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Invention, Entrepreneurship and Prosperity: The Dutch Golden Age

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Abstract. The Dutch 16th and 17th centuries were a period of unprecedented economic prosperity. Since the Dutch economy was and is very small, an important source of growth was bound to be international trade. In this paper we argue that the contributions of entrepreneurship to innovation transcend the standard categories of creation of new products and processes. Entrepreneurship also finds new markets for its products and creates new modes of trade. The Dutch were the globalization pioneers *avant la lettre*. The same considerations apply to the later decline of the Dutch economy. The rise and decline of the Dutch Republic are well explained by a combination of the traditional Total Factor Productivity (TFP) driver, innovations, and two facets of trade, namely openness and entrepreneurship. The evidence for these contentions rests on a remarkable body of economic data that apparently are unique in the early dates to which they pertain and the extensive information they provide.

[1] This author's research was performed at Bar-Ilan University and NYU Polytechnic Institute and the Berkley Center for Entrepreneurship and Innovation at the Stern School of Business. Benjamin de Vries (Bar-Ilan) and William Baumol and Charles Tapiero (NYU) offered constructive input and facilitated this project. Anne Noyes Saini (NYU) masterly edited the manuscript. The authors are also grateful to the Ewing Marion Kauffman Foundation for its support of this work.

1. Introduction

The Dutch Republic embarked on its modern economic growth in the 16th century, preceded in Europe only by the North Italian cities. In this paper we trace the performance of the Dutch economy from well before its Golden Age in the 17th century to well after, which facilitates a better understanding of this fascinating era, both in terms of its timing and the causes of the rise *and* decline. De Vries and Van der Woude (1997) claim that long before the late 18th century British Industrial Revolution, the 'first modern economy' displayed strong per capita growth, interrupted only by wars and other external shocks.

The central question of this paper is how to explain the remarkable performance of this pre-1800 economy. Which factors help to explain the strong economic growth that occurred during the Golden Age, and how large was their contribution? We are enabled by the survival of an impressively rich body of data, and by a recent reconstruction of the national accounts of Holland in this period (Van Leeuwen and Van Zanden 2010). This allows us to measure the standard economic performance measure, TFP, and consider its traditional driver, technology, or, more precisely product and process innovation (as measured by the number of patents issued). However, because the Dutch economy was (and still is) extremely open, we must factor in the role of trade in innovation and TFP, and will find that the entrepreneurs played an important role in the process.

In this analysis, we make extensive use of a data base recently provided by van Leeuwen and van Zanden (2010), covering factor inputs, industry outputs, and trade. These data cover the Dutch Republic's most important province, Holland, where the pregnancy of the Golden Age occurred. The data base itself is remarkable because there apparently exists no other pre 1800 system of national accounts that is nearly so comprehensive. There are, of course, several studies that analyze historical output data econometrically, especially for England (Crafts, 1995), but these cover only industry and a later period (post-1700). As far as we know, our paper is the first econometric analysis within the tradition of growth accounting of an older economy.

2. The rise and decline of Holland's economy

Between 1540 and 1807, Holland's economy expanded and contracted quite spectacularly. Figure 1 shows the paths of both output and population growth.

