Peter (1971). “Introduction” in Ramsey, ed., *The Price Revolution in Sixteenth-Century England*, London: Methuen & Co., pp. 1-17.

Rigby, Stephen (2010). “Urban population in late medieval England: the evidence of the lay subsidies,” *Economic History Review* 63 (2), pp. 393-417.

Schultze, Winfried (1999). “The emergence and consolidation of the ‘tax state’: The sixteenth century,” in Richard Bonney, ed., *The Rise of the Fiscal State in Europe, c. 1200-1815*, Oxford: Claridon Press, pp. 261-79.

Soetbeer, Adolf (1879). *Edelmetall-Produktion und Werthverhältniss zwischen Gold und Silber seit der Entdeckung Amerika’s bis zur Gegenwart*, Gotha: Justus Perthes.

Spufford, Peter (1984). “Le rôle de la monnaie dans la révolution commerciale du XIIIe siècle,” in John Day, ed., *Etudes d’Histoire Monétaire*, Lille : Presses Universitaires de Lille, pp. 355-95.

Spufford, Peter (1987). Coinage and currency, in M. M. Postan and Edward Miller, *The Cambridge History of Europe*, 2d ed., Cambridge: Cambridge University Press, pp. 788-873.

Spufford, Peter (1988). *Money and its Uses in Medieval Europe,* Cambridge: Cambridge University Press.

TePaske, John (2010). *A New World of Gold and Silver*, Leiden: Brill.

van Bath, Slicher (1963). *The Agrarian History of Western Europe a.d. 500-1850*, translated from the Dutch by Olive Ordish, London: Edward Arnold ltd.

Vilar, Pierre (1974). *Or et monnaie dans l’histoire*, Paris: Flammarion.

Watson, Andrew (1967). “Back to gold—and silver,” *Economic History Review*, XX, pp. 1-24.

Wilks, Ivor (1997). “Forests of gold,” in Peter Bakewell, ed., *An Expanding World: The European Impact on World History 1450-1800, vol. 19, Mines of Silver and Gold in the Americas*, Brookfield, Vt., USA: Variorum, pp. 1-39.

Wrigley, E. Anthony (1985). “Urban growth and agricultural change: England and the Continent in the Early Modern Period,” *The Journal of Interdisciplinary History*, 15 (4), pp. 683-728.

Wrigley, E. Anthony and Roger Schofield (1989). *The Population History of England 1541-1871: A Reconstruction*, Cambridge: Cambridge University Press, revised ed. (1st ed. 1981).

