Testable implications of economic revolutions: An application to historic data on European wages

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Testable implications of economic revolutions: An application to historic data on European wages

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Abstract

Motivated by an on-going debate in economic history we develop a simple method to quantify the impact of economic revolutions upon a novel historical data set listing the wages of building craftsmen and labourers in Southeast Europe. Structural breaks are found in the data and signify the effects of economic revolutions. With a small number of localised exceptions economic revolutions, caused by technological and administrative progress, lead to a decrease in the long-term level of wage volatility and overall results suggest close analogies between biological and economic evolution. The Commercial Revolution (mid 16th-early 18th centuries) acts as an important pre-requisite for the later Industrial Revolution (mid 18th-19th centuries). The Price Revolution (15th-16th centuries) results in some short-term increases in wage volatility.

Keywords: Historical Economics, Economic Revolutions, Economic Evolution, European Wages

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1 Introduction

This paper develops a simple model which generates testable implications of economic revolutions in historic data. Economic revolutions are the subject of much debate amongst historians, with reported findings heavily dependent upon the period of study. Medieval historians tend to emphasise the evolutionary or incremental nature of change. Early modern and modern historians tend to adopt a revolutionary approach with economic revolutions characterised by intermittent radical change. Results here give some support to both perspectives. Within the revolutionary school of thought historians often vary in the revolutionary events to which they attach importance. Further, some view each revolution as an isolated event unconnected to previous or subsequent revolutions (Hartwell, 1967; 1971) – a view seemingly at odds with the data considered here. In addition, there is often disagreement amongst historians regarding the exact dates of revolutions (Crafts and Harley, 2000).

Here, we take the view that a genuine economic revolution should have a measurable impact otherwise such a label may simply represent a redundant concept. A revolution may be well documented in a variety of primary and secondary sources but if its changes are restricted to a small group of people or a limited geographical area then it may have actually contributed very little to the overall development of the economy. Furthermore, a revolution may only result in social and/or political changes, rather than economic changes, in which case it does not constitute an economic revolution. In line with the notion of radical and intermittent change a genuine economic revolution should lead to structural breaks in relevant economic variables. In contrast, under an evolutionary interpretation, there is continuous incremental change and the parameters of the economic system remain stable.

Motivated by the historical problem, as outlined above, we develop a mean-variance framework with which to quantify structural breaks in historical time series and apply our model to historical data on European Wages (1264-1913). Our continuous-time model also allows us to overcome problems with missing values in the data. Thus, this paper combines informed historical analysis with rigorous applied statistical techniques and our application to the study of economic history is significant in itself. Further, the novelty of the historic data considered here is such that the empirical analysis of the data is of interest in its own right. Our contribution is also timely due to recent advances in terms of the construction and availability of such historic data (Allen, 2001). Further, it is only relatively recently that the relevant statistical techniques have been developed and computer processor power has improved such an extent as to make such an analysis possible (Zeilis et al., 2003). The formulation of our model is such that the empirical results obtained are easy to interpret and feed through naturally into the over-arching historical narrative. A similar approach taken in Casson and Fry (2011) showed that in the UK the commercial and agricultural revolutions formed essential pre-requisites for the Industrial Revolution which followed later.

The layout of this paper is as follows. Additional historical perspectives and the data itself are described in Section 2. Section 3 develops the stochastic model used. Section 4 gives the empirical results. Section 5 concludes.

