Series on Advanced Economic Issues
Faculty of Economics, VŠB-TU Ostrava

Luboš Komárek

Martin Motl

Zlatuše Komárková

Jan Frait

Michal Hlaváček

Kamil Janáček

Jan Hošek

Ivana Kubicová

Milan Klíma

MONEY, PRICING AND BUBBLES

Ostrava, 2013

Luboš Komárek, Martin Motl, Zlatuše Komárková, Jan Frait, Michal Hlaváček
Faculty of Economic, VŠB-Technical University Ostrava
Sokolská 33, 701 21 Ostrava, CZ
lubos.komarek@yahoo.com, lubos.komarek@gmail.com, lubos.komarek@cnb.cz,
martin.motl@cnb.cz, zlatuse.komarkova@cnb.cz, zlata_komarkova@yahoo.com,
jan.frait@cnb.cz, michal.hlavacek@cnb.cz

Kamil Janáček, Jan Hošek, Ivana Kubicová, Milan Klíma
Czech National Bank
Na Příkopě 28, 115 03 Prague 1, CZ
kamil.janacek@cnb.cz, jan2461.hosek@cnb.cz, ivana.kubicova@cnb.cz,
milan.klima@cnb.cz

Referees
Jan Babecký, Czech National Bank
Werner Hermann, Swiss National Bank
Jouko Vilmunen, Bank of Finland

This book is dedicated to my parents Jarmila Komárková and Milan Komárek,
for all the support and patience they have devoted to me.

This publication was supported by The Grant Agency of the Czech Republic with project No. 403/11/2073 *Procyclicality of Financial Markets, Asset Price Bubbles and Macro-prudential Regulation.*

The text should be cited as follows: Komárek, L. et al. (2013). Money, Pricing and Bubless, SAEI, vol. 25. Ostrava: VSB-TU Ostrava.

Printed in Tiskána Grafico, s.r.o.
Cover design by MD communications, s.r.o.

ISBN 978-80-248-3301-9

Foreword

Money, pricing and bubbles is oriented towards both the analysis of the spectrum of asset prices (exchange rates, property prices, commodity prices) which form on the financial market, and the policies of central banks influencing, among other things, asset prices. The main objective of this book is to give an overview of what we know so far about the various factors which influence the determination of asset prices and their equilibrium values in small economies. It also focuses on the role of central banks, their level of aggressiveness and degree of forward guidance to market participants. Furthermore, the book discusses how best to achieve monetary and financial stability in small open economies.

The book is structured as follows. Chapter 1 briefly summarizes approaches to, and options for, identifying bubbles in asset prices. Chapter 2 discusses approaches and options for the identification of the equilibrium exchange rate, including their estimates for the Czech Republic. Chapter 3, based on an empirical analysis, discusses factors affecting property prices in the Czech regions. Chapter 4 analyses the relationship between monetary policy and oil (commodity) prices. Chapter 5 aims to show both the still very strong position of the USD in the global financial system and assess its likely future position. Chapter 6 deals with the identification and evaluation of central bank aggressiveness. Chapter 7 looks at the genesis of a recent central banking phenomenon – forward guidance. Finally, chapter 8 surveys the optimal reaction of monetary policy to changes in credit dynamics, asset prices and risks to financial stability.

This book is suitable for researchers, university teachers, financial analysts, policy makers and the generally educated public. It is the output of research activity by a research team led by Luboš Komárek in a project supported by The Grant Agency of the Czech Republic with project no. 403/11/2073 *Procyclicality of Financial Markets, Asset Price Bubbles and Macroprudential Regulation*. Luboš Komárek and his co-authors note that everything contained in this book represents their own views and not necessarily those of the institutions where they are employed. All errors and omissions remain entirely the fault of the authors.

