BRUSSELS ECONOMIC REVIEW – CAHIERS ECONOMIQUES DE BRUXELLES
VOL. 52 N° (3/4) AUTUMN-WINTER 2009

INFLATION, INTEREST RATE AND INNOVATIONS IN PRE-WWI GERMANY (1878-1913)*

JACEK WALLUSCH** (UNIWERSYTET EKONOMICZNY W POZNANIU) AND MARKUS BALTZER*** (DEUTSCHE BUNDESBANK)

ABSTRACT:

This paper tries to elucidate the relationship between innovations, interest rate and price movement in Imperial Germany (1878-1913). We use the high-powered patents as a proxy for changes in technology. Using various distributed lag models we found a small, positive and significant response of CPI inflation to the technological shock. No significant influence of interest rates on inflation was found.

JEL CLASSIFICATION: E31, N13.

KEYWORDS: Germany, Inflation, Interest rate, Patents.

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* An early version of this paper was presented at the Second Conference on German Cliometrics, International und Interdisciplinary Perspectives on German Economic and Social History, Tübingen, June 10, 2006. The views expressed are solely our own and are not necessarily shared by the Deutsche Bundesbank.

** Uniwersytet Ekonomiczny w Poznaniu, corresponding author, e-mail: jacek.wallusch@ue.poznan.pl.
Wallusch thanks Krzysztof Kuchcinski for helpful comments on the earlier drafts of this paper.

*** Deutsche Bundesbank, e-mail: markus.baltzer@bundesbank.de

INTRODUCTION

There is little doubt that the introduction of a common patent law of 1877 changed German industry. German firms became more competitive, German commodities improved their quality and German workers became more effective. How did the technological changes affect the German economy? Innovations, R&D, spill-over effects, and patents are usually connected to the meso- and microeconomic history. The meso- and microeconomic approaches in quantitative (see, among others, Streb et al. 2007, Streb et al. 2006) or narrative versions (e.g. Murmann 2003) do not lose their explanatory power without the macroeconomic context. Both approaches are very helpful in explaining the transition to the industrial society (at least in some regions of the country). Some macroeconomic relationships, however, are not visible if these approaches are applied. Among these relationships the interdependencies between interest rate, deflation, and innovations are especially interesting. What could link the R&D departments and the banking sector? To apply this question to Germany of the late nineteenth and early twentieth century seems very interesting as Kaiser's Germany is traditionally linked with two accompanying phenomena: technological boom and deflation.

Upon applying the neoclassical view to this historical period, the picture for the German Empire seems to fit quite well. Product innovations are the contributions of technology to the capacity of the economy. Therefore, these developments should lead to higher labour productivity and ought to exert downward pressure on prices.

Another possible explanation regarding the relationships between interest rate, deflation, and innovations was provided more than a hundred years ago by Knut Wicksell (1898, 1907). The relevance of Wicksell's theory for contemporary economics is obvious since Michael Woodford re-discovered the Wicksellian economics for the New Keynesians in the 1990s. However, its possible application for Kaiser's Germany is not so obvious. Even Wicksell himself doubted it when he has stated that the proposition could not be proved directly by experience (Wicksell 1907). Structural assumptions considered by Wicksell should rather be considered in the light of the late 20th than the late 19th centuries. At first glance his theory does not seem to be appropriate to explain technological boom and deflation in the German Empire, but upon closer inspection, Wicksell's strand of argumentation suggests otherwise. According to his theory, new technologies cause an increase in prices via the interest rate channel. Thus, the German scenario in the late 19th and early 20th centuries of a technological boom going along with a tendency of deflation is compatible with Wicksell as well.

In the following, we argue that the standard theoretical neoclassical view has some shortcomings in explaining the German monetary history in the late 19th and early 20th Century. Pure Wicksellian explanations fit only slightly better to the pre-WWI German development. Although technological changes did affect inflation, interest rate did not.

