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A COINTEGRATION APPROACH TO TOPICS IN EMPIRICAL MACROECONOMICS

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A Cointegration Approach to Topics in Empirical Macroeconomics

Key words: Integrated processes, Cointegration, Vector Auto-Regressive model, The Elasticity of Substitution, Production Function, New Keynesian Phillips curve, Inflation.

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Foreword

Mikael Juselius' doctoral dissertation covers a range of significant issues in modern macroeconomics by empirically testing a number of important theoretical hypotheses. The first essay presents indirect evidence within the framework of the cointegrated VAR model on the elasticity of substitution between capital and labor by using Finnish manufacturing data. Instead of estimating the elasticity of substitution by using the first order conditions, he develops a new approach that utilizes a CES production function in a model with a 3-stage decision process: investment in the long run, wage bargaining in the medium run and price and employment decisions in the short run. He estimates the elasticity of substitution to be below one. The second essay tests the restrictions implied by the core equations of the New Keynesian Model (NKM) in a vector autoregressive model (VAR) by using both Euro area and U.S. data. Both the new Keynesian Phillips curve and the aggregate demand curve are estimated and tested. The restrictions implied by the core equations of the NKM are rejected on both U.S. and Euro area data. These results are important for further research. The third essay is methodologically similar to essay 2, but it concentrates on Finnish macro data by adopting a theoretical framework of an open economy. Juselius' results suggests that the open economy NKM framework is too stylized to provide an adequate explanation for Finnish inflation. The final essay provides a macroeconometric model of Finnish inflation and associated explanatory variables and it estimates the relative importance of different inflation theories. His main finding is that Finnish inflation is primarily determined by excess demand in the product market and by changes in the long-term interest rate.

This study is part of the research agenda carried out by the Research Unit of Economic Structure and Growth (RUESG). The aim of RUESG it to conduct theoretical and empirical research with respect to important issues in industrial economics, real option theory, game theory, organization theory, theory of financial systems as well as to study problems in labor markets, macroeconomics, natural resources, taxation and time series econometrics.

RUESG was established at the beginning of 1995 and is one of the National Centers of Excellence in research selected by the Academy of Finland. It is financed jointly by the Academy of Finland, the University of Helsinki, the Yrjö Jahnsson Foundation, Bank of Finland and the Nokia Group. This support is gratefully acknowledged.

Helsinki, 4 May, 2007

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The difficult process of conducting research has been greatly alleviated by my colleagues at the Swedish School of Economics and Business Administration and at the Research Unit on Economic Structures and Growth (RUESG). I am grateful for all the inspiring discussions over the years and thank them all. I would in particular like to thank Staffan Ringbom who has commented my research, aided me with computer problems, offered advice and encouragement on more occasions than I can count over the years. I would not have survived without his help.

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Finally, I would like to thank my fiancee Matilda and my beloved son Vidar for sharing life with me and making it all worth while. This thesis is dedicated to them.

Helsinki, May 2007
Mikael Juselius

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Chapter I
Introduction

1 Background

Cointegration has emerged during the last decades as an increasingly popular way of dealing with non-stationary macroeconomic data. This development is a consequence of the now well established empirical fact that most macroeconomic time series, such as prices and wages, display non-stationary behavior. This can potentially be a serious problem since non-stationary data invalidate standard inference and may lead to spurious regression, if not taken into account. Cointegration provides an elegant solution. The idea is that a linear combination of two or more non-stationary series can be stationary, if the series share the same stochastic trends. If such a combination exists, the series are said to be cointegrated and the linear combination between them is called a cointegration relationship. It is often the case that cointegration relationships can be interpreted as economic long-run relationships, providing a powerful tool to take theory to data.

That being said, the majority of current research in empirical macroeconomics assumes that data is stationary. There are at least two reasons for this. First, theoretical economic models usually assume stationarity and analyze equilibria. Dynamic adjustment toward equilibrium and stochastic trends are seldom investigated within a theoretical model. Hence, it is often difficult to connect a theoretical model to a realistic statistical model of the data. Second, the most common way of modeling non-stationary time series is by integrated processes. However, these imply unreasonable asymptotic behavior for most economic series. For instance, a unit-root in an auto-regressive process implies that the variance of the series goes to infinity with time. Thus, an economic time series cannot be an integrated process in any structural sense.

The first of these reasons points to a shortcoming in theoretical economic modeling rather than being a compelling argument against allowing for integrated processes. The second reason is clearly valid, but ignores the usefulness of approximating breaks and shifts in the series with integrated processes over shorter periods of time. Integrated processes can be seen as a convenient statistical approximation of series with slope and level shifts. In a similar spirit, cointegration can be seen as a convenient approximation of co-breaking or co-trending series, i.e. series that experience similar breaks and shifts at the same point in time. Thus, there is no reason to attach a structural meaning to, say, a unit-root. Regardless of which interpretation is given to the non-stationary behavior of most economic time series, ignoring the problem invalidates inference and reduces the credibility of the results.

