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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.

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1. Introduction

The Dutch Republic embarked on its modern economic growth in the 16th century, preceded in Europe only by the North Italian cities. The period that has been dubbed "The Dutch Golden Age" is, basically, the 17th century. The early Golden Age spans the period 1590-1648 (the Year of Independence from Spain), a period of unprecedented innovation and prosperity, according to Israel (1998), who also notes that the early Golden Age was followed by a marked slackening, and after 1672 (the Year of Disaster, with the French-English invasion) stagnation, which persisted until the middle of the eighteenth century. Israel dates the end of the Golden Age at 1702 (the death of William III, Stadholder of the Republic and King of England), although England had already taken over world leadership.

In this paper we trace the performance of the Dutch economy from well before the Golden Age (1540) to well after (1807), which facilitates a better understanding of this fascinating era, both in terms of its timing and the causes of the rise and decline. We are enabled by the survival of an impressively rich body of data, to employ the standard economic performance measure,Total Factor Productivity (TFP), and consider its traditional driver, technology, or, more precisely product and process innovation. 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.

Recently ten Raa and Mohnen (2002) have shown that for an international price-taking economy, TFP comprises not only the standard Solow residual (the difference between output and input growth, which measures product and process improvements), but also a terms-of-trade effect. Their analysis is apt for a price-taking economy with competitive imports (like the Canadian economy they investigated). But the introduction of the terms of trade is even more critical for the Dutch Republic, which was an economy that not only adjusted to international price changes, but opened entire new lines of trade, backed by the invention of capital share markets and the exercise of monopoly power in establishing new trade relations. In other words, instead of a neoclassical microeconomic

analysis, here we employ a more direct, reduced form, approach to the measurement and explanation of the economy's performance.

In this analysis, we make extensive use of a data base recently provided by van Leeuwen and van Zanden (2009), 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 earlier system of economic accounts that is nearly so comprehensive. There are, of course, several studies that analyze historical (industrial) output data econometrically, especially for England (Crafts, 1995), but these cover only the post-1700 period. As far as we know, our paper is the first econometric analysis 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.