1. INNOVATIONS, INTEREST RATE, AND INFLATION

1.1. A SIMPLE (NEOCLASSICAL) MODEL

To elucidate the microeconomic relationships between interest, innovations, and price movment, we develop a standard neoclassical model based upon the profit-maximising principle. Consider the case in which a firm *z* is interested in enlarging its capital stock. In a fair bargain the firm *z* and the bank *x* set the price of capital. Let the output y_t supplied by the firm *z* be described by a standard Cobb-Douglas function:

$$y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

where A_t represents the technological variable, K_t capital and L_t labour. The firm *z* maximises profit π_t:

$$\pi_t = p_t^z A_t K_t^{\alpha} L_t^{1-\alpha} - w_t L_t - p_t K_t \left(r_t^x - \frac{p_t}{p_{t-1}} + d_t \right) \tag{2}$$

The cost function is defined as the total compensation of labour $w_t L_t$, the inflation rate p_t/p_{t-1}, the interest rate r_t^x demanded by the bank *x*, and the rate of physical depreciation of capital d_t. Differentiating equation (2) with respect to capital and setting the result to 0 one obtains the first order condition:

$$\frac{\partial}{\partial K_t} \pi_t = p_t^z \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha} - p_t \left(r_t^x + \frac{p_t}{p_{t-1}} + d_t \right) = 0 \tag{3}$$

which leads to the optimal interest rate $\Re_t^x$:

$$\Re_t^x = \frac{p_t^z}{p_t} \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha} - \frac{p_t}{p_{t-1}} + d_t \tag{4}$$

An optimal interest rate is a function of the marginal productivity of capital, the inflation rate and the depreciation of capital. The crucial issue for the further analysis of price movement in Imperial Germany was the rigid interest rate that appeared in the late 19th century. The difference between the actual nominal interest rate and its optimal level might help to explain the price movement.

In a perfect neoclassical world there was no room for imperfectness. Differences between the optimal and actual interest rate could not have occurred, yet deflation in the last decades of the 19th Century was, in fact, explained by this difference. This explanation was presented by Knut Wicksell. What was the source of the interest rate rigidities? Since the Wicksellian heritage is usually connected to Michael Woodford, New Keynesian economics might be the first choice in looking for this explanation. Indeed, the New Keynesian approach offered a significant number of possible causes of interest rate rigidity[1]. Wicksell himself, however, noted that a single bank *has no such power* (...), *it cannot put its rates, whether much higher or much lower than prescribed by the state of the market*. Thus, imperfect information was the feature that should have been added as a 'stylised fact'.

1.2. AN EXTENSION: IMPERFECT INFORMATION

In the next step we extend our model by considering the impact of financial market imperfections which will be subsumed under the expression 'imperfect information'. According to Wicksell, errors in judgment in the banking sector were the main source of discrepancies between the deposit, lending, and the natural rates. In his view of a monetary economy, errors on the downside in particular (i.e. interest rates that were too low) were corrected only gradually over time, as households adjusted their holdings of real balances in light of general price increases and began to command higher deposit rates (Amato, 2005). Moreover, Wicksell (1907) mentioned that even if a single bank wanted to adjust to the natural rate it did not have the power to counteract market forces. Therefore, we do not have an immediate adjustment but only a gradual convergence over time.
The term in (3) p_t^z / p_t reflects the impact of a real demand change and is similar to the variable appearing in Lucas-type output function (Lucas 1973). By introducing imperfect information, the average price p_t must be substituted by its expected value. Hence, the observed nominal interest rate is equal to:

$$r_t^x = \frac{p_t^z}{E_t(p_t)} \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha} - \frac{E_t(p_t)}{p_{t-1}} + d_t \tag{5}$$

Following the New Classical assumption the price observed by z deviates from the average price by the stochastic factor z_t (Lucas 1973):

$$p_t^z = p_t + z_t \tag{6}$$

The variable z_t is normally distributed with 0 mean and a finite variance σ_z^2. The average price is generated by a process $p \sim N(\overline{p}, \sigma_p^2)$. Applying the recursive OLS projection, we obtain the REH-consistent expectations of p_t:

$$E_t(p_t) = \frac{\sigma_z^2}{\sigma_z^2 + \sigma_p^2} \overline{p} + \frac{\sigma_p^2}{\sigma_p^2 + \sigma_z^2} p_t^z . \tag{7}$$

Even if the bank had access to the information and was able to estimate the coefficients in (5) consistently, the actual nominal interest rate was not necessarily the optimal one. Figure 3 shows that persistent inflation, which is a stylised fact of the contemporary business cycle, was clearly not present in Imperial Germany. Thus, setting the optimal interest rate was hindered by the high inflation volatility.