Broadly speaking, two competing methodological approaches to empirical modeling stand out. One places more emphasis on economic theory, deriving econometric equations directly from theoretical equilibrium relationships. The equations are then often augmented with additional information to obtain better descriptions of the data. The theoretical model is empirically evaluated based on the correspondence between its predictions and the estimates. The adherents of this approach usually assume that data is stationary as a direct consequence of the theory at hand. The other approach aims at building a good statistical description of the data and places less emphasis on economic theory. This approach often starts from a large (theory inspired) information set, and reduces it to obtain a parsimonious specification within which theory can be evaluated. The adherents of this data-oriented approach usually allow for unit-roots, breaks etc.. The former modeling approach has been termed 'specific to general' and has the advantage of close correspondence with economic theory, allowing for easy interpretation of the results. The drawback is, however, the lack of statistical credibility. The opposite is true of the second modeling approach, termed 'general to specific'.

This thesis attempts to take the middle ground between these two approaches in investigating a few topical issues in empirical macroeconomics. In accordance with the 'general to specific' view, emphasis is placed on obtaining good descriptions of the data by allowing for integrated series. To this end, the cointegrated VAR (Vector Auto Regression) model is employed as the main statistical workhorse to describe the economic time series at hand. The model provides a convenient way of summarizing the first and second moments of the data, while allowing for non-stationary unit-root behavior. Furthermore, the model is very flexible and does not require strong assumptions, for instance concerning exogeneity, prior to investigation. However, the increased flexibility comes at the cost of weakening the close correspondence with economic theory. Thus, considerable effort is spent on relating the statistical model to economic theory, bridging the gap between theory and data.

This methodological view is reflected in the three problems investigated in this thesis. The first problem is to obtain an empirical estimate of the substitution elasticity between labor and capital. This elasticity is a key structural parameter in describing technology and has been important in, for instance, growth theory. The second problem is that of testing the new Keynesian model (NKM), which is arguably the most popular model of inflation today. The model is a dynamic stochastic general equilibrium (DSGE) model, based on optimizing consumers and firms as well as rational expectations. The final problem that is considered in this thesis is that of evaluating the performance of different economic models of inflation.

2 Integration and cointegration

Most econometric inference relies on the assumption that the time series under investigation are stationary. A process is strictly stationary if its distribution is *not* dependent on the absolute position in the sequence, only on the relative position in the sequence. A process is said to be integrated of order zero, $I(0)$, if it is strictly stationary and its long-run variance is finite and positive. However, it is well known that many macroeconomic time series exhibit stochastic trends. Figure 1 depicts

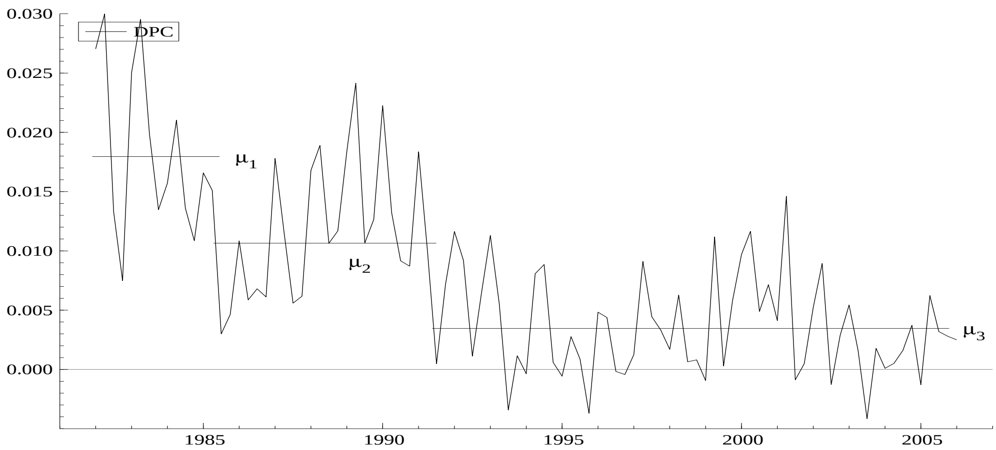

Figure 1: Finnish quarterly inflation over the period 1982:1-2006:1. The straight lines correspond to three potential breaks in the mean, μ, illustrating the non-stationary behavior of the series.

Finnish inflation over the period 1982:1-2006:1. It can be seen from the picture that that the series has no clear mean over the period, which is typical for a trending series.

One class of processes that has been found to provide good approximations to such trends is integrated processes. A process is said to be integrated of order d, denoted by $I(d)$, if its d:th difference is $I(0)$. An $I(1)$ process is also called a unit-root process, because it has an autoregressive representation with a root at unity.

Integrated processes pose a particular challenge in econometrics. For example, asymptotic inference does not hold in the standard regression model under integrated processes, and is likely to be very misleading. Even worse, regressing two unrelated trending series tends to give the false impression that the series are closely related. This problem is known as spurious regression. Hence, it is important to be able to both detect and handle non-stationary integrated processes. The challenge of testing for unit-roots in a univariate framework was first met by Fuller (1976) and Dickey and Fuller (1979) and has since been followed by a plethora of unit-root tests.