Figures

Figure 1A: Price level in England

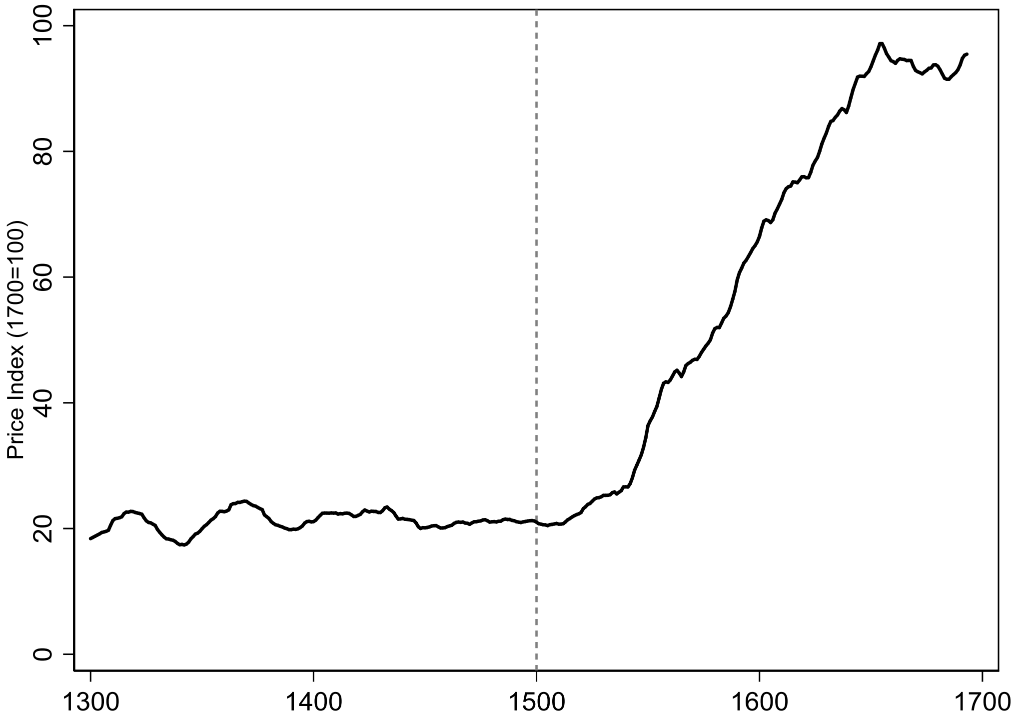


Figure 1B: Growth rate in price level (%)

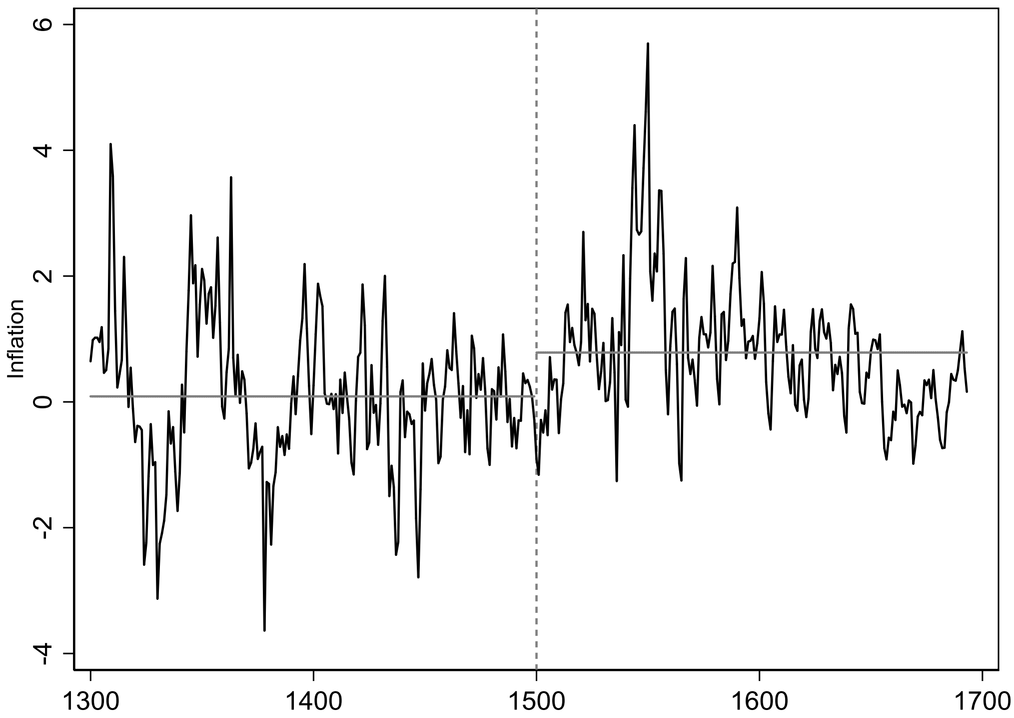


Figure 2A: Population in England

Figure 2B: Growth rate in population (%)