2 Historical perspectives and data

2.1 Historical Perspectives

As discussed in Section 1, and using novel historical data on European wages, we develop empirical tests for the effects of economic revolutions. We thus contribute to the evolutionary/revolutionary debate in economic history, with an extensive list of potential economic revolutions purported to have impacted upon the European economy. Documented pan-European revolutions include:

- Price Revolution (circa 1460-1530)
- Commercial Revolution (16th century–early 18th century)
- Industrial Revolution (mid 18th–19th century)

The Price Revolution (Hamilton, 1934; Munro, 1999) resulted in a Europe-wide process of price inflation. Important contributing factors include a large influx of gold and silver from the Spanish New World (circa 1545 onwards). This was also accompanied by a dramatic increase in silver production in Central Europe (1460-1530). Contributing factors also include demographic factors with a considerable increase in the European population following a period of depopulation and demographic stagnation in the aftermath of the Black Death. The Commercial Revolution (Whitham Rostow, 1975) was a period of European economic expansion characterised by the establishment of new trade routes and increases in commercial activities and associated non-manufacturing activities such as banking, insurance and investment. The Industrial Revolution is characterised by major changes in agriculture, manufacturing, mining, transportation and technology resulting in a substantial increase in the living standards of the mass of the population (Lucas, 2002).

In addition to the above there are also a number of more country-specific events which may have a detectable impact. For example for France this list might include

- French Revolution and Napoleonic wars (1789–1815)
- Increased industrialisation (1815–1860).

For the UK a similar list might include

- Credit revolution (14th and 15th century)
- Glorious Revolution (1689 onwards)
- Agricultural Revolution (18th century)
- Railway Revolution (1860 onwards).

2.2 The data

The data used are real wages for building craftsmen (skilled workers) and building labourers (unskilled workers) recorded at yearly intervals. The data is from Allen (2001) and can be accessed from Allen (2010a-b). To provide context, building craftsman and building labourers tend to be the workers whose wages are most frequently reported in historical records (Allen, 2001). The data examined here synthesises and extends a number of pre-existing datasets and provides a relatively continuous run of data across several centuries. In particular, Allen (2001) offers improved real-wage calculations and data on a greater number of locations compared to similar data in Phelps Brown and Hopkins (1956, 1981). The wage series, as characterised by status, location and dates recorded, are shown in Tables 1-4.

3 The model

The data contain missing values – a problem which necessitates a continuous time model. We use as our starting point the prototypical Black-Scholes model. This model assumes Gaussianity of the log-returns (first differences of the log-wages). As shown in Figure 1 this assumption of normality appears reasonable for the low-frequency (yearly) data considered here.

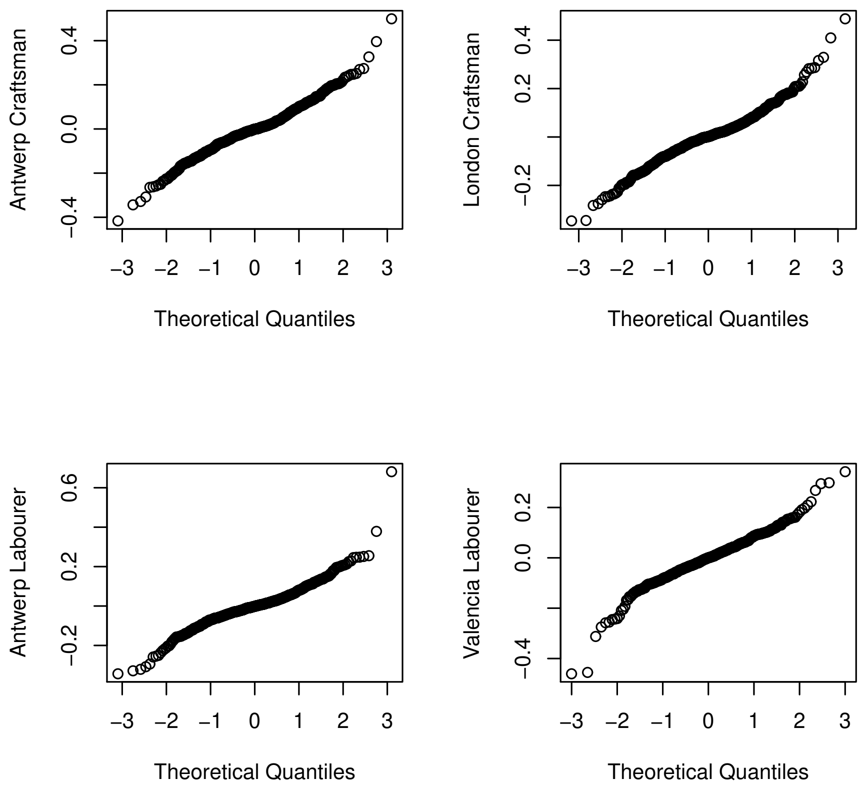

Figure 1: Normal probability plot of real log-returns for selected craftsman and labourer wage series.