The obvious solution to integrated series is to difference the series d times to achieve stationarity (economic time series are rarely integrated of higher order than two in practice). However, differencing leads to a loss of the long-run information in the series, and the resulting series might not be interesting from an economic point of view. Another, far more appealing solution to the problem is cointegration. The time series y_t and X_t, where y is a scalar and X is a vector, are said to be cointegrated if they are integrated of order d, and there exists a linear combination $y_t - \beta' X_t$ that is integrated of order $d - b$, where $b \leq d$. This is written as $\{X_t,\, y_t\} \sim CI(d,\, b)$. The vector $(1,\, \beta')'$ is called a cointegration vector and can often be interpreted as an economic long-run relationship.

An explicit example of cointegration is provided, by letting y_t be the inflation series depicted in figure 1, and letting x_t consist of the short- and long-term Finnish interest rates, depicted in figure 2. These series can be shown to be $I(1)$ processes over the period. Then the linear combination $y_t - (-1,\, 1)' x_t$ is stationary, with cointegration vector $(1,\, -1,\, 1)'$. The cointegration relationship is depicted in figure

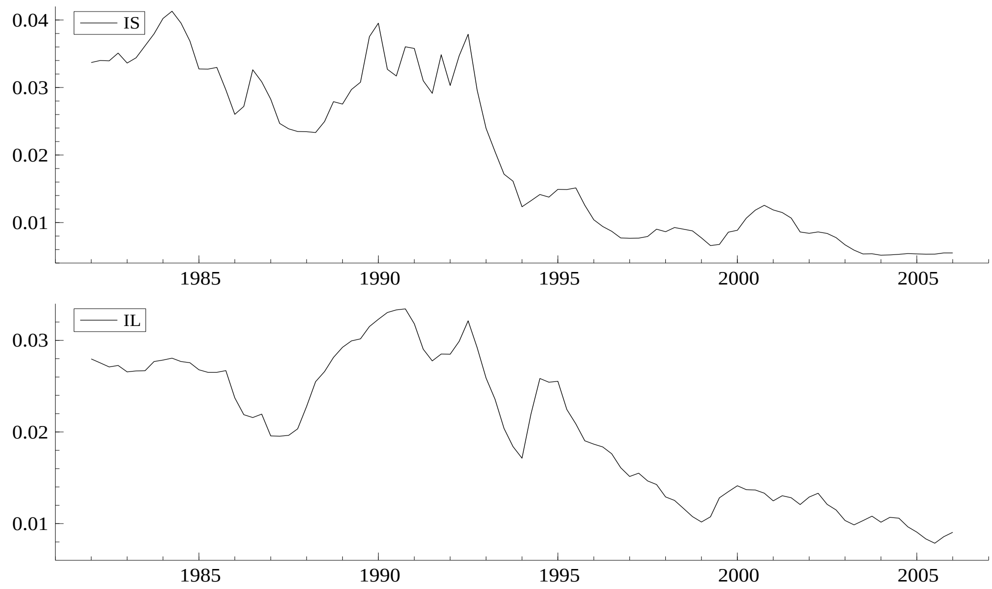

Figure 2: The short- and long-term Finnish interest rates over the period 1982:1-2006:1.

3.

Cointegration or error correction has its origins in an empirical paper by Sargan (1964), followed by Davidson et al. (1978), and formalized a decade later by Granger (1981). Granger showed that cointegration between a set of variables is analogous to the series having the same stochastic trends. A very important breakthrough in this respect was made by Johansen (1988, 1991), who generalized these results to the Gaussian vector auto-regressive model re-parametrized in error correction form.

2.1 The cointegrated VAR model

The p-dimensional cointegrated VAR(k) model provides a very flexible way of modeling time series data and testing for integration and cointegration. The model is a re-parametrization of a VAR(k) model, where a times series vector is regressed its k lagged values and possible deterministic terms. As an example, a VAR(1) model with no deterministic components can be written as

$$X_t = A_1 X_{t-1} + \varepsilon_t \tag{1}$$

where X_t is a p-dimensional time series vector, A_1 is a $p \times p$ matrix, and $\varepsilon_t \sim N_p(0, \Omega)$. The VAR framework allows for fairly complex dynamics in the data, and is flexible in that *all* variables are treated as endogenous at the outset. Different forms of (empirical) exogeneity can be tested as restrictions on the parameters of the model. The model can be re-parametrized in a way that is useful for testing integration and analyzing cointegration. For example, if X_t is integrated of first order, (1) can be re-parametrized as