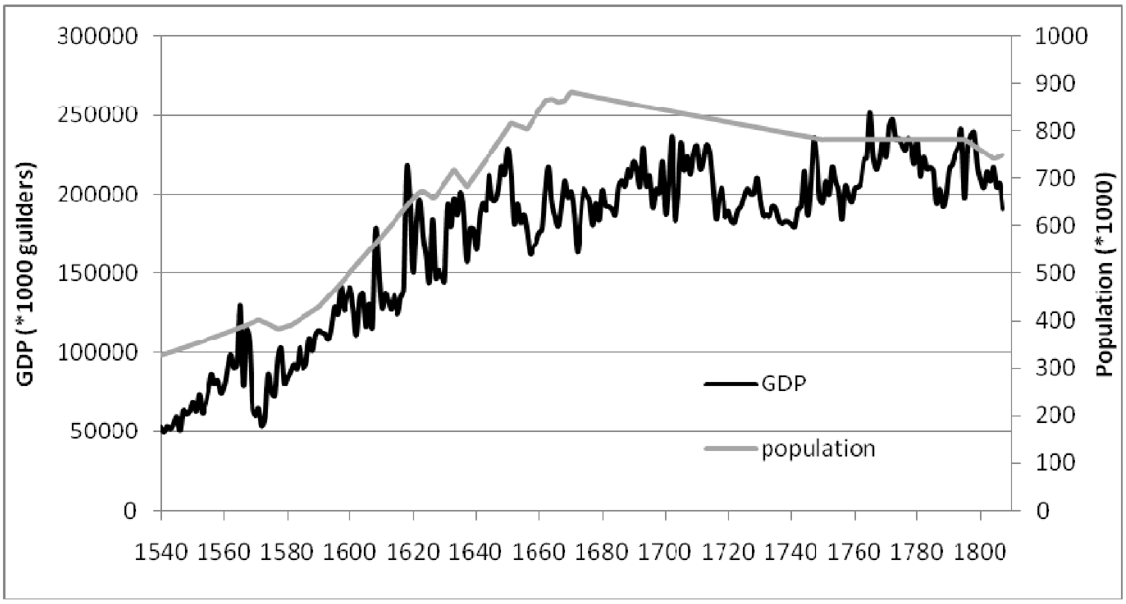

Figure 1: Output and population

During this period, GDP is initially rising rapidly (1540-1565), then collapsing during the very first years of the 1566-1648 Dutch revolt against the Spanish, and growing again very rapidly in the next 75 years (1575-1650). After about 1660 the trend becomes flat, but population growth ends at about the same time, and then contracted until 1750 (De Vries and Van der Woude 1997 discuss these trends in detail.). At this time, of course, there was no 'welfare state,' and people had to chase jobs, often from one country to another, in order to survive. Thus, population mirrored output. When Holland's economy grew, it attracted people, and when it declined the inflow fell dramatically, unable to close the gap between the death and birth rates, typical for urban centers (De Vries 1984). This labor market flexibility tempered the rise and decline of the economy on a *per capita* basis. Holland's capital market was also very flexible. Success attracted foreign investment, and failure induced capitalists to invest abroad, particularly in the rising British economy.

Such a view implies that economic growth accelerated during the high days of the Golden Age. Indeed, Table 1 shows that economic growth took place largely during the period roughly 1540-1620. To get a better idea about the sources of growth Van Zanden and Van Leeuwen (2010) applied a growth accounting analysis for the period after 1540 which is further explained in the next section. The results show that TFP only contributed

Table 1 Estimated sources of economic growth, 1540-1805

	Population	Human Capital	Capital Stock	Land	Weighted Inputs	GDP	TFP
1540-1620	0,88	1,01	1,56	0,17	1,04	1,67	0,63
1620-1670	0,58	1,19	0,73	0,16	0,70	-0,16	-0,86
1670-1750	-0,14	0,31	-0,15	0,04	-0,04	0,13	0,17
1750-1805	0,00	0,17	0,20	0,09	0,10	-0,09	-0,20

Note: TFP shares of inputs: population 40%, capital stock 30%, land 10%, human capital 20%.
Source: Van Zanden and Van Leeuwen (2010)

significantly to growth in the period to ca. 1620. Figure 2 shows the same estimates of TFP, but presented in this case as an index (1540=100). It shows the wave-like character of technological development, which accelerated between 1570 and 1620, but slowly declined in the following century. Such a pattern is also found in studies of the number of patents granted by Dutch authorities (which peak in the 1620s and 1630s, and slowly decline afterwards (Van Zanden and Van Riel; Table 1.5), and by the qualitative information on the rise and decline of Dutch technological leadership collected and analysed by Davids (2008). The figure shown here is also almost identical to the estimates of the growth of TFP in the shipping sector, presented by Van Zanden and Van Tielhof (2009), which also shows strong increase in TFP until the 1620s, and decline afterwards. The technological progress realized in this period also had important implications for the competitiveness of the Holland economy.