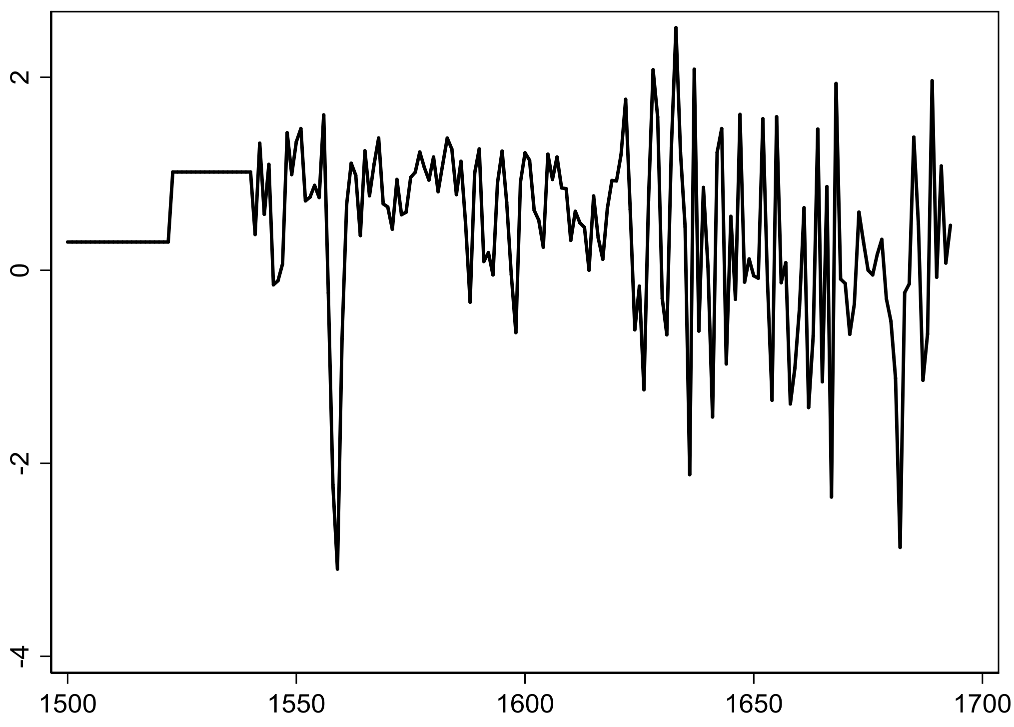


Figure 3A: Silver arrivals in Europe and European Production

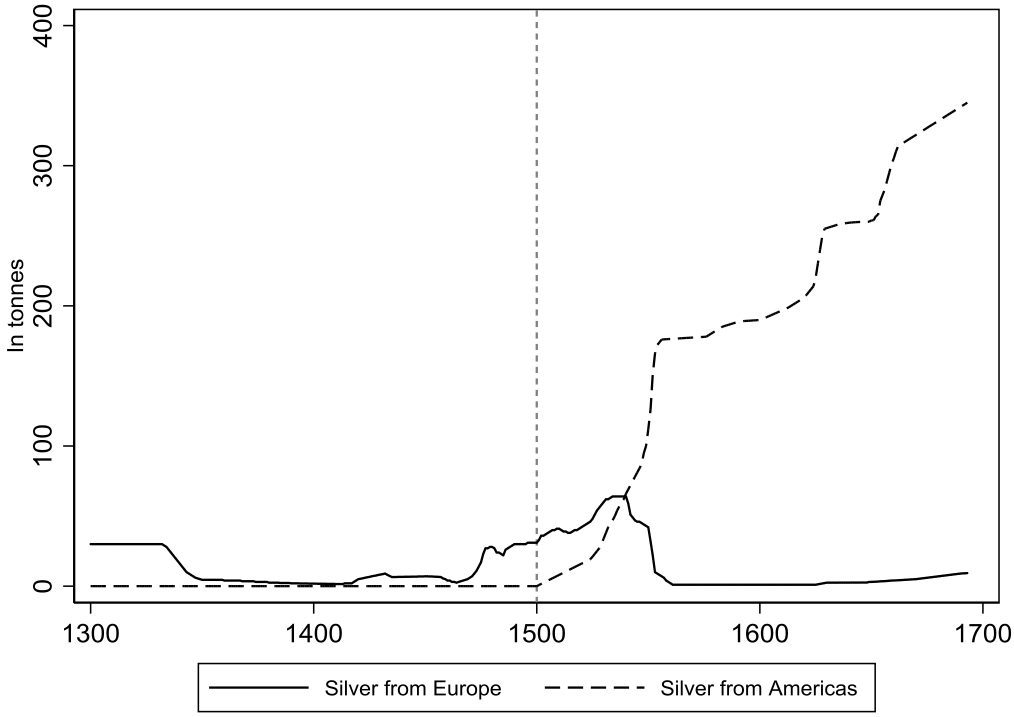


Figure 3B: Total arrivals and production of silver, and silver plus gold, in Europe