Let P_t denote worker's wages at time t and let $X_t = \log\ P_t$. Our model can be written as

$$dX_t = \mu dt + \sigma dW_t, \tag{1}$$

where μ is the drift, σ^2 is the volatility and W_t is a Wiener process.

Let $\Delta X_t = X_{t+1} - X_t$. It follows that under equation (1) the ΔX_t satisfy

$$\Delta X_t \qquad \text{i.i.d.} \qquad \mathrm{N}\left(\mu, \sigma^2\right). \tag{2}$$

Equation (2) has two important implications. Firstly, this property of independent increments allows us to overcome missing values in the raw data. Secondly, equation (2) can be re-written as a regression model (Bingham and Fry, 2010):

$$\Delta X_t = \alpha + \epsilon_t, \tag{3}$$

where the ϵ_t are i.i.d. $N(\mu, \sigma^2)$. Thus, we are able to test for breakpoints in the historical price and wage data using relatively simple statistical tests originally conceived for standard regression models (Bai and Perron, 2003; Zeileis et al., 2003).

We analyse the historic price and wage data by testing for break-points in the drift and in the volatility. The drift and volatility provide important measures of price dynamics – particularly for the low-frequency data considered here. We note that in equations (1)-(3) knowledge of μ and σ completely characterises the stochastic behaviour of prices. This characterisation may also continue to hold in a non-Gaussian setting (Bingham and Kiesel, 2001; Bingham et al., 2003, 2010). Further, under a Markowitzian interpretation, the drift corresponds to the average rate of pay and volatility represents wage risk. Thus, in addition to providing a useful summary of stochastic fluctuations in historic wages and prices, the drift and volatility also provide real information about the changes in economic circumstances faced by workers.

The methodology adopted in this paper is as follows. We test for break-points in drift by testing for breakpoints in the regression equation (3). The appropriate number of break points is chosen automatically using the Bayesian Information Criterion (BIC) (Schwarz, 1978). Statistical uncertainty around estimated breaks is expressed via 95% confidence intervals, calculated using the method of Bai (1997). If confidence intervals for break-points overlap or extend beyond the range of the sample then the estimated number of breakpoints is reduced by one and the model is then re-estimated from the beginning. Thus, we provide an additional safeguard against over-fitting and over-estimating the number of breakpoints. Finally, we use the squared log-returns ΔX_t^2 to proxy the unobserved volatility component in the data. We then test for breakpoints in the volatility by replacing ΔX_t with the squared log-returns ΔX_t^2 in (3).

3.1 Interpretation of breakpoints

There are several different possibilities in which break-points in drift and volatility can occur. Here, we restrict the discussion to a limited number of illustrative examples which are of conceptual or of empirically observable interest (see Section 4).

Increase in drift. An increase in drift represents an increase in the level of workers' affluence. Suppose that we have two regimes. In Regime 1

$$\Delta X_t \sim \mathrm{N}\left(\mu_1, \sigma_1^2\right), \tag{4}$$

and that under Regime 2

$$\Delta X_t \sim \mathrm{N}\left(\mu_2, \sigma_1^2\right). \tag{5}$$

If $\mu_2 > \mu_1$ the change results in an increase in the mean rate of pay with no additional increase in the level of risk. Similar comments apply to the affect of a decrease in drift.