[1] An exposition of this topic is presented by Joseph E. Stiglitz in his Nobel Lecture (2002).

Simplifying the notation by setting $F_t = \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha}$, we can show the difference between actual inflation and optimal inflation. Obviously, it partially depends on the difference between actual and optimal interest rate:

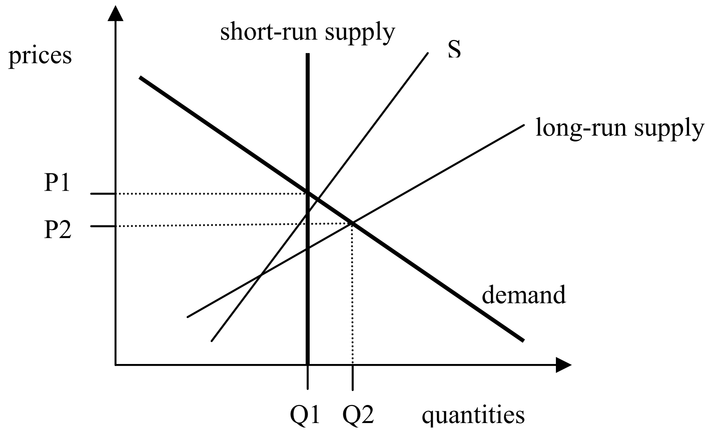
$$\frac{E_t(p_t) - p_t}{p_{t-1}} = \left(\frac{p_t^z}{E_t(p_t)} - \frac{p_t^z}{p_t} \right) F_t - r_t^x + \Re_t^x \cdot \tag{8}$$

The results presented in equation (8) are in tact with Wicksell's findings. If the actual interest rate went beyond its natural, optimal, level, the deflation could have appeared.

1.3. Innovations and inflation

A textbook microeconomic explanation of the relationship between technological progress and prices is rooted in neoclassical tradition. Figure 1 depicts how innovations affect the price in a neoclassical model[2]. In the short run the supply curve is vertical, while the demand curve has a negative slope. The intersection of both curves determines price and quantity (P1, Q1). The introduction of innovation by a cluster of firms shifts the equilibrium to the new point defined by the demand curve and the new supply curve S. Once the innovation is introduced by all firms the long run equilibrium is reached. Quantities increase to Q2, while prices fall to P2.

FIGURE 1. INNOVATIONS AND PRICE LEVEL IN NEOCLASSICAL MODEL



Using equation (5), however, inflation is an increasing function of innovation. Following Wicksell, the technological changes affected inflation in the way presented in equation (8). New investment opportunities - like railroads - had increased the marginal productivity of capital, the interest rate increased and consequently so did inflation. Imperfect information might have influenced the interest rate dynamics. As J. R. Hicks (1977) highlighted, the uncertainty

[2] Lange (1939), who originally presented this figure, referred to Frank Knight (1925). We do not want to consider any changes in competition, though.

concerning aggregate data was an important factor in the late 19th Century. Thus, we presume that innovations caused price increases rather than decreases.

2. MODEL ESTIMATION

Our sample includes annual data for pre-World War I Germany, from 1877 to 1913. We use the high-powered, 10-year-lasting patents as a proxy for technological change even if we are conscious that there has been a wide discussion among economists on the issue of measuring innovative activity and technological progress. Several problems appear in measuring innovation. Firstly, innovation can be seen as a dynamic process rather than a static point in time. However, for empirical measurement we have to rely on static indicators to measure this dynamic process. Furthermore, the quality of innovations is very heterogeneous. An un-weighted counting of innovations ignores the fact that innovations have a wide ranging economic importance. Finally, innovative activity sometimes is not really observable as some companies keep their inventions a trade secret.

The empirical literature relies on different measurement techniques. One is corporate Research and Development spending and/or employment. Today, these figures are usually reported in annual reports or company financial statements. Nevertheless, a major criticism of this methodology is the problem of obtaining information regarding an input measure. We do not have any idea how strong the final economic output of the respective innovative technology is. By using patent data we avoid this problem as the application for a patent represents the final step of a new invention. The sample is yearly and covers the period after the patent law was introduced. We use the high-powered, 10-year lasting patents as a proxy for the innovations (see Figure 2). We employ the consumer price index to measure the price changes. Both series are expressed in natural logarithm, and we used their first differences in estimations.