$$\Delta X_t = \Pi X_{t-1} + \varepsilon_t$$

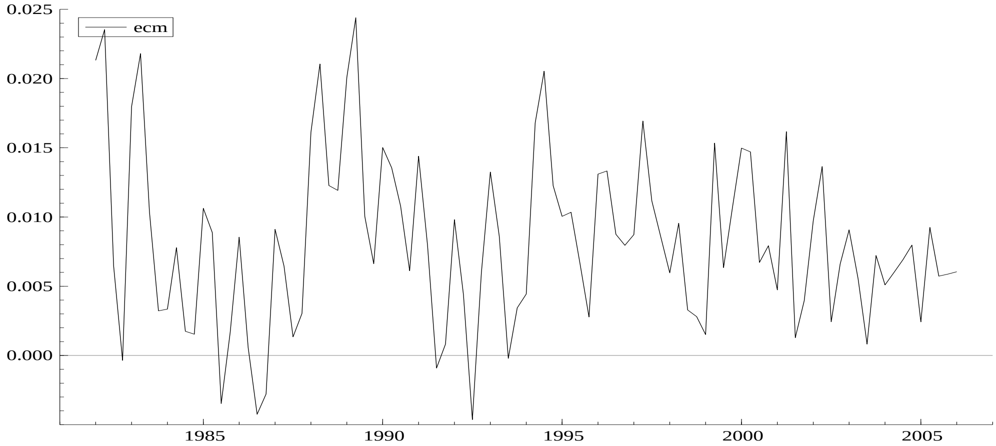

Figure 3: The stationary linear combination $\Delta p_t - i_t^s + i_t^l$, where Δp_t is inflation, i_t^s is the short-term interest rate, and i_t^l is the long-term interest rate. None of the variables are pairwise stationary.

where $\Delta X_t = X_t - X_{t-1}$, and $\Pi = I - A_1$. It turns out that the number of cointegration relations and the number of stochastic trends can be determined by testing the rank of the matrix Π. If the matrix is of full rank then the process is stationary. However, if the matrix has rank $0 < r < p$ then there are $p-r$ stochastic trends and r stationary linear combinations between the variables. In this case, Π can be decomposed into two $p \times r$ matrices, α and β, of full column rank, where the columns of β collects the cointegration vectors. Finally, if the rank of Π is equal to zero, then the series are not cointegrated.

3 Selected topics in empirical macroeconomics

This section presents three topical problems in empirical macroeconomics. The main problems are discussed and explained. A review discussion of the empirical literature in each field is also provided.

3.1 Estimating the elasticity of substitution between capital and labor

The last few decades has seen renewed interest in the functional form of the aggregate production function. In particular, there has been a shift away from the standard Cobb-Douglas production function to the more general constant elasticity of substitution production (CES) function. This development has been fueled by both empirical and theoretical concerns. On the empirical side, it has been noticed that factor shares have not remained constant (Bentolila and Saint-Paul (2003)) even though the Cobb-Douglas specification implies constant shares. On the theoretical side, moving away from the Cobb-Douglas function has led to richer insights, for instance in the context of growth theory (see Solow, 1994).

Within this context, the parameter value of the elasticity of substitution between capital and labor is of particular importance. Several of the specific theoretical results and predictions hinge on the particular value or relevant interval of this elasticity. For instance, in a growth theory context endogenous growth is possible if this elasticity is above one, as demonstrated by Klump and De La Grandville (2000). Moreover, the standard Cobb-Douglas production function is a special case of the CES function when the substitution elasticity is exactly equal to one.

The importance of the elasticity of substitution has resulted in many attempts to estimate this parameter. Typically, the estimates are obtained directly from first order conditions derived from theory, implicitly assuming stationary data. Examples of this approach can be found in the time panel study by Duffy and Papageorgiou (2000) and in the time series studies of Klump et al. (2004) and Antras (2004). A notable exception is provided by Jalava et al. (2006), who use the cointegrated VAR model to obtain a Finnish estimate of the elasticity. An additional problem is that several unrealistic assumptions, such as perfect labor and product markets, are usually needed in order to obtain relatively tractable first order conditions upon which the estimations can be based. In addition, cross country panel studies make strong assumptions on the technological similarity of the countries, which seem difficult to defend.

Due to these difficulties, and because of differences in estimation methods, the overall evidence on the elasticity of substitution is mixed (see Klump et al., 2004 for a review of previous findings). Estimates of the substitution elasticity that are below, equal, and above one have been obtained in the literature. Thus there is a need for a method of estimating the substitution elasticity that can account for the time series properties of the data, while not restricting the analysis by making too unrealistic assumptions. This is the objective of essay I in this thesis.

3.2 The new Keynesian model

The new Keynesian model has emerged as an attractive candidate for monetary policy analysis in recent years, and it is currently the favored choice by both policy makers and academics. It belongs to the class of dynamic stochastic general equilibrium (DSGE) models, with optimizing households and firms, rational expectations, and nominal price rigidities. In its basic form, the core of the model consist of two structural equations. The first is an optimizing IS curve, relating current output to expected future output and the real interest rate, and the second is a new Keynesian Phillips curve (NKPC), relating current inflation to expected future inflation and marginal costs, Clarida et al. (1999). The model is closed by deriving a policy rule for the nominal interest rate under some policy regime, for instance discretion or commitment. The baseline model has been extended in numerous directions over the past decade, for instance by incorporating labor market imperfections, Erceg et al. (2000), or by accounting for investments in capacity, Razin (2005). Open economy extensions have been considered by several authors, for example Svensson (2000), Clarida et al. (2002), Gali and Monacelli (2002), and Monacelli (2005).