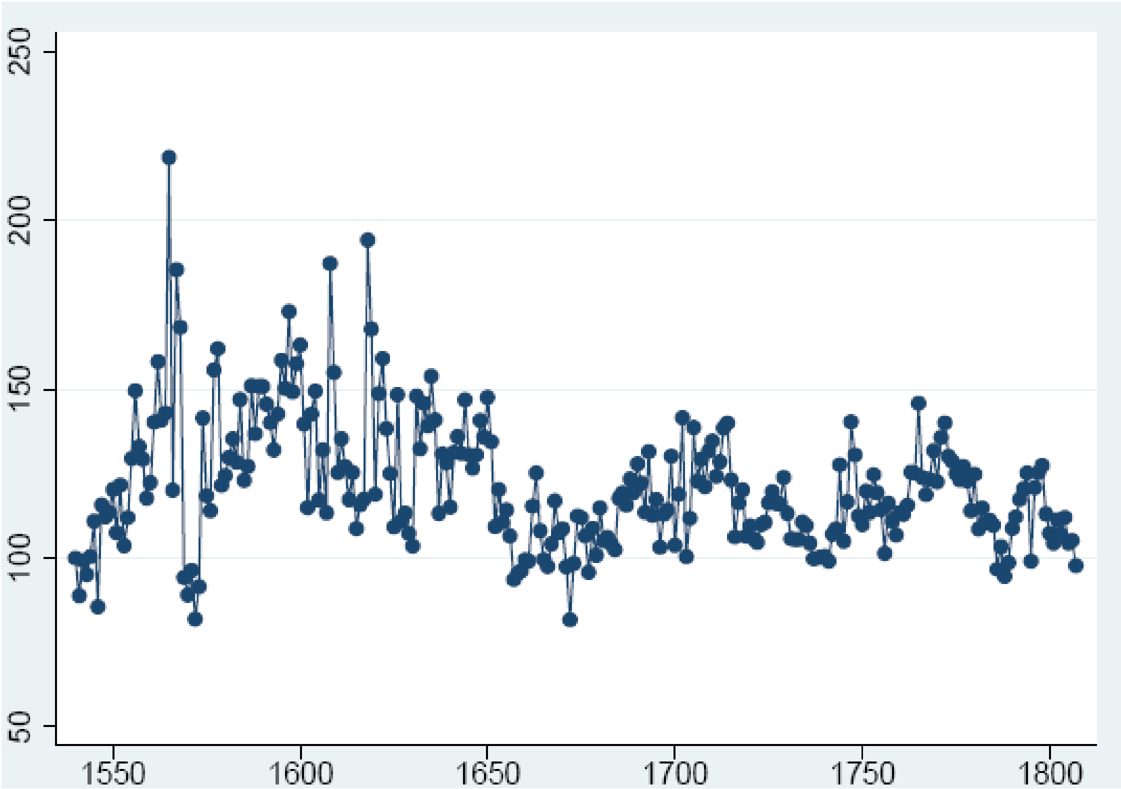

Figure 2: TFP from 1540 (normalized to 100) to 1807

When after the 1620s, this wave of technological change subsided, competitiveness came under pressure, as competitors learned to copy the Dutch technologies, or developed their own. Most of the growth was now caused by increasing implementation of capital intensive, labour saving technologies (i.e. Davids 2008; Van Zanden and Van Leeuwen 2010), combined with a decreasing population. Furthermore, Davids (2008) stresses a de-linking of the production of useful knowledge from industry – in a way the disintegration of the 'knowledge economy' that made possible the sharp rise of productivity in the first half of the Golden Age.

Other factors explaining the performance of the Dutch economy in this period suggested by the literature are its openness and the supply of entrepreneurship. Hence, three basic factors seem to explain economic development and its downturn: technological change, openness (as an indicator of exchange with foreign competitors), and entrepreneurship (as an indicator of the infrastructure). All are directly or indirectly linked to technology and its implementation. This also confirms Israel's (1998) distinction between the early Golden Age and the later Golden Age. Whereas Figure 1 and particularly Figure 2 show, that in the early Golden Age, the economy was poised for growth, all signals were green: GDP, population, and TFP. In the later Golden Age, TFP recovered from the early 1650s crash, but only because Holland's population was much reduced.

This pattern, though, did not apply at all to all sectors of the economy. Whereas industry and services were clearly experiencing a phase of strong growth, agriculture did not experience a similar increase during the first phase of the Golden Age. As Table 2 shows, between 1540 and 1620 industry and services grew massively, while agriculture stagnated. Only after the decline set in in the 1670s, agriculture became the fastest growing sector, even though this was largely because of declining growth rates in the other sectors.