Luboš Komárek
Ostrava 11. 12. 2013

Content

Detailed content

List of Abbreviations

ADF	Augmented Dickey-Fuller test
AR	Autoregression model
ARA	Amsterdam–Rotterdam–Antwerp
BEER	Behavioral Equilibrium Exchange Rate
BoJ	Bank of Japan
BP filter	Band-Pass filter
BS	Balassa-Samuelson effect
CCR	Canonical Cointegration Regression
CEEC	Central and Eastern European Countries
CF	Consensus Forecasts
CNB	Czech National Bank
CPI	Consumer Price Index
CRB	Commodity Research Bureau Index
CZSO	Czech Statistical Office
DARER	Debt-Adjusted Real Exchange Rate
DEER	Desirable Equilibrium Exchange Rate
ECB	European Central Bank
EMU	European Monetary Union
ERER	Equilibrium Real Exchange Rate
ERM II	Exchange Rate Mechanism II
Fed	the Federal Reserve
FEER	Fundamental Equilibrium Exchange Rate
FG	Forward Guidance
GARCH	Generalized Autoregressive Conditional Heteroskedasticity model
HP filter	Hodrick-Prescott filter
CHEER	Capital Enhanced Equilibrium Exchange Rate
IRI	Institute for Regional Information
IT	Inflation targeting countries
ITMEER	Intermediate Term Model-Based Equilibrium Exchange Rate

KPSS	Kwiatkowski, Phillips, Schmidt and Shin test
LGD	Loss Given Default
LNG	Liquefied Natural Gas
NATREX	Natural Equilibrium Exchange Rate
NER	Nominal Exchange Rate
NFA	Net Foreign Asset
NiGEM	National Institute Global Econometric Model
N-IT	non-inflation targeting countries
NX	Net Exports
OLS	Ordinary Least Squares
OPEC	Organization of the Petroleum Exporting Countries
PD	Probability of Default
PEER	The Permanent Equilibrium Exchange Rate
PP	Phillips-Perron test
PPI	Producer Price Index
PPP	Purchasing Power Parity
PR	Policy Ratio
QQE	Quantitative and Qualitative Monetary Easing
RER	Real Exchange Rate
TR	Trade-off Ratio
ULC	Unit Labour Costs
VAR	Vector Autoregression model
VEC	Vector Error Correction model
VIX	Chicago Board Options Exchange Volatility index
WTI	West Texas Intermediate
BIS	Bank for International Settlements

Chapter 1

Identification of Asset Price Bubbles

By Luboš Komárek and Ivana Kubicová

This introductory chapter briefly summarizes approaches to and options for identifying bubbles in asset prices. Further, the chapter draws on bubble literature and it theoretically discusses classification of asset price bubbles according to features such as differences in the rationality of investors, their informational (a)symmetry, limits in arbitrage and heterogeneous beliefs. It also highlights the identification problems related to determining the fundamental value of an asset. We argue that the disequilibrium asset price is a necessary but not sufficient condition for finding a bubble in a given asset. The market and country specifics have to be borne in mind. The chapter also specifies the procedure for monitoring and early identification of asset price bubbles. We recommend using all the available spectrum of tools in the most effective arrangement, ranging from charting methods (trends, filters, price-to-income ratios) via one-equation fundamental-based models to complex and structurally rich models.

1.1 Introduction

This chapter intends to briefly introduce the wide scope of bubble related literature. In particular it summarizes approaches to and options for identifying disequilibrium asset price movements, i.e. the situation where an asset price moves significantly away from its fundamental-based value. The chapter takes into account mainly stock prices, real estate prices and exchange rates but does not discus them separately in detail. Further, it focuses on theories relating to the emergence, dynamics and persistence of asset price bubbles and it also theoretically discusses main stream methods for identifying such bubbles. It also highlights the problems related to determining the fundamental value of an asset and, subsequently, the difficulty of distinguishing deviations of the market price of an asset from its fundamental value. The chapter also specifies the effective procedure for monitoring and early identification of asset price bubbles.

We define in general terms an asset price bubble as an explosive and asymmetric deviation of the market price of an asset from its fundamental value, with the possibility of a sudden and significant reverse correction.[1] Developing countries are mostly liable to higher growth and also volatility of asset prices, which appear mainly from underdeveloped segments of the financial market. Therefore we argue that for a final assessment of the risks of the presence of asset price bubbles, we have to be bear in mind the market and country specifics. Furthermore, the theories of asset price bubbles have not been sufficiently investigated for small open economies.