The popularity of the NKM is partly due to its relative simplicity and theoretical elegance. However, the real breakthrough came with Gali and Gertler (1999), who estimated the NKPC on Euro Area data and reported favorable results. Gali and

Gertler argued that the early investigations into the new Keynesian Phillips curve failed (see for instance Fuhrer, 1997) because the wrong measure of marginal costs had been used. They proposed the use of labor's share of income as a measure of marginal costs instead[1]. This contribution has been followed by several others, for instance Gali et al. (2001), Sbordone (2002), Giordani (2004), Matheron and Maury (2004), Batini et al. (2005), and Roberts (2005) and includes open economy extensions and supply side refinements. The second core equation, the optimizing IS, has received far less attention in the literature, the most notable exceptions being Fuhrer (2000), Fuhrer and Rudebusch (2004), and Kara and Nelson (2004).

In general, the results from these studies tend to support the NKM, and in particular the NKPC. However, a number of empirical concerns have also been raised. Most studies estimate one of the core equations, while empirical identification requires a system approach. Furthermore, the results are sensitive to the estimation method that is employed. For instance ML (Maximum Likelihood) based procedures tend to reject the NKM, or individual equations thereof, while GMM (General Method of Moments) based procedures tend to obtain favorable results (GMM estimates are likely to be very imprecise due to such problems as weak instruments Ma, 2002). Finally, the majority of the studies assume that the data is stationary, even though this assumption is difficult to defend from a statistical point of view. Thorough discussions of these issues can be found in Mavroeidis (2004), Bardsen et al. (2004), and Rudd and Whelan (2005*b*).

The preceding discussion makes it clear that there is a need to evaluate the performance of the NKM by an approach that takes these difficulties into account. This is the objective in essays 2 and 3. In essay 2, the NKM is tested on U.S. and Euro Area data, within the framework of the cointegrated VAR model. In essay 3, a small open economy variant of the NKM is tested on Finnish data.

3.3 Evaluating competing models of inflation

The new Keynesian Phillips curve, and more generally models within the Keynesian tradition, emphasize excess demand for goods and services in modeling inflation. However, there are several other explanations of inflation, as well. A major strand of inflation models views exogenous money creation in excess of output growth as the most important cause of inflation. This branch of inflation models has its modern origin in Friedman (1956) and is reflected in more recent models such as the p^* model of Hallman et al. (1991). A third approach to inflation modeling emphasizes the role of imperfections in both labor markets and product markets. This approach models prices and wages as an outcome of the bargaining over mark-ups between employers and labor unions. This view can be summarized by the incomplete competition model (ICM) of Kolsrud and Nymoen (1998). Finally, external theories of inflation emphasize the transmission of inflation from abroad, either directly by increases in foreign prices or as a result of exchange rate movements. The external transmission channels of inflation are typically included in open economy models of inflation such as Bardsen et al. (2003) or Monacelli (2005).

[1] Rudd and Whelan (2005*a*) show that labor's share is inconsistent with the observed pro-cyclical behavior of marginal costs.

Most of these inflation theories are intermixed to some extent. For instance, the NKM contains a monetary part, while both the ICM and open economy NKMs take imported inflation into account. Hence, the distinctions between these models are partly a matter of emphasis, rather than a clear cut disagreement on the explanations. Ultimately, determining which factors are of greatest importance for the inflation process is an empirical question. This has been the topic of some previous inflation studies starting from Surrey (1989) on U.S. and U.K. data, and Juselius, K. (1992) on Danish data. Following in the same tradition, Metin (1995) investigates Turkish data. Hendry (2001) models U.K. inflation using a slightly different approach. A related study can also be found in Jansen (2004) on European data. Finnish inflation forecasts has also been investigated in a similar spirit by Muhleisen (1995).

The general conclusion of these studies is that there is no single explanation for inflation, but rather that inflation is a many faceted phenomenon. Investigating the determinants of Finnish inflation is the topic of essay IV in this thesis.

4 Summaries of the essays

This section summarizes the essays in the order that they appear in the thesis. The presentation emphasizes the methodology that is used and the main findings of the studies. The common theme of the essays is the application of the cointegrated VAR model to the economic topics discussed in the previous section.

4.1 Essay I: Long-Run Relationships Between Labor and Capital: Indirect Evidence of the Elasticity of Substitution

The first essay provides Finnish evidence on the parameter region of the elasticity of substitution between capital and labor within the framework of the cointegrated VAR model. The data sample consist of quarterly Finnish manufacturing data spanning 1980:1-2005:4.