Table 2. Compound annual growth by sector (5 year averages)

	agriculture	industry	services	GDP	population
1510-1540	0.69	0.75	0.39	0.57	0.65
1540-1620	**0.59**	**1.34**	**1.98**	**1.53**	0.88
1620-1670	0.47	0.51	-0.64	-0.14	0.58
1670-1750	-0.36	-0.13	0.39	0.12	-0.14
1750-1805	0.42	0.20	-0.37	-0.09	0.00

This difference between agriculture and industry/services can also be seen in below Figure 3. The TFP in industry and services is very similar to TFP whole economy – perhaps the determinants are also the same; TFP in agriculture seems to be driven by very different factors – perhaps this can be analyzed as well.

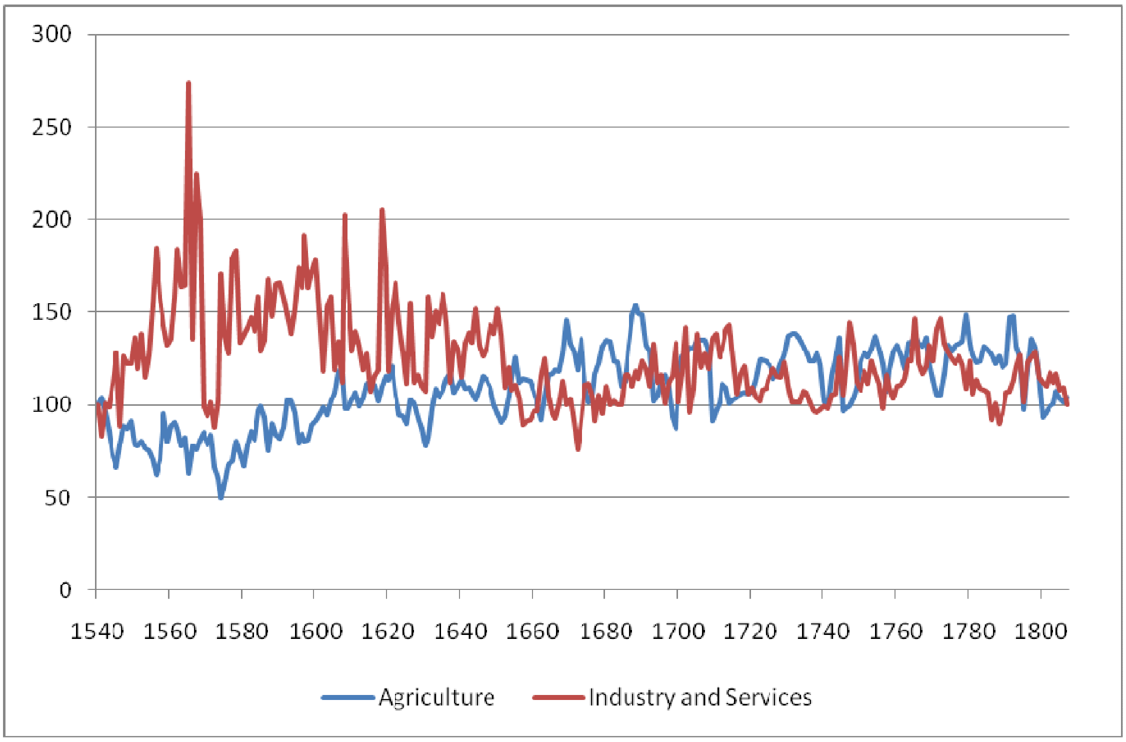

Figure 3: TFP from 1540 (normalized to 100) to 1807 by sector

3. Total Factor Productivity

Our starting point is the series of TFP as plotted above. We proceed on the assumption that labor, *L*, capital, *K*, human capital, *H*, and arable land, *A*, produce output, *Y*, in accord with a Cobb-Douglas function.[2] Following van Leeuwen and van Zanden's (2010) analysis of value shares, we adopt as input elasticities 0.4 for labor, 0.3 for capital, 0.2 for human capital, and 0.1 for land. The sum of these elasticities is the returns-to-scale elasticity; here it is 1, which corresponds to constant returns to scale. It follows that the relation between the inputs and output is given by $Y_t = TFP_t L_t^{0.4} K_t^{0.3} H_t^{0.2} A_t^{0.1}$ where