Although the theoretical decomposition of an asset price into components arising from fundamental factors and components affected by non-fundamental factors (e.g. euphoria or over-optimistic investment sentiment) seems straightforward, empirical application associated with the explicit expression of the values of individual components is very limited. Where non-fundamental factors account for a major part of asset price growth, identifying a bubble is more complicated, since non-fundamental factors are not directly measurable. However, market sentiment or risk perception can be approximated using specific indices, for instance the Chicago Board Options Exchange Volatility Index (VIX).[2] From a fundamental point of view, the current price of an asset is formed primarily on the basis of economic agents' expectations, which are based, in turn, on currently available information regarding discounted future cash flows. An asset price can be expressed as a discount factor multiplied by the flows of all future payments relating to the asset. It is affected by the following factors: (a) the expected flow of returns that the asset may generate (e.g. dividend), (b) the expected flow of returns on holdings of an alternative asset, (c) the expected price realised on the future sale of the asset, and (d) the relative risk and liquidity associated with holding the asset.

Since the fundamental value of an asset is not directly observable, it must be estimated. This means we have to rely on the discounted flow of all future payments, which is not observable either and must be estimated This gives rise to the first pitfall of identifying asset price bubbles, namely estimating the fundamental value of the asset. DeMarzo, Kaniel and Kremer (2007) tighten up the definition of a bubble by specifying three components: (i) the market price of an asset is higher than the discounted sum of its expected cash flows, with the discount factor being equal to the risk-free interest rate; (ii) cash flows have a non-negative correlation with aggregate risk; (iii) risk-averse investors rationally choose to hold the asset, despite their knowledge of (i) and (ii). In an attempt to estimate the fundamental value more realistically, Ofek and Richardson (2003) define a range for the fundamental value of an asset, with the upper boundary of

---

[1] In the classification of asset price bubbles presented later, this definition comes close to the concept of a rational bubble.
[2] The indicator of implied volatility derived from option prices reflects the traders' consensus forecast regarding short-term volatility and sentiment for the coming 30 days.

the range being of more interest. The upper boundary is formed on the basis of an estimate of the maximum achievable future cash flows of a company in a given sector and the minimum possible discount factor. Subsequently, if the market value of the asset is still higher than the fundamental value estimated in this way, a bubble is found in the price of the asset. Siegel (2003) proposes an operational definition of an asset price bubble as any time the realised asset return over given future period is more than two standard deviations from its expected return. He argues that a bubble cannot be identified immediately, but one has to wait a sufficient amount of time to determine whether the previous prices can be justified by subsequent cash flows.

Why are bubbles so popular and why are we interested in them? The first perspective is the interest of economic agents – in particular economic policy makers – in the effects of bubbles on the real economy, especially when those bubbles burst. The other perspective is investors' potential ability to use knowledge of the formation of bubbles to achieve excess returns – see, for example, Brunnermeir and Nagel (2004). These authors show the timing of riding the technology bubble in the case of some hedge funds. Although the two perspectives have different motivations, they share an intense effort to identify bubbles ex ante.

Seen from the first perspective, bubbles can affect the real economy either by distorting economic – and especially investment – decisions, or via the wealth channel and through banking sector balance sheets, i.e. specifically by affecting: (i) household consumption through the wealth channel (growth in property prices and financial assets held by households is perceived as growth in wealth and consumption financing sources), (ii) the banking sector balance sheet (property prices often serve as collateral in lending operations)[3], (iii) investment (according to Tobin's Q theory, the capital available for investment becomes cheaper as a result of growth in market equity prices, which in the case of a growing bubble implies an excessive decrease in the price of capital and distortion of investment decisions, hence inefficient investments with negative effects in the future may be made). These effects differ in strength over time and across economies, but they affect the real economy in the same direction.[4] The issue of whether the performance of the economy will be affected when a bubble bursts does not depend solely on asset prices; also important are the economic environment, the state of the financial sector, its ability to absorb shocks, its vulnerability and its

[3] If property prices rise, the probable loss from selling the collateral on mortgage loans decreases, which, in turn, notionally increases the bank's capital and allows it to expand its investments and loans. However, a slump in property prices can lead to credit constraints, a credit crunch and a negative impact on economic activity.

[4] According to many studies (e.g. Bordo and Jeanne, 2002a, b, and Borio and Lowe, 2002), credit booms and asset price busts have had grave financial and economic consequences. For a discussion of asset prices and monetary policy from the perspective of transitional economies see Frait and Komárek (2007).

fragility and the subsequent probability and strength of the monetary or fiscal policy response.