I first demonstrate that the standard approach, whereby the elasticity of substitution is estimated directly from first order conditions derived from a competitive model, is inapplicable to the Finnish manufacturing data. The most likely explanation for this failure are the simplistic assumptions of competitive product and factor markets.

I propose a different approach to drawing inference on the elasticity of substitution which is easily applied to more realistic models. The idea is that estimates of the elasticity of substitution may be retrievable from behavioral equations derived from complicated models, by conducting comparative statics with respect to this parameter. The empirical problem is to investigate if the observed long-run behavior of the data is consistent with the results from the comparative statics.

In particular, I use a theoretical relationship between wages and the capital-labor share derived by Koskela and Stenbacka (2006) in a model that assumes a CES production function coupled with labor and product market imperfections. Koskela and Stenbacka show that the relationship between wages and the capital-labor share is negative (positive) when the elasticity of substitution is below (above) one. The relationship vanishes in the Cobb-Douglas case, i.e in the case when the elasticity of substitution is one. This relationship provides an opportunity to make inference on the parameter region of the elasticity of substitution by investigating if a corresponding long-run relationship can be found in the data.

I find a negative cointegration relation between wages and the capital-labor share. This result is consistent with a modeling approach of the Finnish economy that assumes a CES production function with an elasticity of substitution below one, combined with both product and labor market imperfections. Furthermore, the Cobb-Douglas production function is an inadequate description of the Finnish production process.

4.2 Essay II: Testing the New Keynesian Model on U.S. and European data

In the second essay, the restrictions implied by core equations of the new Keynesian model are tested within cointegrated VAR models on U.S. and aggregate Euro Area data. The data sets contain quarterly observations over the sample periods 1960:1-2005:2 for the U.S. data and 1970:1-2003:4 for the European data. Both data sets are standard and have been extensively used in the literature.

Previous empirical studies on the NKM have faced a number of difficulties. For instance, most studies focus on only one of the core equations, while empirical identification requires a system approach. Furthermore, it is also common to assume stationarity, contrary to what is usually found in actual data. These difficulties can be handled by the method for testing linear rational expectation (RE) hypotheses on a cointegrated VAR model developed by Johansen and Swensen (1999, 2004). In particular, the method allows for testing complete RE systems on non-stationary data.

I apply the Johansen and Swensen method to testing the NKM on both U.S. and European data. The core equations of the model are rejected on both data sets. Sensitivity analyzes with respect to different sample periods and different measures of marginal costs do not change the results.

The Johansen and Swensen method also implies necessary (but not sufficient) conditions on cointegration for any linear RE model, which are easily tested. Testing such conditions provide a less stringent way of testing a RE model, and corresponds to testing whether the long-run behavior of the data is consistent with the assumed model. The cointegration implications of the NKM are rejected on both data sets in all cases, with only one interesting exception. The cointegration implications of the new Keynesian Phillips curve are not rejected on European data when labor's share is used as a measure of marginal costs. However, the cointegration implications of the optimizing IS curve are rejected on the same data, implying an overall rejection of the model. Methods that assume stationary data are likely to confuse acceptance of the model with acceptance of the cointegration implications.

Finally, the overall coefficient estimates and the stability conditions proposed by Blanchard and Kahn (1980) suggest non-stationary backward looking behavior rather than forward looking stationary behavior. Together these results imply that the evidence of the NKM on both U.S. and European data is weak.

4.3 Essay III: Finnish inflation: a New Keynesian Perspective

The third essay tests the NKM, and a small open economy extension thereof by Monacelli (2005), by the Johansen and Swensen method on Finnish data. I use an extended data set that covers the open economy case for the quarterly sample 1982:1-2005:3. Previous studies, for instance Batini et al. (2005) and Giordani (2004), have found that open economy extensions are important and strengthen the evidence in favor of the NKM.

The restrictions implied by the NKM and its open economy extension are rejected on the Finnish data. Contrary to the previous open economy NKM studies, the extension to the open economy does not strengthen the evidence in favor of the model. However, I find that the open economy data set improves the statistical model. Hence, the open economy effects are clearly important.

As in essay II, the cointegration implications of the NKM, are investigated as well. The cointegration implications are rejected for the Phillips curve and I find that the information within the NKM cannot account for the long-run stochastic trend in inflation. If the missing information is approximated by a linear trend, then there is some evidence that the output gap is related to inflation. The cointegration implications of the optimizing IS curve cannot be rejected, and the adjustment coefficients indicate a clear IS curve interpretation. However, as before, the estimated coefficients and the stability conditions point to a non-stationary backward-looking solution. Finally, in the open economy case I find that money does not matter in line with the predictions of the NKM.

4.4 Essay IV: Estimating the Determinants of Finnish Inflation

The final essay estimates the relative importance of different inflation theories on Finnish data. The investigation is partly motivated by the rejection of the NKM in essay III, and partly by the common finding in more data-oriented empirical inflation studies that there is no single explanation of inflation (see for instance Hendry, 2001). I use Finnish quarterly data, spanning the years 1982:1-2006:1.