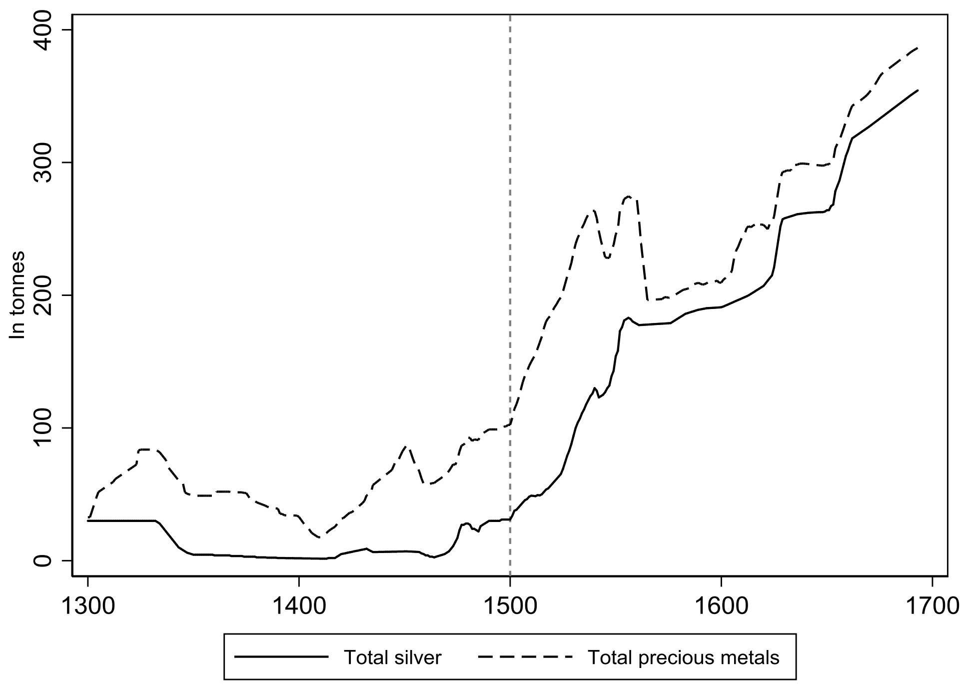


Figure 4A: Real GDP in England

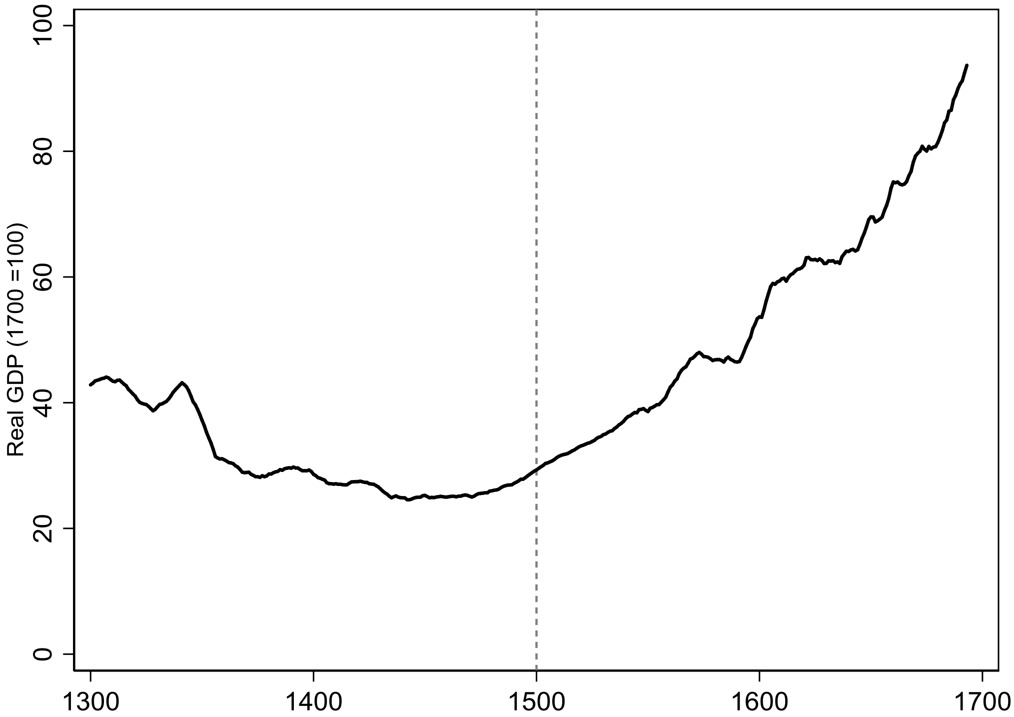
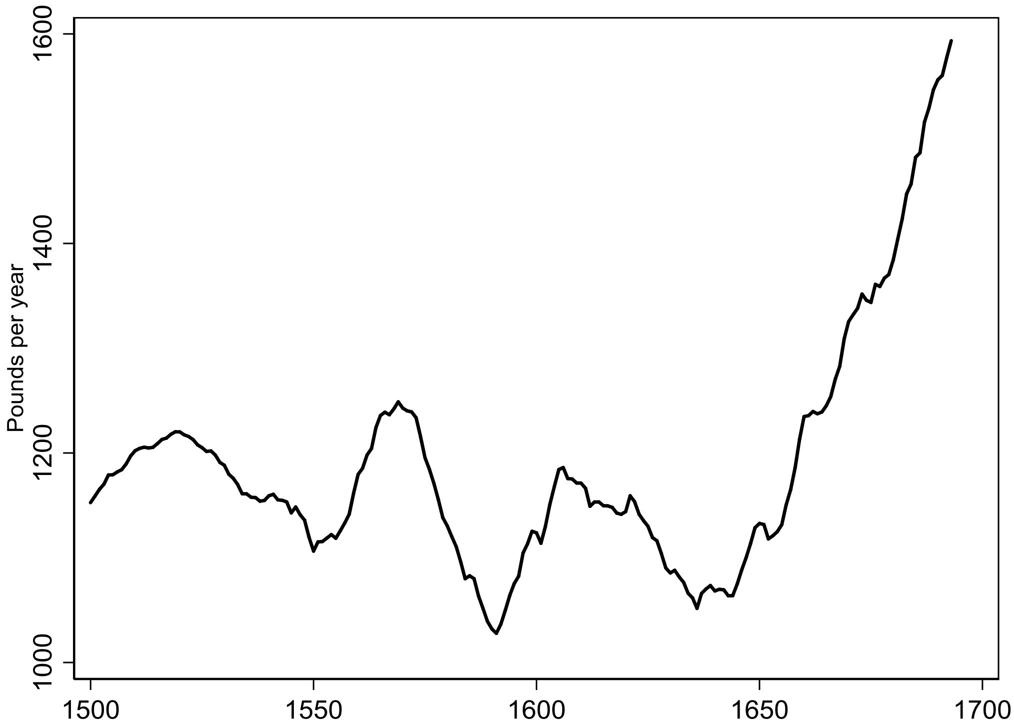


