Economy

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Nonparametric Estimation and Comparison of the G7 Phillips Curves

Diploma Thesis

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List of Nomenclature

The Notation of terms and variables is following the order of their appearance within the text. For a better orientation the page, where it first appears is specified in the left column. A few abbreviations have been used twice since that has not been avoidable in order to follow common notation. For instance u is unemployment in chapter 2 and 4, but also denotes a distance variable for neighborhood smoothers in chapter 3.

In the context of Phillips curve theory upper case letters denote absolut measures of a parameter, whereas lower case variables mark either rates of an absolute measure (in percent), indices or logs. Abbreviations are also written with upper case letters. Matrices and vectors in chapter 3 are fat and cursive, whereas R-program code (except for Appendix C) is just fat.

Nomenclatures for Chapter 1 and 2

First time on page	**Notation, abbreviation**	**Description**
1	OPEC	Organisation of the Petroleum Exporting Countries
	PC	Phillips Curve
2	UK	United Kingdom
3	G7	Group of the seven major industrial democracies
6	US	United States
	Dw	Rate of change of money wage rates (in short: wage inflation)
	u	Unemployment rate as a share of 1
	t	The current time period (usually used as a subindex)
	u_*	unemployment corresponding to zero wage inflation
8	u_f	Frictional unemployment
	c	A constant
	N	Total employment
	N^D	Total employment demand
	N^S	Total employment supply
	x	Excess demand rate
9	NAIRU	Non-Accelerating Inflation Rate of Unemployment
	SRPC	Short-Run Phillips Curve
12	Dp	Rate of change of the price level (in short: price inflation)

First time on page	**Notation, abbreviation**	**Description**
	ϱ_i	The ith coefficient in the "triangle" model equation
	M	A polynomial in the lag operator
	z	A vector of supply shocks parameters
	ε	A random variable
	NKPC	New Keynesian Phillips Curve
	P_t^*	Desired price of a firm in period t
	P_t	Overall price level in period t
	α	Coefficient for the desired price in the NKPC
	$\bar{u}$	Notation for the Natural Rate of Unemployment (NAIRU)
13	P_t^{set}	Price set by the individual firm in the NKPC
	ϕ	Portion of firms in the NKPC, randomly chosen to adjust prices in the NKPC framework
	$E_t(P_{t+j}^*)$	In t expected desired price for period $t+j$
14	W_t	Wage rates
	$\hat{Y}_t$	Output in period t
	κ_w	Coefficient for the demand pressure term in a wage NKPC
	κ_p	Coefficient for the demand pressure term in a price NKPC
	$log\ w_t^n$	Natural real wage, the equilibrium real wage, when both wages and prices are flexible
	β	Coefficient for $E_t[\Delta logW_{t+1}]$ and $E_t[\Delta logP_{t+1}]$, the expected wages and prices in the following period (t+1) respectively
	GDP	Gross Domestic Product
16	AD	Aggregate Demand
	AS	Agregate Supply
	N_l	Total labor employment
	$\bar{N}_l$	Total labor employment corresponding to the NAIRU
	N_c	Total capacity employment
	$\bar{N}_c$	Total capacity employment corresponding to the NAIRU
	$D12p$	Inflationary climate (specific formula is provided in 2.4)
17	CPI	Consumer Price Index
18	μ	Markup as a share of 1
20	OLS	Ordinary Least Squares
	δ_i	Phillips Curve coefficients with some subindex i
21	du/dt	Derivative of the unemployment rate over time
23	p_t	Natural logarithm of price P_t
	w_t	Natural logarithm of wage W_t
	pm_t	Natural logarithm of an import price deflator
	γ_i	Wage Phillips Curve coefficients with subindex i
	φ	An Error term

First time on page	Notation, abbreviation	Description
	a_i	Price Phillips Curve coefficients with subindex i
	b_i	Wage Phillips Curve coefficients with subindex i
	n_W	Time worked relative to contractual work time
	n_I	Inventory use relative to balanced inventory use
24	Dyn	Growth of labor productivity Yn
	Yn	Labor productivity measured in monetary units