[2] This follows van Leeuwen and van Zanden (2010), with human capital added. Labor is measured by total population. Capital stock is the sum of construction and shipbuilding capital stock. Land is the cultivated area, and human capital is the average years of education. Output is measured by GDP in constant prices, corrected for the Gerschenkron (1947) effect, because of which the relative prices of fast growing sectors were declining compared with the prices of branches of industry that grew more slowly. Output and the four inputs have been normalized to 100 in 1540. Arable land has been increasing over this period by about 30% because of land reclamations (new polders).

multiplicative factor, TFP_t, total factor productivity, measures output as a function of the level of input. We want to understand the pattern followed by this measure of performance over a long period, including the Golden Age.

4. Technology

Technology is considered as the standard driver of TFP and is usually measured by R&D or some output measure of innovation, such as innovation counts or patent counts. The patents granted in the Netherlands (The General State and the various provinces) are reported in Doorman (1940), and we use these data as an index of technological change (see Davids 2008). However, because we measure the level of TFP rather than its growth rate, we must construct a *patent stock*, *P*. In order to do this, we start from an initial value of 0 (which seems reasonable because our time series begin as early as 1540, while the first patent granted was only in 1559) and use a 10 percent depreciation rate.[3] , following Pakes and Schankerman (1984). Figure 4 traces the evolution of the patent stock from 1540 to 1807.

[3] Pakes and Schankerman (1984) estimated a rate of patent depreciation of 25%. Even though the patents granted in the Netherlands in the 16^{th}-18^{th} century had generally a shorter lifetime than nowadays (somewhere between 2 and 10 years), we nevertheless considered that these inventions outlasted their patent lifetime, and hence we considered a lower depreciation rate of the order of 10%.

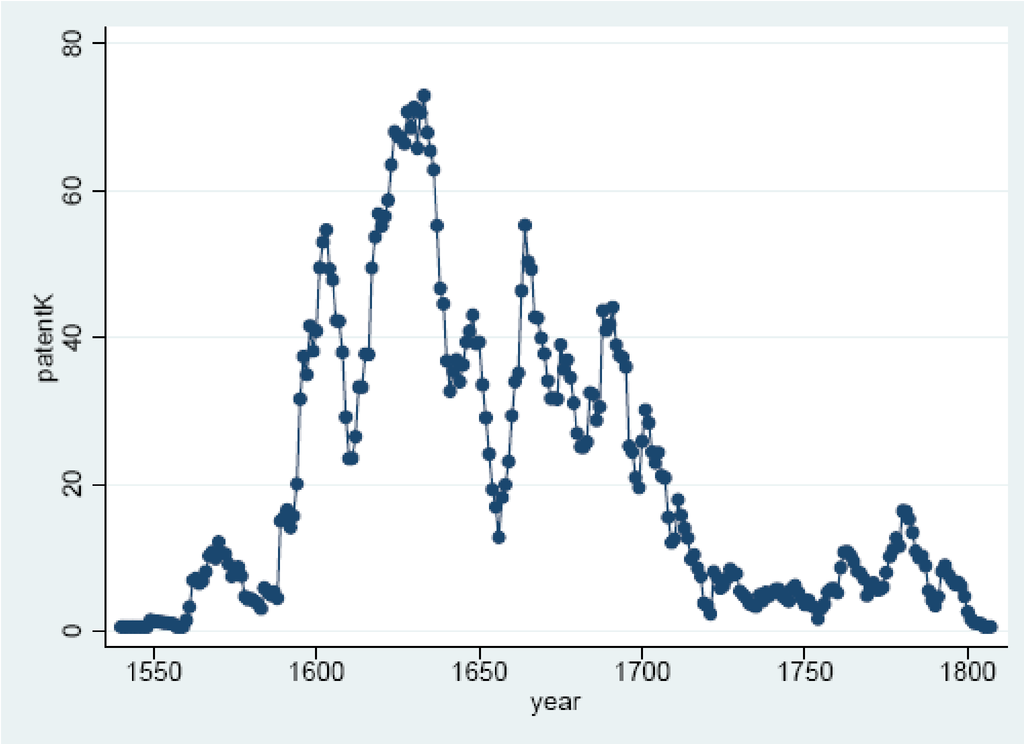

Figure 4: The patent stock from 1540 to 1807.