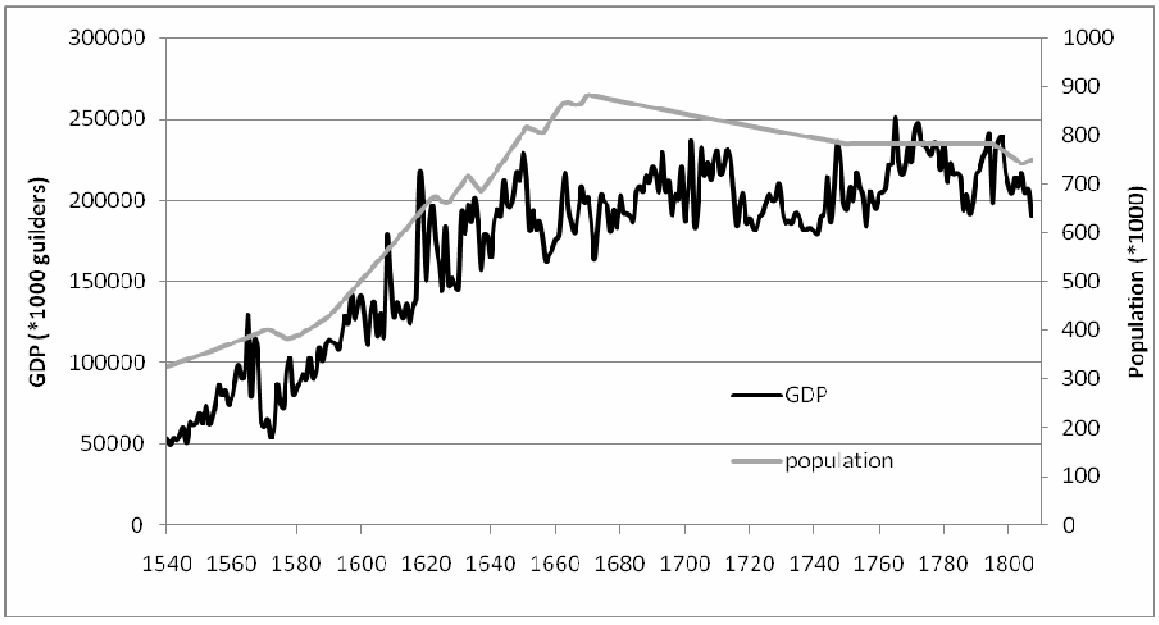

Figure 1: Output and population

During this period, GDP was initially flat, then climbed steeply (1570-1650), and finally flattened again. Meanwhile, Holland's population grew until 1670 and then contracted until 1750. This population contraction offset the decline in output. 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, it repulsed them. This labor market flexibility tempered the rise and decline of the economy on a *per worker* basis. Holland's capital market was also flexible. Success attracted foreign investment, and failure induced capitalists to invest abroad. Since TFP is essentially output per unit of factor input, an aggregate of labor, physical, and human capital, as well as land, its development was more tempered, and it has been argued that Holland's economy continued to perform well after the Golden Age (van Leeuwen and van Zanden, 2009). However, as shown in Figure 2, TFP followed a hump-shaped pattern. (The construction will be explained in the next section.)

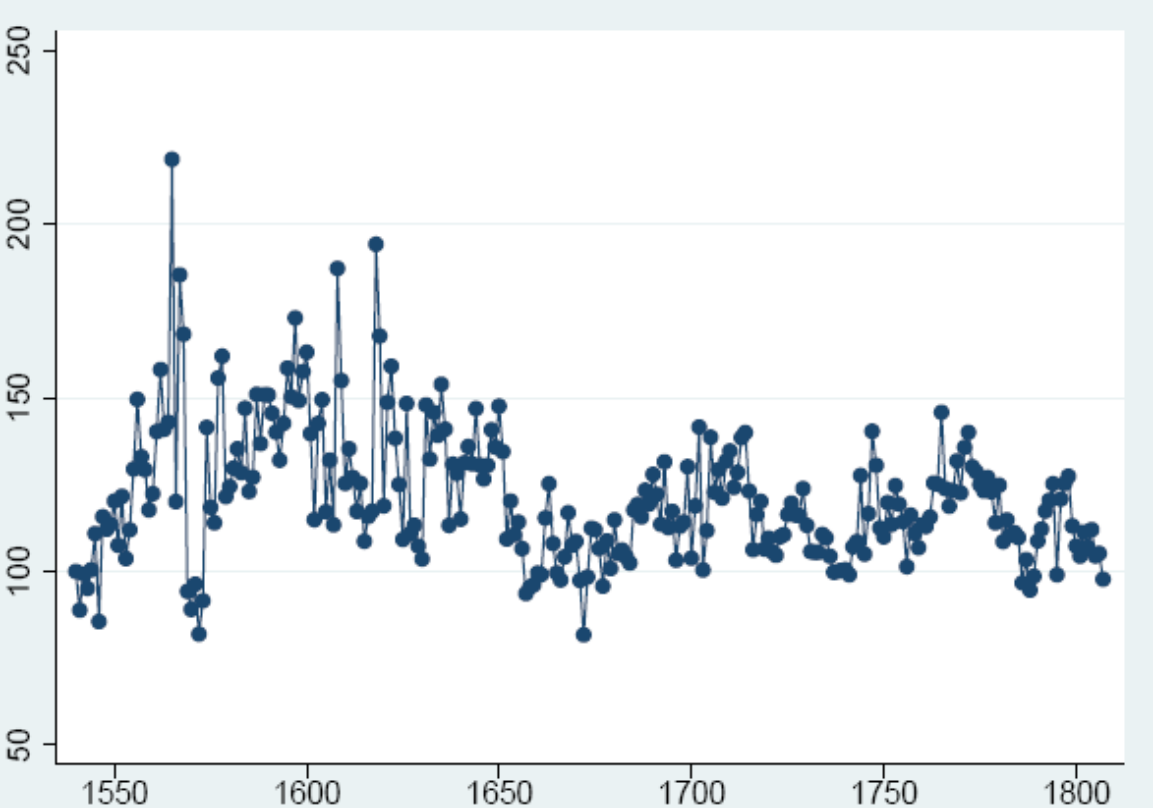

Figure 2: TFP from 1540 (normalized to 100) to 1807

Figures 1 and particularly 2 confirm Israel's (1998) distinction between the early Golden Age and the later Golden Age. 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.