Decrease in volatility. A decrease in volatility indicates a reduction in the level of risk and suggests that wages have become more stable over time. Suppose that we have two regimes. In Regime 1

$$\Delta X_t \sim \mathrm{N}\left(\mu_1, \sigma_1^2\right), \tag{6}$$

and that under Regime 2

$$\Delta X_t \sim \mathrm{N}\left(\mu_1, \sigma_2^2\right). \tag{7}$$

If $\sigma_2^2 < \sigma_1^2$ then the change results in a reduction in the level of wage risk without reducing the average rate of pay. Similar comments apply to the effect of an increase in volatility.

See-saw change. Suppose that we have three separate Regimes. The volatility initially increases but then decreases. In Regime 1

$$\Delta X_t \sim \mathrm{N}\left(\mu_1, \sigma_1^2\right), \tag{8}$$

whilst under Regime 2

$$\Delta X_t \sim \mathrm{N}\left(\mu_1, \sigma_2^2\right), \tag{9}$$

and in Regime 3

$$\Delta X_t \sim \mathrm{N}\left(\mu_1, \sigma_3^2\right), \tag{10}$$

with $\sigma_1^2 < \sigma_2^2$ and $\sigma_3^2 < \sigma_2^2$. Similar to equations (6)-(7) we have a process of long-term wage stabilisation if

$$\sigma_3^2 < \sigma_1^2. \tag{11}$$

Similarly, we have a long-term increase in wage volatility if

$$\sigma_1^2 < \sigma_3^2. \tag{12}$$

We can test the hypotheses (11-12) using a simple variance-ratio test (see e.g. Snedecor and Cochran, 1989; Chapter 6). If there are n_1 observations (log-returns) in Regime 1 and n_3 observations (log-returns) in Regime 3, calculate unbiased estimates of the population variance $\hat{\sigma}_1^2$ and $\hat{\sigma}_3^2$ and perform a two-sided F-test using

$$\frac{\hat{\sigma}_1^2}{\hat{\sigma}_3^2} \sim F_{n_1-1,n_3-1}. \tag{13}$$

End-of-boom period. We can see from equations (4)-(5) and the text below that a decrease in drift corresponds to a reduced level of prosperity. However, there is also a sense in which a simultaneous reduction in both drift and volatility may also herald the end of a boom period. Suppose that we have two regimes. In Regime 1

$$\Delta X_t \sim \mathrm{N}\left(\mu_1, \sigma_1^2\right), \tag{14}$$

and in Regime 2

$$\Delta X_t \sim \mathrm{N}\left(\mu_2, \sigma_2^2\right), \tag{15}$$

with $\mu_2 < \mu_1$ and $\sigma_2 < \sigma_1$. Suppose we have some threshold H representing a *high* level of pay, with $H > \mu_1$. In Regime 1 the probability of exceeding the well-paid threshold is given by

$$1 - \Phi\left(\frac{H - \mu_1}{\sigma_1}\right), \tag{16}$$

where $\Phi(\cdot)$ denotes the cdf of a $N(0, 1)$ random variable. Similarly, in Regime 2 this probability is given by

$$1 - \Phi\left(\frac{H - \mu_2}{\sigma_2}\right). \tag{17}$$

It is easy to show that the function $\overline{f}(\mu, \sigma)$ defined by

$$\overline{f}(\mu, \sigma) = 1 - \Phi\left(\frac{H - \mu}{\sigma}\right) \qquad (H > \mu), \tag{18}$$

is an increasing function of μ and σ:

$$\frac{\partial \overline{f}}{\partial \mu} = \frac{1}{\sigma}\phi\left(\frac{H - \mu}{\sigma}\right) > 0, \tag{19}$$

$$\frac{\partial \overline{f}}{\partial \sigma} = \frac{1}{\sigma}\left(\frac{H-\mu}{\sigma}\right)\phi\left(\frac{H-\mu}{\sigma}\right) > 0, \quad (20)$$

where ϕ is the density of a $N(0,1)$ random variable. Hence the effect of a simultaneous reduction in drift and volatility is a reduced level of affluence as measured by the probability of exceeding the well-paid threshold measured by equations (16)-(17).