We assumed the money market rate (Privatdiskontsatz) to be the interest rate, based upon Donner (1934). Figure 3 shows that apart from a few outliers the Privatdiskont moves in a quite narrow range between 2% and 4%. In the long run we detect a slight decreasing trend for the first half of the examined period which matches a decrease of prices. On the other hand, the second half of this period, which was characterized by a price increase, can be described as an increasing trend in interest rates. Furthermore, there seems to be an increase in volatility within this second period. However, this preliminary descriptive observation does not offer a possible insight into the influence of the interest rate on inflation or vice versa. Therefore we have to look at the following econometric analysis.

FIGURE 2. YEARLY RATE OF CHANGE OF PATENTS

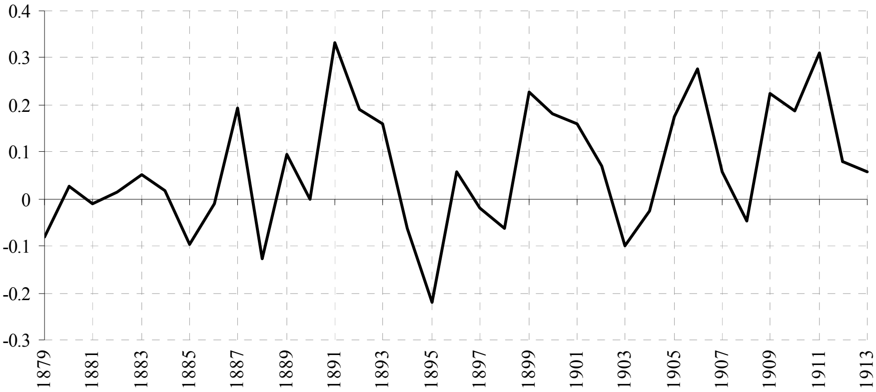
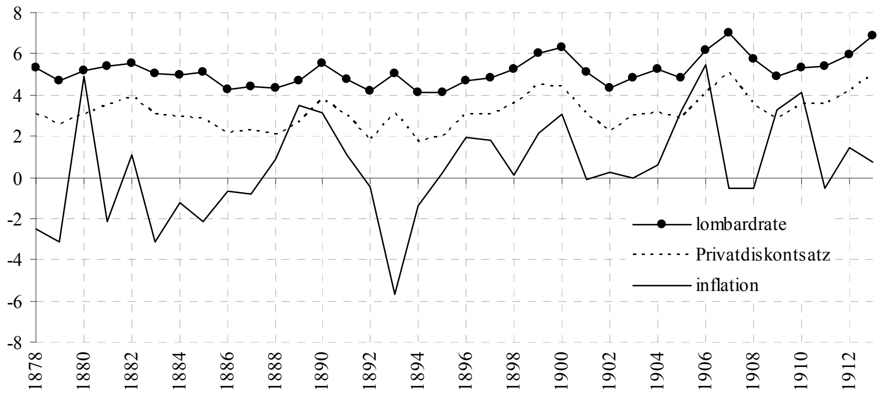


FIGURE 3. INTEREST RATES AND INFLATION



2.1. DISTRIBUTED LAG ESTIMATIONS

To trace out the relationships between interest rate r_t, innovations a_t, and inflation we applied various versions of the distributed lag models. Our goal was to capture the effects of the application of new technologies without loosing too many degrees of freedom. The implementation of new technology, as figure 1 suggests, was distributed over time. Since the sample was small, the latter was especially important for choosing an appropriate procedure. Distributed lag models satisfied both restrictions.

We began the analysis with a multivariate distributed lag model:

$$p_t / p_{t-1} = b_0 + \sum_{i=1}^{k} b_i \Delta r_{t-1} + \sum_{i=1}^{k} g_i \Delta a_{t-1} + \varepsilon_t \qquad (9)$$

Since the sample was small, we first followed Lütkepohl (1985, 2005) as well as Aznar and Salvador (2002) when choosing the lag length, by using the Schwarz criterion. The minimisation of the Schwarz criterion had indicated $k = 2$, but the coefficient at lag 3 appeared to be significant, so we enlarged the number of lags to 3. The results, along with the Newey-West HAC standard errors (reported in parentheses), are presented in table 1.