The main empirical difficulty in comparing different theoretical models of inflation within the same framework is the potentially large number of variables involved. This problem can be circumvented by an approach originally suggested by Surrey (1989) and adopted by Juselius, K. (1992) to the cointegrated VAR framework. The idea is to divide the large information set into smaller information sets that correspond to particular theories. Cointegration is subsequently investigated in each information set separately and the resulting cointegration relationships are then used as the main explanatory variables when estimating the equation of interest.

I follow this approach in investigating the causes of Finnish inflation. However, I extend the approach by providing estimates of the complete system rather than just providing estimates of the inflation equation. I also allow the data series to be integrated of order two. The main finding is that Finnish inflation is primarily determined by excess demand in the product market and by changes in the long-term interest rate. Other explanations, such as mark-up pricing, money creation in excess of output growth, and external pressures, are not very important, apart from the indirect influence that they have on excess demand and the long-term interest rate.

I also compare the system estimate of the inflation equation to a single equation estimate. The single equation estimate has more significant explanatory variables than the relatively "clean" system estimate. This suggest that single equation estimates may be misleading and may lead to finding "more" explanations of inflation than is warranted.

Finally, as in essay III, I find strong evidence of an IS curve relationship that simultaneously determines both short-term interest rates and real output. I also find that the long-term interest rates are determined by an approximate uncovered interest rate parity (UIP) condition.

References

Antras, P. (2004), 'Is the U.S. Aggregate Production Function Cobb-Douglas? New Estimates of the Elasticity of Substitution', *Contributions to Macroeconomics* **4**(1), 1161–1197.

Bardsen, G., Jansen, E. and Nymoen, R. (2003), 'Economteric inflation targeting', *Econometrics Journal* **6**, 430–461.

Bardsen, G., Jansen, E. and Nymoen, R. (2004), 'Econometric Evaluation of the New Keynesian Phillips Curve', *Oxford Bulletin of Economics and Statistics* **66**, 671–686. Supplement.

Batini, N., Jackson, B. and Nickell, S. (2005), 'An open-economy new Keynesian Phillips curve for the U.K.', *Journal of Monetary Economics* **52**, 1061–1071.

Bentolila, S. and Saint-Paul, G. (2003), 'Explaining Movements in the Labor Share', *Contributions to Macroeconomics* **3**(1), 1103–1136.

Blanchard, J. O. and Kahn, C. M. (1980), 'The Solution of Linear Difference Models under Rational Expectations', *Econometrica* **48**(5), 1305–1312.

Clarida, R., Gali, J. and Gertler, M. (1999), 'The Science of Monetary Policy: A New Keynesian Perspective', *Journal of Economic Literature* **37**(4), 1661–1707.

Clarida, R., Gali, J. and Gertler, M. (2002), 'A simple framework for international monetary policy analysis', *Journal of Monetary Economics* **49**, 879–904.

Davidson, J., Hendry, D., Srba, F. and Yeo, S. (1978), 'Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingdom', *The Economic Journal* **88**, 661–692.

Dickey, D. and Fuller, W. (1979), 'Distribution of the Estimators for Autoregressive Time Series with a Unit Root', *Journal of the American Statistical Association* **74**, 427–231.

Duffy, J. and Papageorgiou, C. (2000), ‘A Cross-Country Empirical Investigation of the Aggregate Production Function Specification’, *Journal of Economic Growth* **5**, 87–120.

Erceg, C. J., Henderson, D. W. and Levin, A. T. (2000), ‘Optimal monetary policy with staggered wage and price contracts’, *Journal of Monetary Economics* **46**, 281–313.

Friedman, M. (1956), The Quantity Theory of Money: A Restatement, *in* M. Friedman, ed., ‘Studies in the Quantity Theory of Money’, University of Chicago Press.

Fuhrer, J. C. (1997), ‘The (Un)Importance of Forward-Looking Behavior in Price Specifications’, *Journal of Money, Credit and Banking* **29**(3), 338–350.

Fuhrer, J. C. (2000), ‘Habit Formation in Consumption and Its Implications for Monetary-Policy Models’, *The American Economic Review* **90**(3), 367–390.

Fuhrer, J. C. and Rudebusch, G. D. (2004), ‘Estimating the Euler equation for output’, *Journal of Monetary Economics* **51**, 1133–1153.

Fuller, W. (1976), *Itroduction to Statistical Time Series*, John Wiley, New York.

Gali, J. and Gertler, M. (1999), ‘Inflation dynamics: A structural econometric analysis’, *Journal of Monetary Economics* **44**, 195–222.

Gali, J., Gertler, M. and Lopez-Salido, D. J. (2001), ‘European inflation dynamics’, *European Economic Review* **45**, 1237–1270.

Gali, J. and Monacelli, T. (2002), Monetary Policy and Exchange Rate Volatility in a Small Open Economy. CEPR Discussion Papers 3346.

Giordani, P. (2004), ‘Evaluating New-Keynesian Models of Small Open Economy’, *Oxford Bulletin of Economics and Statistics* **66**, 713–733. Supplement.