3. Total Factor Productivity

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

[2] This follows van Leeuwen and van Zanden (2009), 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

Leeuwen and van Zanden's (2009) analysis of value shares, we obtain 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 $Y = TL^{.4}K^{.3}H^{.2}A^{.1}$, where multiplicative factor, T, measures output as a function of the level of input. Variable T therefore represents TFP and is employed to measure the performance of the economy. This is given by the input and output data via the relationship $T = Y/L^{.4}K^{.3}H^{.2}A^{.1}$. Because we want to understand the pattern followed by this variable over a long period, including the Golden Age, we also must investigate technology and trade related explanations.

Product and process innovations are considered to be standard drivers of TFP, and are usually measured by number of patents. The patents granted in the Netherlands (The General State and the various provinces) are reported in Doorman (1940), and we use these data for our analysis here. 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 25 percent depreciation rate, following Pakes and Schankerman (1984).

4. Trade

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. 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

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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.

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. Israel (1998) argues that, in the late 17th century, the Dutch showed noticeably less dynamism than the English and the French in opening up new strands of (Asian) 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 is 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, $O = x_{1t} + ... + x_{5t} = 5\mu$, where μ is the first moment or mean level of trade (as fraction of GDP). *Entrepreneurship* is measured by the spread or standard deviation of trade (the square root of the second, centered, moment): $E = \sqrt{\{[(x_{1t} - \mu)^2 + ... + (x_{5t} - \mu)^2]/5\}}$.