TABLE 1. ESTIMATION RESULTS, EQUATION (9)

Variable	*t*	*t* − *1*	*t* − *2*	*t* − *3*
lombard rate	0.012	0.001	0.009	−0.004
	(0.005)	(0.005)	(0.005)	(0.005)
innovations	0.063	−0.003	−0.066	0.055
	(0.023)	(0.024)	(0.033)	(0.022)
adj. R^2 = 0.189, log likelihood = 84.149, SC = -4.393, DW = 1.541				
Privatdiskontsatz	0.010	0.004	0.007	−0.003
	(0.04)	(0.004)	(0.003)	(0.004)
innovations	0.062	0.000	−0.067	0.060
	(0.023)	(0.024)	(0.034)	(0.023)
adj. R^2 = 0.197, log likelihood = 84.308, SC = -4.403, DW = 1.678				

Interesting but strikingly surprising are the values of b_i's coefficients. Their sums are in both cases positive, which is contradictive to theory as well as to popular wisdom. The reported standard errors suggested, however, that the sign of the sum was of no importance. We carried out the Wald test with null:

$$H_0 : b_1 + b_2 + b_3 + b_4 = 0 \tag{10}$$

to check whether the sum significantly differed from 0. Considering the small sample properties, we employed the *F*-distribution as an approximation of the distribution of Wald test statistic[3] in order to test the hypothesis. Table 2 summarises the results.

TABLE 2. WALD TEST RESULTS

Interest rate	Test value	$F_{(0.05;1;24)}$	Probability	Result
lombard rate	4.749	4.260	0.039	rejected
Privatdiskontsatz	7.554	4.260	0.011	rejected

In both cases the null was rejected, so we conclude that the impact of the interest rate upon inflation was significant but very small. The causality, however, went the other way around. A simple experiment detected a significant influence of lagged inflation on the current interest rate.

We decided to apply a standard version of the distributed lag model:

$$p_t / p_{t-1} = \sum_{i=1}^{k} \gamma_i \Delta a_{t-i} + \eta_t . \tag{11}$$

[3] See Lütkepohl (2005) and Charemza and Deadman (1992).

In selecting the k we first minimised the Schwarz criterion to set k = 2. The estimation results are as follows:

$$p_t/p_{t-1} = \underset{(0.022)}{0.066}\Delta a_t - \underset{(0.024)}{0.001}\Delta a_{t-1} - \underset{(0.029)}{0.065}\Delta a_{t-2} + \underset{(0.02)}{0.045}\Delta a_{t-3}$$

adj R^2 = 0.161, SC = -4.639, DW = 1.326.

Using the estimated values of the coefficients, we conducted an impulse response analysis. Figure 4 depicts the response of inflation to a non-factorised one unit innovation in rate of change of patents (solid line). We estimated the confidence bounds (dashed lines) employing the Newey-West HAC covariance matrix Σ_{γ}^{NW}. The standard errors of the consecutive responses Φ_j are equal to the square root of the 1, 1st element of the matrix:

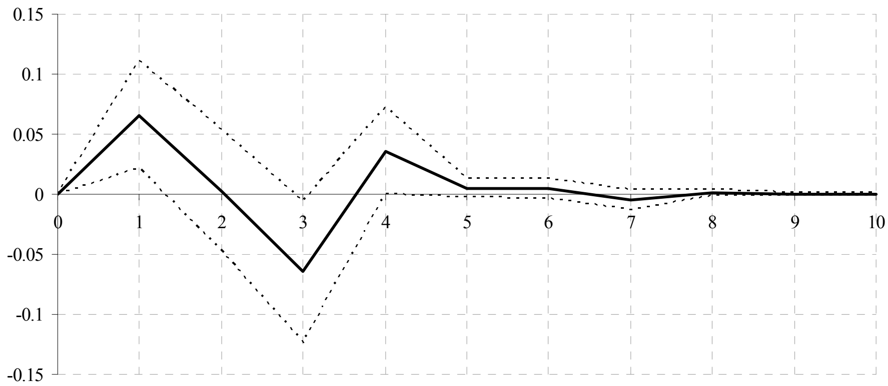
$$G_j \Sigma_{\gamma}^{NW} G_j^{'} \tag{12}$$

where[4]

$$G_j = JG_{j-1}\Gamma' + J \otimes \Phi_{j-1},\ J = I_4,$$

$$\Gamma = \begin{bmatrix} \gamma_0 & \gamma_1 & \gamma_2 & \gamma_3 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}.$$