Granger, C. (1981), ‘Some properties of time series data and their use in econometric model specification’, *Journal of Econometrics* **16**, 121–130.

Hallman, J., Porter, R. and Small, D. (1991), ‘Is the Price Level Tied to the M2 Monetary Aggregate in the Long Run?’, *The American Economic Review* **81**(4), 841–858.

Hendry, D. F. (2001), ‘Modelling UK Inflation, 1875-1991’, *Journal of Applied Econometrics* **16**, 255–275.

Jalava, J., Pohjola, M., Ripatti, A. and Vilmunen, J. (2006), ‘Biased Technical Change and Capital-Labour Substitution in Finland, 1902-2003’, *Topics in Macroeconomics* **6**, 1–19.

Jansen, E. (2004), Modelling Inflation in the Euro Area. Norwegian University of Science and Technology, Working Paper Series No. 6.

Johansen, S. (1988), 'Statistical Analysis of Cointegration Vectors', *Journal of Economics Dynamics and Control* **12**, 231–54.

Johansen, S. (1991), 'Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models', *Econometrica* **59**, 1551–1580.

Johansen, S. and Swensen, A. R. (1999), 'Testing exact rational expectations in cointegrated vector autoregressive models', *Journal of Econometrics* **93**, 73–91.

Johansen, S. and Swensen, A. R. (2004), 'More on testing exact rational expectations in cointegrated vector autoregressive models: Restricted constant and linear term', *Econometrics Journal* **7**, 389–397.

Juselius, K. (1992), 'Domestic and Foreign Effects on Prices in an Open Economy: The Case of Denmark', *Journal of Policy Modeling* **14**(4), 401–428.

Kara, A. and Nelson, E. (2004), 'International Evidence on the Stability of the Optimizing IS Equation', *Oxford Bulletin of Economics and Statistics* **66**, 687–712. Supplement.

Klump, R. and De La Grandville, O. (2000), 'Economic Growth and the Elasticity of Substitution: Two Theorems and Some Suggestions', *The American Economic Review* **90**(1), 282–291.

Klump, R., McAdam, P. and Willman, A. (2004), 'Factor Substitution and Factor Augmenting Technical Progress in the US: A Normalized Supply-Side System Approach', *ECB Working Paper Series* **367**.

Kolsrud, D. and Nymoen, R. (1998), 'Unemployment and the open economy wage-price spiral', *Journal of Economic Studies* **25**(6), 450–467.

Koskela, E. and Stenbacka, R. (2006), Equilibrium Unemployment and Capital Intensity Under Product and Labour Market Imperfections. Helsinki Center of Economic Research.

Ma, A. (2002), 'GMM estimation of the new Phillips curve', *Economics Letters* **76**, 411–417.

Matheron, J. and Maury, T.-P. (2004), 'Supply-side refinements and the New Keynesian Phillips curve', *Economic Letters* **82**, 391–396.

Mavroeidis, S. (2004), 'Weak Identification of Forward-looking Models in Monetary Economics', *Oxford Bulletin of Economics and Statistics* **66**, 609–635. Supplement.

Metin, K. (1995), 'An Integrated Analysis of Turkish Inflation', *Oxford Bulletin of Economics and Statistics* **57**(4), 513–531.

Monacelli, T. (2005), 'Monetary Policy in a Low Pass-Through Environment', *Journal of Money, Credit, and Banking* **37**(6), 1047–1066.

Muhleisen, M. (1995), Monetary Policy and Inflation Indicators for Finland. IMF Working Paper, 95/115.

Razin, A. (2005), ‘Aggregate Supply, Investment in Capacity, and Potential Output’, *Journal of Money, Credit and Banking* **37**(1), 179–190.

Roberts, J. M. (2005), ‘How Well Does the New Keynesian Sticky-Price Model Fit the Data?’, *Contributions to Macroeconomics* **5**(1), 1–37.

Rudd, J. and Whelan, K. (2005*a*), ‘Does the Labor’s Share Drive Inflation?’, *Journal of Money, Credit and Banking* **37**, 297–312.

Rudd, J. and Whelan, K. (2005*b*), ‘New tests of the new-Keynesian Phillips curve’, *Journal of Monetary Economics* **52**(6), 1167–1181.

Sargan, D. (1964), Wages and Prices in the United Kingdom: A Study in Econometric Methodology, *in* ‘Econometric Analysis for National Economic Planning’, Butterworth, London.

Sbordone, A. M. (2002), ‘Prices and unit labor costs: a new test of price stickiness’, *Journal of Monetary Economics* **49**, 265–292.

Solow, R. (1994), ‘Perspectives on Growth Theory’, *Journal of Economic Perspectives* **8**(1), 45–54.

Surrey, M. (1989), ‘Money, Commodity Prices and Inflation: Some Simple Tests’, *Oxford Bulletin of Economics and Statistics* **51**(3), 219–238.

Svensson, L. E. O. (2000), ‘Open-economy inflation targeting’, *Journal of International Economics* **50**, 155–183.