5. Trade and entrepreneurship

Because the Dutch economy was driven by trade, which, in turn, affects productivity, we must include trade in our performance analysis. The rise of the Republic's economy evidently was driven by entrepreneurship in overseas trading (Israel, 1998). The Dutch explored new routes which entailed different merchandise, beginning with the Baltic and following later with Spain and Portugal. When barred by political or logistical difficulties, the Dutch were creative in adoption of new modes of trade, such as the 'long haul' route to the Indies (primarily the East), which by-passed Spain. As such, the Dutch were the globalization pioneers *avant la lettre*. The same considerations apply to the later decline of the Dutch economy. In the late 17th century, the Dutch showed noticeably less dynamism than the English and the French in opening up new strands of Asian and Atlantic commerce.

The traditional trade-based influences on performance include openness and the ratio of trade (exports plus imports) to GDP. It is not our intent to diminish the importance of openness, but it seems clear that the magnitude and influence of innovative trade entrepreneurship are not measured effectively by this attribute. Whereas openness can be taken to have a substantial influence on the volume of trade, innovative entrepreneurship pertains to the geographic spread of trade, particularly by inauguration of new routes. These are different facets of the spatial distribution of trade. For our purposes, we take into account measures of both openness and entrepreneurship.

For this analysis, we use Dutch shipping capacity data for five trade routes, the Sound (Baltic), the East-Indian Company VOC (Asia), the West-Indian Company WIC (Americas), the Rivers (Continental Europe), and an aggregate of the other routes, which will be called "the Rest". We thus have aggregate data, x_{it}, where $i = 1, ..., 5$ are the five routes, and t indexes time, which we have scaled as fractions of GDP. *Openness* is measured by the volume of trade, $O_t = \sum_{i=1}^{5} x_{it}$. *Mercantile entrepreneurship* is measured by the spread or standard deviation of trade (the square root of the second, centered, moment): $E_t = \sqrt{\{[(x_{1t} - \mu)^2 + ... + (x_{5t} - \mu)^2]/5\}}$. Openness and entrepreneurship are both normalized by GDP.