FIGURE 4. RESPONSE OF INFLATION TO INNOVATIONS



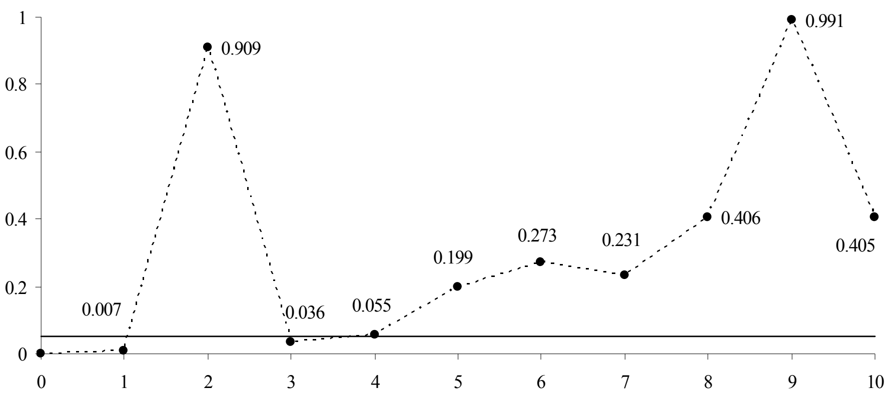
[4] For G_1 see Lütkepohl (2005). Note, however, that (12) differs from the formula presented by Lütkepohl.

A technological shock resulted in a positive response of inflation. The reaction, however, was of a relatively small magnitude. The estimated elasticity did not exceed the 7% level. The inceptive positive response was offset by a sharp decline in inflation dynamics in the very next year. The return to the initial equilibrium level lasted slightly longer than 7 years.

Since we examine the significance of the reaction, the small magnitude of the responses is of secondary importance. Figure 5 presents the probabilities of rejecting the no-response hypotheses. In other words, if the dotted line is placed below the solid line, the response is significant. In a standard VAR analysis the responses are significant if at least k (K − 1) are significant (Lütkepohl 1993 and 2005). In our case the number of 'lags' is $k+1$ and the number of variables is 2, so we checked the first 4 responses. Since the first response is individually significant at an asymptotic 0.7% (see the entries beside the dotted line in figure 5) level, the null of no response is rejected at the 2.7% significance level.

It is worth mentioning that in the standard VAR analysis testing for response significance is similar to testing for Granger-causality[5]. Thus, this result is of the primary importance for tracing out the relationship between innovations and inflation in the German Empire. The conducted analysis detected a small positive and significant reaction of inflation to a technological shock. The response was therefore in keeping with predictions based upon Wicksell's theory. Contrary to Wicksell's explanation, the interest rate channel was not the vehicle for technological changes in influencing inflation.

FIGURE 5. SIGNIFICANCE OF THE RESPONSES



2.2. MODEL RE-ESTIMATION: SHILLER ESTIMATOR

When dealing with the annual data, the number of lags k is small. This suggests that the weights β_i's might be estimated directly using OLS (Almon 1965). We have already assumed, following the neoclassical microeconomics, that the effect of

[5] See Lütkepohl (2005), remark 8 on page 115.

innovations had been distributed over some period of time. Going further, a prior parametrisation regarding the smoothness of the lag curve might be formed. This is what Shiller (1973) described as *prior knowledge that the lag coefficients should trace out a "smooth" or "simple" curve*. To get an additional insight into the weights, we re-estimate the model (11) using the Shiller procedure (1973, 1980). The vector of Shiller coefficients $\beta_{S,i}$'s is obtained by estimating (Taylor 1974):

$$\begin{bmatrix} p_t / p_{t-1} \\ \mathbf{0} \end{bmatrix} = \begin{bmatrix} \mathbf{A} \\ \frac{\sigma_\eta}{\xi} \mathbf{R}_d \end{bmatrix} \mathbf{B}_S + \begin{bmatrix} \eta \\ \upsilon \end{bmatrix} \tag{13}$$

where[6] $\xi = \left(\sum_{i=0}^{k} 8 \gamma_i \right) / 4$ and **A** consist of current and lagged regressors reported in (11). The matrix $\mathbf{R}_d$ is a matrix of *d + 1* differences, which ij^{th} element is equal to:

$$ij = \begin{cases} 0 & \textit{for} \quad j < i \\ 0 & \textit{for} \quad j - i < d + 1 \\ -1^{j-i} \begin{pmatrix} d+1 \\ j-i \end{pmatrix} & \textit{otherwise} \end{cases}$$