Empirical research confirms the economic intuition that more serious impacts on the real economy stem from the bursting of property market bubbles than that of stock market bubbles (see, for example, Helbling and Terrones, 2003a, b, and Bordo and Jeanne, 2002a, b). The effects stemming from the sudden bursting of property market bubbles generate higher output losses and last longer on average (about 4 years) than in the case of stock market bubbles (around 1.5 years). The bursting of property market bubbles also poses a greater threat to the financial stability of a country/region if the banking sector is more exposed through loans secured by property. On average it also generates greater social tension associated with subsequent housing-related problems.

The purely investor-based perspective differs from the economic policy maker perspective. The aim here is to capture the moment of reversal in the price of an asset and to profit from this. It is clear that this set of investors is in the minority, otherwise a bubble could not occur.

Some asset prices (property prices, certain share prices) are procyclical, i.e. they rise during the upward phase of the economic cycle. This is usually accompanied by excessive lending, which feeds the rise in asset prices. Such procyclicality may stem from a favourable macroeconomic environment and over-optimism among economic agents, which can destroy rational assessment of the situation and lead to excessive risk-taking, especially as regards credit risk. A correlation can thus be found between the cyclical behaviour of the real economy and cyclicality in risk perception and assessment. A cycle of financial risk thus arises, as experience shows. This means that although perceived risk declines, the actual risk that might materialise in the future rises during boom times and financial imbalances increase at the same time. The risk materialises at times of contraction, while the financial imbalances should be gradually eliminated.

The main ambition of this introductory chapter is to present the main theories on the emergence of asset market bubbles and to theoretically outline how bubbles can be identified using traditional quantitative methods. The text is structured as follows. Section 1.2 outlines the issue of why bubbles emerge and why they could persist. Section 1.3 defines and discusses the classification of bubbles. Section 1.4 highlights the specific characteristic of each asset market. Section 1.5 introduces the options for the empirical testing of bubbles. The final section concludes.

1.2 How do bubbles emerge?

A theoretical effort to understand bubbles was made by Keynes (1936), who admitted the possible emergence of speculative bubbles. By contrast, Friedman (1953) and Fama (1965) tended towards the view that bubbles cannot form because rational speculators stabilise prices and sophisticated investors will not let bubbles develop.[5]

Experience from the world economy has shown that bubbles appear and disappear repeatedly in various asset categories; moreover, they tend to spill over between asset markets. What is generally known about bubbles is their dynamics, which tend to involve an exponential increase in the asset price with reverse correction afterward. However, the reasons for the emergence of bubbles are not as clear. Given the complexity of the environments in which bubbles appear, it is likely that their emergence is conditional on the interplay of macroeconomic and microeconomic factors. Following recent developments in the global economy, the excessively easy monetary policies of central banks, global liquidity surpluses and insufficient financial sector regulation and supervision have been blamed as contributors to the emergence of bubbles.[6]

A technology bubble developed in the USA as a result of growth in share prices due to rapid technological change. This led to exaggerated expectations among investors and imprudent assessment of the risks of individual share issues. Although the evaluation of these issues might initially have been based on careful analysis and rational consideration, the subsequent overvaluation was more a sign of irrationality, over-optimism and self-fulfilling expectations.[7] As a result of this episode, both academics and practitioners started to think more carefully about the issues explaining the emergence of bubbles: Why did rational investors not enter the market and try to get market prices to converge to their fundamental values? What kind of irrationality can appear in trading? Were there too few rational investors to affect market prices? The following paragraph will outline – and section 1.3.2 will describe in more detail – the following key question: Why do bubbles persist even with rational investors? Can arbitrage[8] fail to have a convergence effect on prices, i.e. can it fail to lead to convergence or postpone the convergence of the market price to the fundamental price?

---

[5] Friedman (1953) distinguishes between stabilizing and destabilizing speculation. He argues that rational speculators stabilize prices although there are also speculators who drive market prices away from fundamental values by (on average) buying assets when prices are high and selling them when prices are low. But such destabilizing speculators are excluded from the market relatively soon.

[6] Bubbles are examined here from the theoretical and microeconomic or financial point of view. Issues relating to economic policy and the global liquidity surplus have been deliberately left out.