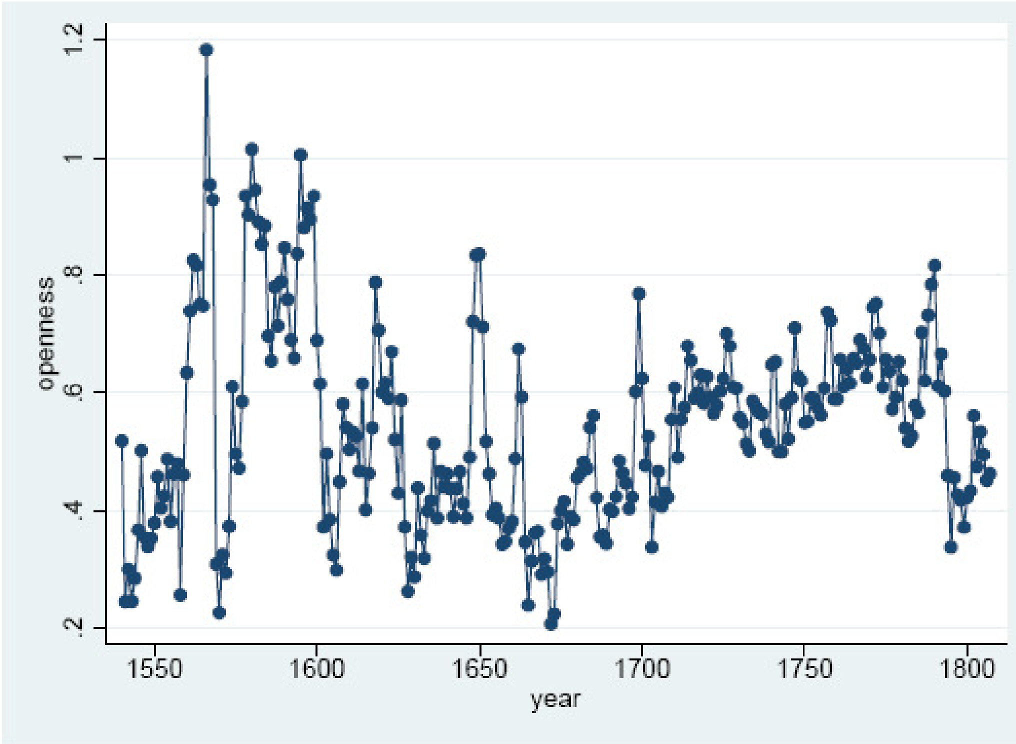

Figure 5: Openness from 1540 to 1807

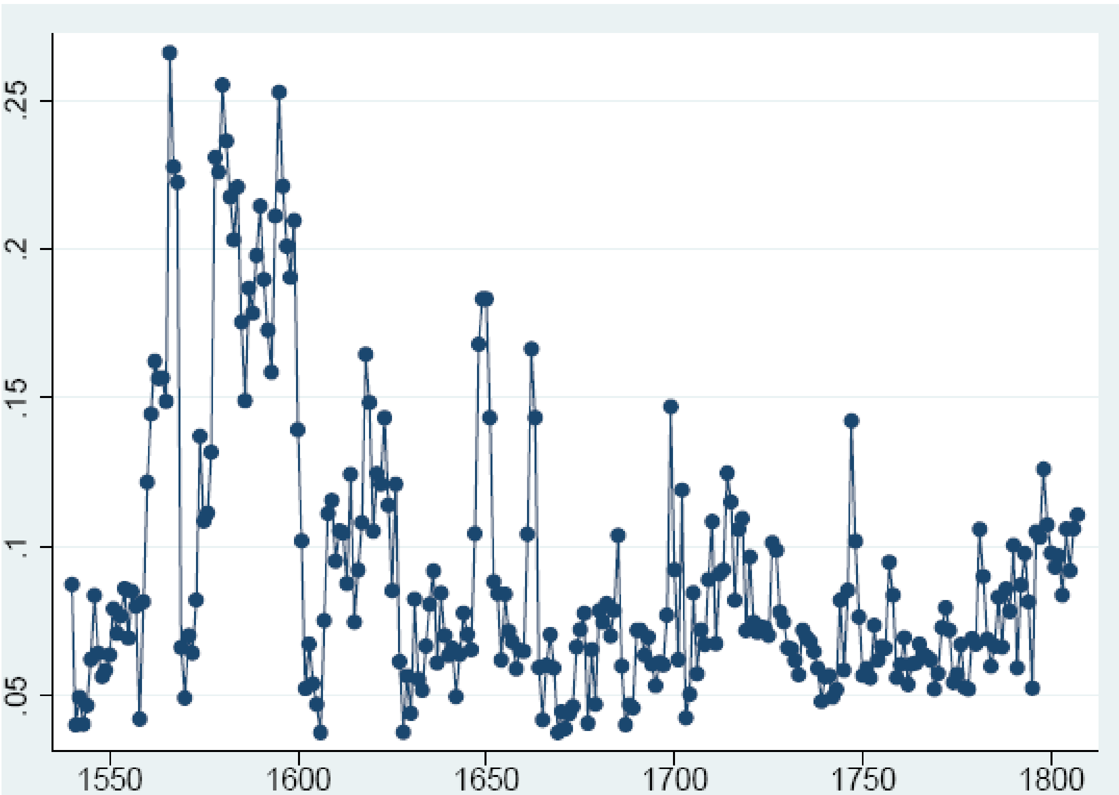

Figure 6: Mercantile entrepreneurship from 1540 to 1807

The results shown in Figure 5, which plots entrepreneurship over time, lend support to Israel's (1998) focus on economic dynamism as the driver of prosperity in the late 16th and the 17th century and its petering out in the late 17th century. Comparison of openness (Figure 5), entrepreneurship (Figure 6), and patent stock (Figure 4) with TFP (Figure 2) is startling. The four graphs show a hump shape and may be viewed as a description and at least part of the diagnosis of the mechanism underlying the early Golden Age, in economic terms.

In the next section we will substantiate these observations by an econometric analysis of TFP in terms of the traditional, technological variable, innovations, as well as the trade variables, openness and entrepreneurship.

6. Explaining output growth

The analysis leads us to regress TFP measure, *T*, on patent stock, *P*, openness, *O*, and entrepreneurship, *E*. Here, we use a log-linear specification so that the coefficients are elasticities.[4] As shown in Table 1, all three variables are positive and highly significant.