We ran equation (13) assuming $d = 1$, so the $\mathbf{R}_d$ is a (3*x*4) matrix, and obtained the following vector of Shiller estimators:

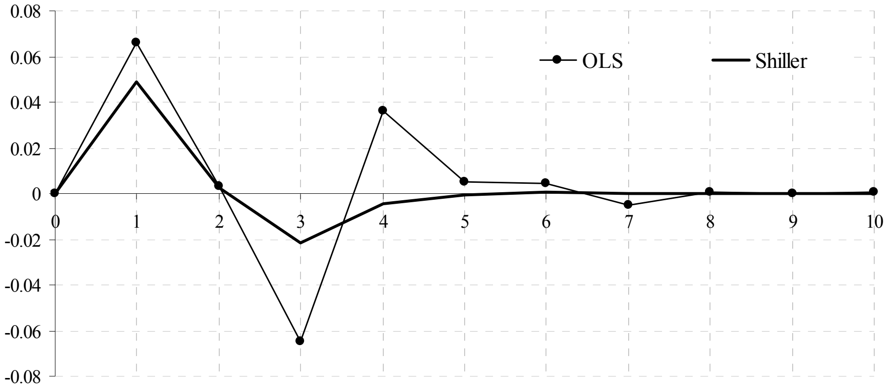
$$\mathbf{B}_S = \begin{bmatrix} 0.049 & 0.0001 & -0.021 & -0.002 \end{bmatrix}'.$$

In figure 6 we compare the estimated responses for OLS (doted line) and Shiller estimators (solid line). Not surprisingly, the magnitude of the $\mathbf{B}_S$-based responses is a little smaller and the deviations from the initial equilibrium are smoother. Similarly to the OLS coefficients, the positive impact on inflation dies out after two years.

The difference that must be reported concerns the path the system takes as it tends towards the initial equilibrium. After setting off the positive response in period 2, the system 'stays' below the horizontal axis. It means that the initial inflation equilibrium, represented by the zero-inflation level, is reached after approximately 4 years of deflation. It may then justify the neoclassical concept of a price decrease affected by a technological shock.

[6] For comments on the ξ -coefficient determination see Maddala (1977, p. 386).

FIGURE 6. IMPULSE RESPONSE: SHILLER AND OLS ESTIMATES



SUMMARY

The years between the Franco-Prussian War and WWI appear to have been a period of strong technological development. Economists, especially those of the neoclassical provenance, have not lagged behind and have incorporated technological progress as one of the most important variables. Marginal cost analysis has illustrated the role that innovations have played in influencing price dynamics. In this paper we asked the question whether or not the neoclassical model explained these relationships correctly.

Using the standard neoclassic profit optimising exercise to trace out the link between inflation and innovations, a negative relationship should be found. A condition that needs to met in order for the sign to be negative is perfect information that affects the interest rate setting. What happened when the commercial banks did not posses perfect information? Knut Wicksell offered an explanation: the actual interest rate deviated from its natural level and either deflation (when the observed interest rate exceeded the natural one) or inflation appeared. The Wicksellian model led to conclusions different from the neoclassical ones. Prices increased when a new technology was introduced.

To answer the question we asked we applied various distributed lag models. These models were especially helpful since we wanted to capture the effects of the application of new technologies without loosing too many degrees of freedom. We regressed the CPI inflation (*privater Verbraucherindex*, see Hoffmann 1965) against various interest rates (*Privatdiskontsatz*, discount rate, and Lombard rate, see Donner 1934) and the rate of change of the high-powered, 10-yearlasting patents. Being in line with the former research on this period (Baltzer 2007) we found no significant influence of the interest rates on inflation. On the other hand we observed a positive response of inflation to the technological shock. Even though the magnitude of the reaction may be considered small, the response was significant. The inceptive positive response was offset by a sharp decline in inflation dynamics in the very next year. A return to the initial equilibrium level lasted slightly longer than 7 years.