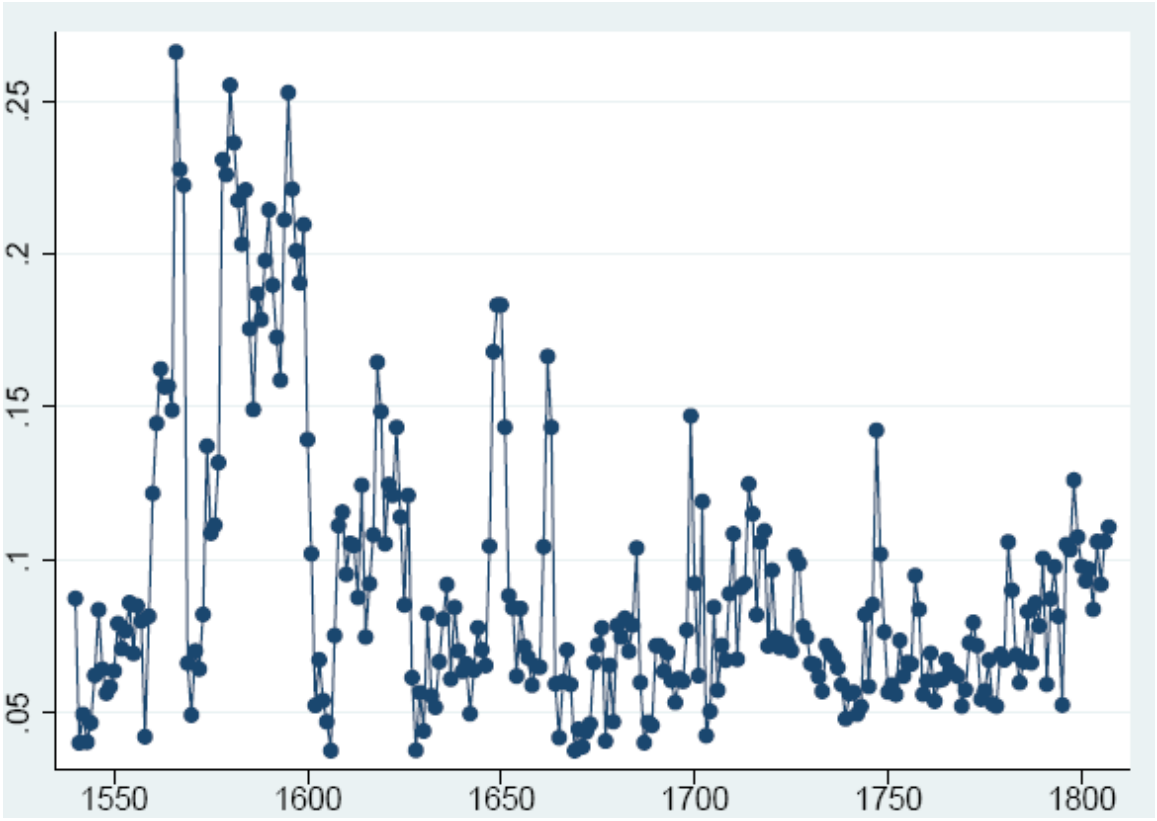

Figure 3: Entrepreneurship from 1540 (normalized to 100) to 1807

The results shown in Figure 3, 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 entrepreneurship (Figure 3) with TFP (Figure 2) is startling. Both graphs show a hump shape. Since TFP is the leading performance measure and entrepreneurship is considered an important driver of TFP, Figures 2 and 3 may be viewed as a description and at least part of the diagnosis of the mechanism underlying the Dutch 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.

5. Performance analysis

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.[3] As shown in Table 1, all three variables are positive and highly significant.

Regressor	**Coefficient**	**T-value**	**95% Confidence interval**	
Patent stock	0.030	5.59	0.019	0.041
Openness	0.120	3.55	0.054	0.187
Entrepreneurship	0.136	5.55	0.088	0.185
Constant term	5.150	104.95	5.054	5.247

Table 1: Regression of TFP on innovation, openness and entrepreneurship

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 also can convert the elasticity to a rate of return by multiplying it by the ratio of the average output to the average patent stock (as $\frac{dY/Y}{dP/P} = 0.03$ implies $\frac{dY}{dP} = \frac{Y}{P}0.03$). This yields a marginal return on a patent of approximately half a million 1880 Florins, which represents roughly 0.2% of the GDP in Holland in 1880. As a rough comparison, today a patent often is evaluated at about $1 billion of R&D, which represents approximately 0.1% of Holland's 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.

[3] 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.

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, 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.

6. Lessons

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.

References

Crafts, N.F.R. (1995), "Exogenous or Endogenous Growth? The Industrial Revolution Reconsidered," *Journal of Economic History* 55, 4, 745-72.

Doorman, G. (1940), *Octrooien voor Uitvindingen in de Nederlanden uit de 16e-18e Eeuw*. 's-Gravenhage.

Gerschenkron, A. (1947), "The Soviet Indices of Industrial Production," *Review of Economics and Statistics* 29, 3, 217–226.

Hall, B., J. Mairesse and P. Mohnen (2010), "Measuring the returns to R&D," in B. Hall and N. Rosenberg (eds.), *Handbook of the Economics of Innovation*, Elsevier.

Israel, J. (1998), *The Dutch Republic: Its Rise, Greatness, and Fall 1477-1806*, Oxford University Press, Oxford.

Lewer, J. and H. Van den Berg (2003), "How Large is International Trade's Effect on Economic Growth?" *Journal of Economic Surveys* 17, 3, 363-96.

Pakes, A. and M. Schankerman (1984), "The Rate of Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources," in Z. Griliches (ed.), *R&D, Patents and Productivity*, University of Chicago Press, Chicago.

ten Raa, Th. and P. Mohnen (2002), "Neoclassical Growth Accounting and Frontier Analysis: A Synthesis," *Journal of Productivity Analysis* 18, 2, 111-28.

van Leeuwen, B. and J. Luiten van Zanden (2009), "The Origins of 'Modern Economic Growth'? Holland between 1347 and 1800," working paper.