4 Empirical results

A plot of real log-returns for selected wage series is shown in Figure 2. These plots give an indication of possible structural breaks; the level of volatility appears to be generally lower in the second half of the sample with some indication of enhanced wage volatility towards the middle of the sample. However, in contrast, only a limited amount of evidence for changes in drift/mean is apparent.

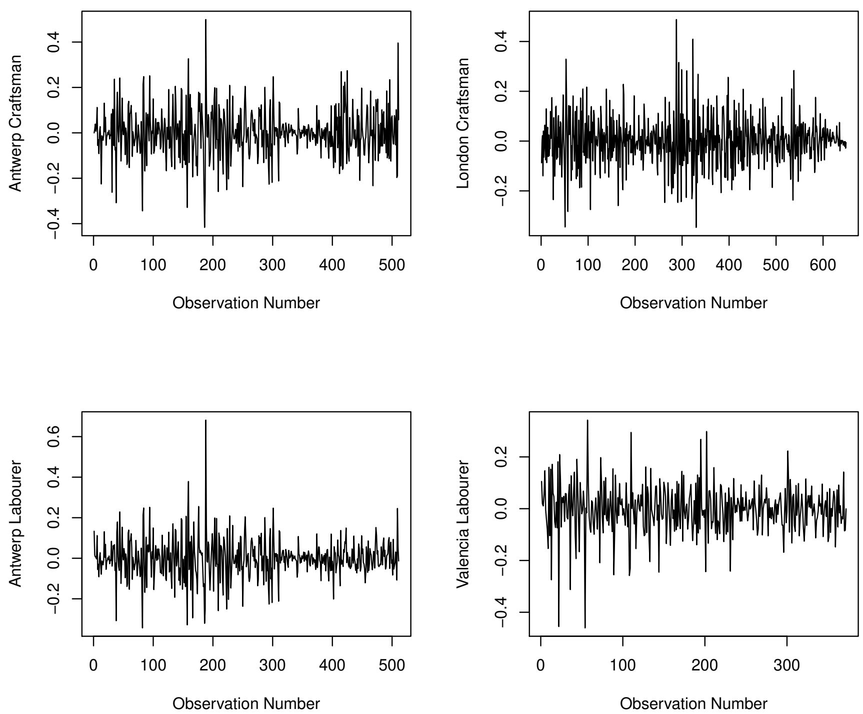

Figure 2: Time series plot of selected real wages (craftsmen and labourers).

These simple observations are largely borne out by the results. As shown in Tables 1 and 3 structural breaks were found in fifteen of the thirty six series examined, suggesting that structural breaks are an intrinsic feature of such historic series – particularly for the data on Craftsmen's wages. However, as listed in Tables 2 and 4, in the majority of series no evidence of breakpoints are found giving some support also to the evolutionary view of economic history.

Table 1: Data on Craftsman Wages: Breakpoints found

City (From:To)	**Description**	**Estimated breakpoint (95% Confidence Interval)**
Antwerp 1399-1910	Increase in volatility followed by a decrease	1545 (1445-1560) 1627 (1619-1708)
London 1264-1913	Increase in volatility followed by a decrease	1540 (1378-1565) 1662 (1659-1742)
Paris 1431-1911	Decrease in long-term volatility	1722 (1708-1872)
Strasbourg 1395-1869	Increase in volatility followed by a decrease	1495 (1402-1500) 1640 (1627-1747)
Florence 1326-1913	Decrease in long-term volatility	1562 (1561-1671)
Naples 1548-1806	Decrease in long-term volatility	1572 (1570-1620)
Valencia 1413-1785	Increase in volatility followed by a decrease	1518 (1466-1526) 1573 (1565-1627)
Krakow* 1409-1910	Increase in long-term volatility	1618 (1541-1619)
Warsaw 1558-1913	Decrease in long-term volatility	1677 (1675-1739)
Lwow* 1520-1796	Increase in long-term volatility	1754 (1674-1762)
Hamburg* 1871-1913	Decrease in drift Decrease in volatility	1878 (1876-1895) 1877 (1876-1887)