Table 1 also shows that the traditional driver of TFP, innovation, is found to have an elasticity of 0.03. The patent stock can be considered as an alternative to the R&D stock for measuring the inventory of knowledge, when the purpose is to estimate an elasticity or rate of return. In the literature, the elasticity of output with respect to innovation is generally measured from the input side using an R&D stock, and this is reported to be approximately 0.08 (Hall, Mairesse and Mohnen, 2010). Our estimate of elasticity of TFP to the patent stock of 0.03 is smaller but not far off. We can also do a back of the envelope exercise and convert the elasticity to a rate of return by multiplying it by the

[4] As we took the logs of the stock of patents, zeros prior to 1559 were set equal to 0.1. After 1559, hardly a year went by without at least one patent application.

ratio of the average output to the average patent stock (as $\frac{dY/Y}{dP/P} = 0.03$ implies $\frac{dY}{dP} = \frac{Y}{P}0.03$). Dividing this marginal value by the average GDP in 1800 prices we obtain a marginal return on patent of approximately 0.16 %. It is difficult to summarize by one number the value of a patent, given the high skewness in the distribution of patents and the additional asymmetry of distributions across sectors. As a rough comparison, Bessen (2006) evaluates the average patent in the U.S. at 3% of the R&D. If we multiply this number by a 2% R&D/GDP ratio, which corresponds more or less to the Dutch R&D intensity, we obtain an average value of patent of 0.06% of GDP. Our return estimate is larger than this but, again, not far off. It is fascinating that, in the Golden Age, innovation appears to have had an impact of the same magnitude as it has in modern economies.

Regressor	**Coefficient**	**t-value**
Capital/labor	0.173	1.79
Human capital/labor	0.234	3.17
Arable land/labor	0.302	4.09
Patent stock	0.057	5.30
Openness	0.212	5.33
Entrepreneurship	0.052	1.73
Constant term	0.814	12.42

Table 1: Regression of labor productivity on other (than labor) input to labor ratios, and on innovation, openness and entrepreneurship as drivers of TFP (imposing constant returns to scale)

The standard trade measure, openness, has an elasticity of 0.12. This means that an increase in openness of 1% raises growth by a one-eighth of a percentage point. This magnitude is slightly less than what Lewer and Van den Berg (2003) found for modern economies: elasticities of 0.43/0.15/0.22/0.21 for high/upper-middle/lower-middle/low income countries, respectively.

Our new variable, mercantile entrepreneurship, is found to have strong impact; its elasticity is 0.14. This means that an increase in entrepreneurial activity of 1% raises growth by one-seventh of a percentage point. If this is indeed so, it follows (quite plausibly) that the entrepreneur was indeed a major contributor to economic growth in the Dutch Republic. The rise in TFP from 100 to 150 over the period 1550-1650 can be decomposed as follows. The growth factor $1+g$ = 150/100 = 1.5 is the product of the growth factors of patents $1+g_P = (P_{1650}/P_{1550})^{0.030}$ = Pierre, openness $1+g_O = (O_{1650}/O_{1550})^{0.120}$ = Pierre and entrepreneurship $1+g_E = (E_{1650}/E_{1550})^{0.136}$ = Pierre (see Table 1). The share of entrepreneurship is $g_E/(g_P + g_O + g_E)$ = .

7. Conclusion

The rise and decline of the Dutch Republic can be explained by a combination of the traditional TFP driver, innovations, and two facets of trade: openness and entrepreneurship. Economic decline may put pressure on research and development outlays and often intensifies calls for protection, but it seems clear that yielding to these pressures aggravates the problems. Instead, the better solution involves creation of an economic climate that encourages entrepreneurship in the wide sense of not only facilitating new products and processes but also new lines of trade.

In closing, it must be emphasized once again that these results follow from a noteworthy set of data that constitute one of the earliest records extant of the workings of an economy in the vanguard of European industrial revolutions. It is all the more remarkable that these data describe a tiny economy recently ravaged by decades of war, which rose to dominate the world economy for the better part of a century or more. The evidence that innovative entrepreneurship played a substantial part in this extraordinary achievement indeed offers further substantial evidence of the importance of this activity to the general welfare.

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