[7] The debate about the technology bubble and its emergence is far from over. For example Pastor and Veronesi (2006) provide an interesting debate about the technology stock.

[8] Arbitrage is according to Sharpe and Alexander (1990) defined as the simultaneous purchase and sale of the same, or essentially similar, security in two different markets for advantageously different prices. Also as Shleifer and Vishny (1997) pointed out that theoretically such arbitrage requires no capital and entails no risk.

One possible way of clarifying the emergence of bubbles is to draw on behavioral finance theory.[9] This involves a belief that the residual value in the pricing of an asset is due not to the omission of a fundamentally important variable from the asset valuation equation, but to not fully rational behaviour by some economic agents. If the mispricing of an asset is recognised by rational investors, it should theoretically be removed by arbitrage. Arbitrageurs should take a position that will cause the mispricing to be eliminated and, as a result, bubbles should theoretically not emerge. But those investors could have different motivations in taking positions and also they could have limitations to entering into price stabilizing (converging) positions. Practical experience has shown that asset mispricing can persist for quite some time.[10] This raises the issue of arbitrage effectiveness and the speed of the convergence between actual price and fundamental value of the assets. According to behavioral finance theory, the functioning (effectiveness) of arbitrage is affected by costs (e.g. transaction costs, holding costs, identification costs) and the risk (e.g. noise trade risk, synchronization risk and fundamental risk) assumed by arbitrageurs arising from such transactions. For these reasons, arbitrage may be limited. The issues are addressed, for example, by Barberis and Thaler (2003), Abreu and Brunnermeier (2002, 2003), De Long et al. (1990a) and Shleifer and Vishny (1997). Other possible answers to the key question regarding the persistence of bubbles can be found in articles focusing on positive feedback bubbles (e.g. De Long et al., 1990b)[11], or heterogeneous beliefs combined with short-sale constraints (e.g. Ofek and Richardson, 2003).

1.3 Classification of bubbles

Individual views about the emergence of asset price bubbles[12] differ on the causes of the emergence of bubbles as well as on suitable methods for identifying and recognising them in real time. Four main categories of model – differing

[9] This theory helps explain market inefficiency primarily by considering the psychological factors which influence the behaviour of economic agents (e.g. overconfidence, wishful thinking) and by considering so called limits to the arbitrage. Behavioral finance theory uses models in which some agents are not fully rational. According to this theory, rational and irrational agents trade with each other, which can result in the persistence of mispricing. Moreover this mispricing also relates to various incentives of traders (e.g. different trading strategies) and limits to entering positions (e.g. implementation costs and identification costs).

[10] Experience over the centuries has shown the opposite outcome. The history of bubbles dates back, for example, to the 17th century (tulip mania) and the 18th century (the South Sea bubble).

[11] Positive feedback investors buy assets when prices rise and sell them when prices fall. Specifically, their strategies involve, for instance, following the trend or extrapolating asset price expectations as well as trading using stop-loss orders, i.e. liquidation of positions when the asset price reaches a certain limit. According to DeLong et al. (1990b) rational speculation can be destabilizing if positive feedback traders are present.

[12] See, for example, Blanchard and Watson (1982) or Froot and Obstfeld (1991).

according to the conditions of the emergence of bubbles – are recorded in the literature (see, for example, Brunnermeier, 2007). The first category of models is based on the assumptions of rational investors and identical information. In this approach, bubbles follow an explosive path. The second category again involves rational investors, but this time they are asymmetrically formed. Bubbles form under more general conditions since their existence need not be generally known, unlike in the previous category of models. The third category is related to behavioral finance theory. In this case, bubbles can persist for a time, since the limits in arbitrage inhibit rational investors from the elimination of price impacts caused by behavioral traders. Unlike the two previous categories, this category does not rely solely on fully rational investors, but focuses on the interaction and trading between rational and irrational investors. The fourth category assumes that bubbles emerge under the heterogeneous beliefs of investors about fundamental values, which can be based on psychological biases.

1.3.1 Rational bubbles – rational investors and symmetric information

Two kinds of rational bubble, i.e. the bubble according to Blanchard and Watson and the intrinsic bubble according to Froot and Obstfeld are explained below.