Table 2: Data on Craftsman Wages: No breakpoints found

City	**From:To**
Amsterdam	1500-1910
Oxford	1264-1913
Milan	1326-1605
Madrid	1551-1913
Augsburg	1502-1800
Leipzig	1565-1796
Munich	1427-1765
Vienna	1440-1800
Gdansk	1535-1800

Table 3: Data on Labourer Wages: Breakpoints found

City (From:To)	**Description**	**Estimated breakpoint 95% Confidence Interval**
Antwerp 1399-1910	Increase in volatility followed by a decrease	1545 (1400-1550) 1627 (1626-1722)
London 1301-1913	Long-term decrease in volatility	1710 (1694-1824)
Naples 1548-1806	Long-term decrease in volatility	1598 (1593-1761)
Valencia 1413-1785	Long-term decrease in volatility	1470 (1466-1585)

Table 4: Data on Labourer Wages: No breakpoints found

City	**From:To**
Amsterdam	1500-1910
Paris	1431-1786
Strasbourg	1395-1869
Florence	1326-1913
Milan	1326-1913
Madrid	1551-1913
Augsburg	1502-1766
Leipzig	1565-1796
Vienna	1440-1800
Gdansk	1535-1800
Krakow	1409-1910
Warsaw	1558-1913

There is some indication of an increase in wage volatility in the 15-16th centuries (Antwerp Craftsmen 1445-1560; London Craftsmen 1378-1565; Strasbourg Craftsmen 1402-1500; Valencia Craftsmen 1466-1526; Antwerb Labourer 1400-1550) roughly coincident with the Price Revolution (see Section 2). However, in each of these cases this increase in volatility is countered by a decrease in wage volatility across the 17th-18th centuries (Antwerp Craftsmen 1619-1708; London Craftsmen 1659-1742; Strasbourg Craftsmen 1627-1747; Valencia Craftsmen 1565-1627; Antwerb Labourer 1626-1722). As shown in Table 5 there is also some evidence of a long-term decrease in volatility according to equation (11) (London and Antwerp). A number of wage series in Table 3 (Craftsmen) and Table 5 (Labourers) also see a long-term decrease in volatility according to equations (6)-(7). Falls in wage volatility tend occur mainly across the 17-18th century, corresponding to the Commercial Revolution (see Section 2), (Antwerp Craftsmen 1619-1708; London Craftsmen 1659-1742; Strasbourg Craftsmen 1627-1747;

Florence Craftsmen 1561-1671; Naples Craftsmen 1570-1620; Valencia Craftsmen 1565-1627; Warsaw Craftsmen 1675-1739; Antwerp Labourer 1626-1722; Naples Labourer 1593-1761) but in some cases extend across periods associated with the Industrial Revolution (London Labourer 1694-1824; Paris 1708-1872).

Table 5: Data on Craftsman and Labourer Wages: Interpretation of see-saw changes

Series	**Interpretation**	F**-statistic**	p**-value**
Antwerp Craft Wages	No evidence for long-term decrease in volatility	1.175	0.256
London Craft Wages	Evidence for long-term decrease in volatility	1.687	0.000***
Strasbourg Craft Wages	No evidence for long-term increase in volatility	0.808	0.228
Valencia Craft Wages	No evidence for long-term decrease in volatility	0.975	0.897
Antwerp Labour Wages	Evidence for long-term decrease in volatility	1.730	0.000***