Nomenclatures for Chapter 3

At first on page	Notation, abbreviation	Description
27	X	Predictor variable X
	Y	Response variable Y
28	GCV	Generalized Cross Validation
	AIC	Akaike Criterion
29	x_i	ith observation of the predictor X
	y_i	ith observation of the response Y
	i	Index for observations
	n	Total number of observations
	CV	Cross Validation
	R	Statistical software
	β_0	Absolut parametric regression coefficient
	β_i	Parametric regression coefficient for the x_i
30	$\hat{y}_i$	Estimated value corresponding to the observed x_i
	$\hat{\beta}_i$	Estimation of the ith regression coefficient
	$\bar{x}$	Mean of the x_i
	$\bar{y}$	Mean of the y_i
31	p	Dimension of $\boldsymbol{X}$, number of predictor variables
	$\boldsymbol{H}$	Hat matrix
	d	Degree of a polynomial
33	g	Nonlinear function
34	θ_i	Coefficient for nonlinear regression
	$N()$	Normal distribution function
	σ^2	Variance of the response Y
	$\boldsymbol{I}$	Identity matrix
35	$\hat{f}(x_i)$	Estimated function of the observations x_i
	k	Index for observations belonging to the neighborhood $N(x_i)$
	$N(x_i)$	Neighborhood of x_i, i.e. set of the x_k points
36	ζ	Span for the linear-weighted running line smoother

At first on page	Notation, abbreviation	Description
	z	Total number of observations belonging to the neighborhood $N(x_i)$
	w_k	weight given specifically to the point (x_k, y_k) in $N(x_i)$
	$W()$	Weight distribution function for Loess and Lowess
	u	Serves as a replacement for a complex distance measure for neighborhood smoothers
	j	Index, here $j = 1, ..., d$
	ς_i	Residuals, i.e. $y_i - \hat{y}_i$
	τ	Median for robust regression estimation
37	δ_k	New weight given to (x_k, y_k) for the iterations of a Lowess
	$B()$	Weight distribution function for the iterations of a Lowess
	o	Serves as a replacement for $\varsigma_k/6\tau$
	T	Number of iterations for the Lowess
38	$K()$	Weight distribution function for Kernel smoothing
	α	Chosen bandwidth of the kernel
39	Π	Number Pi
41	G	Number of knots for regression splines
	ξ_j	Position of the jth knot
	m	Order of a derivative
45	λ	Roughness penalty
	A	Matrix defined in the text
46	$S()$	Smoothing spline function
	a	Lower limit of an integral
	b	Upper limit of an integral
47	NCS	Natural Cubic Spline
	γ_j	Second derivative at the jth knot
	h_i	Distance between the ith and $i+1$th knot
	Q	Matrix for the NCS calculation
	q	Elements of the matrix Q
	R	Matrix for the NCS calculation
	r	Elements of the matrix R
48	L	Matrix of the Cholesky decomposition
	D	Matrix of the Cholesky decomposition
	l	Elements of the matrix L
	d	Elements of the matrix D
49	O	Order of algebraic operations
50	GAM	Generalized Additive Model
	SAS	Statistical Software
	c	Starting value for the Backfitting procedure
55	RSS	Residual Sum of Squares
57	UBRE	Unbiased Risk Estimator
58	df	Degrees of Freedom

Nomenclatures for Chapter 4

At first on page	Notation, abbreviation	Description
59	IMF	International Monetary Fund
	Eurostat	Statistical Office of the European Communities
70	R^2	Coefficient of determination
	$\bar{R}^2$	Corrected coefficient of determination
	RSE	Residual standard error
	DW	Durbin-Watson test
	F	F-test statistic
73	CDN	Canada
	F	France
	D	West-Germany
	I	Italy
	J	Japan
	GB	United Kingdom
	USA	United States of America

Chapter 1

Introduction

The start of this century has turned out to be a crucial crossroad for macroeconomics on three counts. Firstly, the *New Economy* at the end of the last decade, often suspected to suspend the traditional economical rules (see for example Boldin (1998)) was breaking down, which gave back the belief that those rules still exist. Secondly, almost at the same time the European Monetary Union experiment started, where the outcome is still uncertain, especially with regards to the goal of exclusively fighting against inflation (see the European Central Bank mission statement at http://www.ecb.int). [1] The third problem arises from the war against terrorism, which is already a serious cost driving factor because of higher security requirements, greater uncertainty faced by all economical agents and higher oil prices, whereby the latter issue has just recently been resolved for some time by the OPEC (Organization of the Petroleum Exporting Countries) having declared to increase the production of oil.

All three points are in fact strongly connected to the notorious concept of the *Phillips curve* (PC), which has been introduced by Alban William Phillips (1958). The main idea of it is that a positive correlation exists between, broadly speaking, the level of capacity utilization and the change of prices on a market. For instance lower unemployment rates, associated with higher production of output, would correspond to higher positive wage increases, whereas higher unemployment would lead to lower wage increases, possibly even to wage decreases (cf. Phillips (1958)).