Figure 4A: Real GDP per capita in England



Tables

Table 1: Gold and silver production and arrivals from the Americas (1501-1700)

	Gold and Silver production and arrivals (tonnes)		Gold and silver arrivals in silver equivalents (tonnes)‡	
	Production Humboldt (1811)	Arrivals† Morineau (1985)	Gold	Silver
1501-1525	45	46	36	10
1526-1550	125	110	50	60
1551-1575	240	192	19	173
1576-1600	290	205	19	186
1601-1625	340	245	45	200
1626-1650	395	290	35	255
1651-1675	445	330	25	305
1676-1700	500	370	30	340

Note: † The last five numbers in the column are Morineau (1985) but the first three are the authors' adaptations of Barrett (1990); see text. ‡ Authors' calculations; see text.

Table 2: Estimates of the English price level, 1500-1700

	Dependent variable: log of prices									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Population (lpop)	1.78***	-	1.58***	-	-	-	-	-	-	-
	(123.78)		(27.60)							
Silver (lsilv)	-	0.84***	0.11***	-	-	-	-	-	-	-
		(33.77)	(4.30)							
lpop (lagged)	-	-	-	1.61***	-	0.95***	1.56***	1.53***	1.72***	1.94***
				(64.87)		(30.17)	(30.40)	(24.09)	(18.84)	(21.57)
lsilv (lagged)	-	-	-	-	0.68***	0.31***	0.35***	-	-	-
					(58.04)	(25.15)	(28.02)			
Output (lO)	-	-	-	-	-	-	-0.72***	-0.50***	-0.15	-0.60***
							(-12.31)	(-8.53)	(-1.35)	(-5.84)
Silver from the Americas (lagged)	-	-	-	-	-	-	-	0.12***	-	-
								(12.03)		
Gold (lagged)	-	-	-	-	-	-	-	-	-0.02	-
									(-1.05)	
log of precious metals (lagged)	-	-	-	-	-	-	-	-	-	0.28***
										(9.99)
Observations	194	194	194	194	194	194	194	194	194	194
R-squared	0.983	0.875	0.985	0.957	0.934	0.986	0.991	0.988	0.957	0.967

Note: The t-statistics in parentheses are based on robust (White) standard errors. Coefficients are statistically different from zero at the ***1%, **5%, and *10% level.