With reference to Table 1 there are a number of cases which are worthy of special mention (denoted by *). In each of these three cases, a series of localised external shocks appears to disrupt the natural path of economic development. There was a great fire of Hamburg in 1842 (Schott, 2002). Up to a quarter of the inner city was destroyed and left an estimated 20,000 homeless. Reconstruction took more than 40 years. The loss of prosperity indicated by the near simultaneous decrease in drift and volatility in Table 1 (see equations 14-15) thus corresponds to this period of reconstruction coming to an end and building craftsmen thus facing less favourable conditions as a consequence. The increase in wage volatility in Krakow corresponds to a documented decline in the city's importance towards the end of the 16th century. The capital of the Polish-Lithuanian commonwealth switched from Krakow to Warsaw in 1596. This period of history also encapsulates a period of escalating religious tensions in Europe between Protestants and Catholics culminating in the outbreak of the Thirty Years War in 1618. The increase in volatility in Lwow can also be explicitly ties to wars and conflicts. We note the battle of Lwow in 1675 and the pillaging of the city in 1704 during the Great Northern War. During the seven years war 1756-63 there was also a dispute between Prussia and the Polish Lithuanian Commonwealth. Not only were there Prussian invasions of Polish territory in 1759 and 1761 (Scott, 2001) but there were also important economic dimensions to the conflict. For many years Prussia circulated counterfeit Polish currency – resulting in considerable monetary problems for the commonwealth. During this period Prussian troops also bombarded Polish ports, thus thwarting Polish attempts to create a modern fiscal system (Davies, 1996).

In sum, it appears that economic revolutions, when they occur, tend to result in a reduction of the long-term level of wage volatility. This arises as a result of technological and administrative innovation and suggests close analogies with biological and economic evolution – a theme explored inter alia by Foster (2000) and Thurner et al. (2010). For the data considered here results suggest the following. The Price Revolution causes some increases in wage volatility. With localised exceptions, the Commercial Revolution brings about a reduction in wage volatility – a process that continues in Paris and London through the Industrial Revolution. Findings here match those of Whitham Rostow (1975), O'Brien (2006), (2010) and Casson and Fry (2011) amongst others, which see the Commercial Revolution as an important pre-requisite for the later Industrial Revolution.

5 Conclusions

Motivated by an on-going debate in historical economics we develop a simple model to quantify the effects of economic revolutions. Increased economic stability results in a reduced level of real-wage volatility. Both a reduction in drift and a simultaneous reduction in the level of drift and volatility are both linked to a reduced level of prosperity amongst workers.

Our empirical application is to a novel dataset giving the real wages of building craftsmen and labourers in Southeast Europe in Allen (2001). The significance of the data is such that empirical analysis of this data is of interest in its own right with results give some support to both evolutionary and revolutionary perspectives of economic development. In line with an evolutionary or incremental interpretation, in the majority of wage series no evidence of structural breaks is found. However, structural breaks are seen in a non-trivial proportion (41.7%) of all wage series examined and, as in Casson and Fry (2011), seem to be an intrinsic property of such historical economic time series. Structural breaks thus arise as a hallmark of several economic throughout Europe in the years (1264-1913). General findings are that economic revolutions are associated with a reduction in the level of long-term wage volatility during the Commercial Revolution. These results match with a number of previous findings; namely that the Commercial Revolution acts as an important precursor of the later Industrial Revolution. We find that the effect of continued technological and administrative progress is to reduce long-term wage volatility. This offers an intriguing analogy between biological and economic evolution, a theme explored by a number of recent works.

Results indicate some increases in the level of wage volatility, particularly amongst craftsmen, during the Price Revolution (15-16th century). However, these temporary increases are typically offset by later reductions in wage volatility during the Commercial Revolution. There are also some localised exceptions to the general picture of economic evolution leading to long-term reductions in wage volatility. However, in each of these cases, increases in wage volatility or reductions in the rate of pay can be explicitly linked to the effects of external shocks such as wars/religious conflicts and the Great Fire of Hamburg.

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