[1] The Deutsche Bundesbank (1987, p. 9) considered the anti-inflation policy as a requirement to produce economic prosperity and low unemployment rates, whereas Stiglitz (1997) and Hoogenveen and Kuipers (2000) strongly doubt this view.

Of course, the choice between two different situations like these does not seem to be that difficult, but one has to note that wage increases are usually strongly connected to inflation, the increase in prices, and thus to the devaluation of the national currency. This issue has been known a long time before, namely by Irving Fisher (1926), Arthur Cecil Pigou (1933) and John Maynard Keynes (1936), but Phillips' paper has caught the most attention, partly due to the graphical representation it gave for the relation just described.

From the very beginning, the Phillips-curve (PC) was causing a big controversy. The model has been praised as the "core of most large-scale macroeconomic models used by central banks, governments, and commercial forecasters" (Gali (2000)). Alan Blinder (1997) even called it "the clean little secret" of macroeconomics. Similar euphoria did accompany the early 1960's, especially when Samuelson and Sollow (1960) encouraged policy makers to exploit the so called trade-off between inflation and unemployment. However, the critiques by Friedman (1968) and Phelps (1968), who strictly deny a stable curve in the long run, and empirical evidence get Lucas and Sargent (1978) to call the model an "econometric failure on a grand scale". The reason for this statement, the experience of high inflation together with high unemployment during the 1970's, was mainly attributed to the oil price shocks in those years, but also to the change in expectations (Blanchard (2003, p. 168)) of economical agents. However, various enhancements and recreations of the original Phillips curve (for instance Phelps (1968), Gordon (1982) and Calvo (1983)) and its success in predicting economical measurements, as well as its ability to guide *monetary policy* makers (mentioning the *Taylor rule* (1993), see also Leeson (1997)) reinforced the relevance of the model.

One of the strengths of the Phillips curve discussion is the early tie to empirical observation and thereby to statistical methodology. Phillips (1958) already applied a simple fitting technique, which can be seen as some sort of *nonlinear regression*, as he figured the wage Phillips curve of the UK to be nonlinear. On the contrary, Gordon (1970, 1977) and others used a linear framework to be estimated. However, mainly the estimation of the functional relation between inflation and unemployment has been done in a *parametric* setting. This has the disadvantage of a potential loss of information due to narrowing the focus to a specific form (e.g. *linear regression*) beforehand. Stiglitz (1997) and Akerlof (2002) for instance suggest that the Phillips curve features important nonlinearities. Even though the *polynomial* and the nonlinear regression might be quite successful in tracking nonlinearities, those methods still depend a lot on skills and goodwill of the analyst. In this regard *nonparametric* procedures generally represent a superior alternative. Its motto is: "Let the data show us the appropriate functional form." (Hastie and Tibshirani (1990, p. 1)). In other words those techniques attempt to extract the relation of variables exclusively data driven. During the last decades this field of statistics experienced a tremendous boom, certainly pushed by the introduction and the fast progress of the computer technology, such that today it is providing a wide range of models, *smoothing* procedures, fit selection criteria etc.

The goal of this thesis is to apply nonparametric methodology in order to investigate the Phillips curves of all G7 members states, the USA, Japan, Germany, Great Britain, France, Italy and Canada. Thereby it will build upon the theoretical approach of Flaschel et al. (2004), which is modeling two distinct wage and price Phillips curves, taking account of the *wage-price spiral*. Furthermore it includes a measure of *adaptive expectations* as well as *myopic perfect foresight* of inflation. It is expected that not only important nonlinearities of the Phillips curve will be observable in many countries, but the analysis may also provide evidence of essential differences between countries. A broad international investigation in this regard has rarely been conducted, DiNardo and Moore (1999) and Hoogenveen and Kuipers (2000) being a few exceptions. However, it promises interesting insights, namely about the behavior of the famous macroeconomic relationship in various environments.

The remainder of the paper is organized as follows. Chapter 2 is devoted to sketching the scientific history of the Phillips curve, as well as some of the more important specifications developed along the way. It then leads to the justification and the formulation of the concrete Phillips curve framework, originated by Fair (2000) and Flaschel et. al. (2004). In Chapter 3 an introduction is given in parametric regression, *neighborhood smoothing*, *spline smoothing*, *additive models*, and a few *model selection* criteria. In doing so it concentrates on the empirical practicability of those techniques and it tries to sensitize the reader to understand the strength and weaknesses of the different procedures, often supported by graphical representations. In Chapter 4 parametric as well as nonparametric analyses of the