Combining the results, neither a pure neoclassic nor Wicksellian theory explained the inflation dynamics. A positive initial impact of innovation argues against the neoclassical microeconomics, as does the insignificant influence of interest rates against Wicksell. Knut Wicksell's theory of interest rate still influences economists (see, among others, Woodford 2003). It is very likely, however, that the Wicksellian renaissance will omit the economic history. The reason why is simple - the assumed structure was rather typical for the end of the 20th but not for the 19th Century[7]. Nevertheless, we must admit that we indeed found a positive Wicksellian positive relationship between innovations and inflation. To justify the neoclassical microeconomics, we should add that once the Shiller estimator is used, the neoclassical concept of a price decrease affected by a technological shock becomes visible. After setting off the positive response two years after the shock, the system 'stays' in the deflationary equilibrium until the response dies out almost completely.

REFERENCES

Almon, Sh., 1965. The Distributed Lag between Capital Appropriations and Expenditures, *Econometrica* 33(1), 178-196.
Amato, J. D., 2005. The Role of the Natural Rate of Interest in Monetary Policy, BIS Working Paper 171.
Aznar, A. S. M., 2002. Selecting the Rank of the Cointegration Space and the Form of the Intercept Using an Information Criterion, *Econometric Theory* 18, 926947.
Charemza, W. W. and D. F. Deadman, 1992. New Directions in Econometric Practice. General to Specific Modelling, Cointegration and Vector Autoregression, Edward Elgar: Aldershot.
Donner, O., 1934. Die Kursbildung am Aktienmarkt. Grundlagen zur Konjunkturbeobachtung an den Effektenm¨arkten. Berlin.
Hicks, J. R., 1977. Economic Perspectives: Further Essays on Money and Growth, Oxford University Press.
Hoffmann, W. G., 1965. Das Wachstum der deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts, Springer: Berlin.
Knight, F. H., 1925. Cost of Production and Prices over Long and Short Periods, *Journal of Political Economy* 29(4), 304-335. Lange, Oskar (1939), Neoklasyczna szkoa w ekonomii, in: O. Lange,Wybórpism. Ekonomia - przedmiot, zakres i metody, vol.2, PWN:Warszawa.
Lucas, R. E. Jr., 1973. Some International Evidence on Output-Inflation Tradeoffs, *The American Economic Review* 63(3), 326-334.
Lütkepohl, H., 1985. Comparison of Criteria for Estimating the Order of a Vector Autoregressive Process, *Journal of Time Series Analysis* 6, 35-52.
Lütkepohl, H., 1993. Testing for Causation between Two Variables in Higher Dimensional VAR Models, in: H. Schneeweiß, K. F. Zimmermann (eds.), *Studies in Applied Econometrics*, Physica: Heidelberg, 7591.
Lütkepohl, H., 2005. New Introduction to Multiple Time Series Analysis, Springe-Verlag: Berlin Heidelberg.
Maddala, G. S., 1977. Econometrics, McGraw-Hill: New York.

[7] It is worth mentioning that JR Hicks noticed that in his essays on money (1977).

Murmann, J. P., 2003. Knowledge and Competitive Advantage: The Coevolution of Firms, Technology and National Institutions, Cambridge University Press: Cambridge.
Shiller, R. J., 1973. A Distributed Lag Estimator Derived from Smoothness Priors, *Econometrica* 41(4), 775-788.
Shiller, R. J., 1980. Distributed Lag Estimators Based on Linear Coefficient Restrictions and Bayesian Generalization of these Estimators, HIS Journal 4, 163-180.
Streb, J., J. Baten and S. Yin, 2006. Technological and Geographical Knowledge Spillover in the German Empire 1877-1918, *Economic History Review* (59), 347-373.
Streb, J., J. Wallusch and S. Yin, 2007. Knowledge Spill-Over from New to Old Industries: The Case of German Synthetic Dyes and Textiles (1878-1913), *Explorations in Economic History* 44(2), 203-223.
Taylor,W. E., 1974. Smoothness Priors and Stochastic Prior Restrictions in Distributed Lag Estimation, International Economic Review 15(3), 803-804.
Wicksell, K., 1898. Geldzins und Guterpreise, Gustav Fischer: Jena.
Wicksell, K., 1907. The Influence of Interest Rate on Prices, *Economic Journal* (17), 213-220.
Woodford, M., 2003. Interest and Prices: Foundations of a Theory of Monetary Policy, Princeton University Press: Princeton.