Table 3: Estimates of English inflation, 1500-1700

	Dependent variable: growth in prices				
	(1)	(2)	(3)	(4)	(5)
Growth in population	0.11***	0.12***	0.14***	0.14***	0.14***
	(6.68)	(8.15)	(7.97)	(7.78)	(7.94)
Growth in silver	0.02***	0.02***	-	-	-
	(5.04)	(5.54)			
Growth in output	-	-0.55***	-0.58***	-0.58***	-0.58***
		(-7.14)	(-6.69)	(-6.52)	(-6.61)
growth in silver from the Americas	-	-	0.002***	-	-
			(2.63)		
Growth in gold	-	-	-	-0.001	-
				(-0.50)	
Growth in precious metals	-	-	-	-	0.01**
					(2.59)
Observations	194	194	194	194	194
R-squared	0.350	0.485	0.385	0.361	0.385

Note: The t-statistics in parentheses are based on robust (White) standard errors. Coefficients are statistically different from zero at the ***1%, **5%, and *10% level.

Table 4: Urbanization : Fraction of English population living in towns of more than 10,000 or 5,000 inhabitants

Broadberry et al. (2015): 10,000 criterion					
1377	1500	1550	1600	1650	1700
2.60	3.63	3.71	6.20	9.32	13.82

Bairoch et al. (1988): 5,000 criterion					
1400	1500	-	1600	-	1700
5.7	4.6		7.9		11.8

Table 5: Estimates of English inflation with additional controls, 1500-1700

	Dependent variable: growth in prices				
	(1)	(2)	(3)	(4)	(5)
Growth in population	0.12***	0.11***	0.11***	0.11***	0.10***
	(7.77)	(7.62)	(7.44)	(7.56)	(6.30)
Growth in silver	0.02***	0.02***	0.02***	0.02***	0.02***
	(4.40)	(4.40)	(4.52)	(4.24)	(3.91)
Growth in output	-0.54***	-0.54***	-0.55***	-0.55***	-
	(-6.96)	(-6.64)	(-6.72)	(-6.68)	
Growth in urbanization	0.18	0.21*	0.23**	0.24*	0.26**
	(1.54)	(1.90)	(2.13)	(1.89)	(2.32)
Growth in Government services	-	0.01*	0.01*	0.01*	0.01**
		(1.74)	(1.80)	(1.74)	(2.06)
Death rate dummy	-	-	0.002	0.002	-
			(1.37)	(1.30)	
Growth in temperature	-	-	-	-0.01	-
				(-0.13)	
Observations	194	194	194	194	194
R-squared	0.493	0.504	0.509	0.509	0.375

Note: The t-statistics in parentheses are based on robust (White) standard errors. Coefficients are statistically different from zero at the ***1%, **5%, and *10% level.

Table 6: Estimates of English inflation over the extended period 1450-1700

	Dependent variable: growth in prices			
	(1)	(2)	(3)	(4)
Growth in population	0.12***	0.12***	0.12***	0.12***
	(6.99)	(6.89)	(6.99)	(7.08)
Growth in silver	-0.00001	-	-	-
	(-0.02)			
Growth in output	-0.58***	-0.58***	-0.57***	-0.57***
	(-6.71)	(-6.72)	(-6.85)	(-6.86)
Growth in urbanization	0.15***	0.15***	0.16***	0.16***
	(4.21)	(4.51)	(4.67)	(4.85)
Growth in Government services	0.002	0.002	0.003	0.003
	(0.83)	(0.88)	(1.05)	(1.08)
Growth in gold	-	0.001	-	-
		(0.42)		
Growth in precious metals	-	-	0.01***	-
			(3.00)	
Growth in precious metals, French exchange rate	-	-	-	0.01***
				(3.36)
Observations	244	244	244	244
R-squared	0.388	0.388	0.409	0.416

Note: The t-statistics in parentheses are based on robust (White) standard errors. Coefficients are statistically different from zero at the ***1%, **5%, and *10% level.