The rational bubble according to Blanchard and Watson

Rational bubbles are generated by extraneous events and the spreading of rumours. The emergence of such bubbles is due to investors' self-fulfilling expectations regarding future asset price growth which are not directly related to fundamentals, e.g. waves of over-optimism and sentiment. A rational bubble must grow at a rate that produces the expected rate of return. It gains in size as investors expect the asset to be sold at a profit in the future.

The emergence of rational bubbles, as specified in Blanchard and Watson (1982), is motivated by non-fundamental factors. The market price of asset can be decomposed into the following components:

$$P_t = P_t^f + B_t, \tag{1.1}$$

where P_t is the market price of the asset, P_t^f denotes the fundamental value of the asset and B_t is the bubble component. Blanchard and Watson's contribution consists in specifying the dynamics of the bubble, which grows at a rate $\bar{r}$ with probability π and will burst with complementary probability $(1-\pi)$; the bubble contains a forecast error u_t, i.e.:

$$B_{t+1} = \begin{cases} \dfrac{(1+\bar{r})B_t}{\pi} + u_{t+1} & \text{with probability } (\pi) \\ 0 + u_{t+1} & \text{with probability } (1-\pi) \end{cases} \quad E(u_{t+1}) = 0, \tag{1.2}$$

where $\bar{r}$ is the long-term average return on the asset and $E(\bullet)$ denotes the expected variable.

Before the bubble bursts, the present return on assets grows faster than the historical average return. This is due to investors' assumption that the asset price will continue rising and generate the required expected rate of return. If investors believe the bubble will burst in the future, it will indeed burst as a result of self-fulfilling expectations.

The intrinsic bubble according to Froot and Obstfeld

The emergence of the rational bubble described above is not related to fundamental factors (e.g. shares in relation to dividends) and the bubble component arises outside the framework of such factors, as a result of non-fundamental factors. Nevertheless, one can identify a bubble that is a specific example of a rational bubble – the so-called intrinsic bubble of Froot and Obstfeld (1991). A prerequisite for this bubble is the dependence of an asset on fundamentals represented by dividends in a non-linear deterministic approach. The bubble thus arises from overreactions to reports concerning stochastic dividends. It is specified as a non-linear power function of the product of an arbitrary constant and dividends raised to a higher power:

$$B(D_t) = cD_t^{\lambda}, \tag{1.3}$$

where B denotes the bubble component and D_t dividends; c and λ are parameters satisfying the conditions $\lambda > 1$ and $c > 0.$ It holds true that:

$$\hat{P}_t = P_t^f + B(D_t), \tag{1.4}$$

where $\hat{P}_t$ is the market price of the stock and $\hat{P}_t^f$ is the fundamental-based part of the price.

The bubble component $B(D_t)$ is determined by changes in dividends. Their growth rate is given by trend growth in dividends, the log of dividends and a random term with conditional mean zero and variance (a so-called geometric martingale of dividends). If the fundamentals remain unchanged, the bubble component remains constant. If the fundamentals show persistence, the bubble component and the asset price will be exposed to persistent deviations from the fundamental value.

The above-mentioned bubbles are equally driven by self-fulfilling expectations, but with the difference that the Blanchard and Watson bubble is affected by factors that do not relate to fundamentals, while the intrinsic bubble is affected by fundamental factors.

1.3.2 Bubbles relating to limited arbitrage

As indicated in the introduction, there may be a category of investors whose trading is influenced by constraints and behavioral factors, i.e. investors who can make systematic mistakes and are thus not fully rational (behavioral traders). In this environment, bubbles form as a result of the interaction between fully rational, sophisticated, fully informed investors (rational arbitrageurs) and partially (ir)rational investors (behavioral traders). Given limited arbitrage, bubbles can persist for a time, since rational arbitrageurs cannot and/or do not want to fully correct the mispricing of assets for the reasons described below (see for example Barberis and Thaler, 2003).

Fundamental risk

An arbitrageur is exposed to fundamental risk by being wrong about the arbitrage position he takes and suffering a loss as a result. The pre-requisite is that there are no perfect substitutes between assets in particular class of asset. For instance, the arbitrageur buys shares A and, at the same time, sells shares B, which are a substitute for shares A. The arbitrageur is aware of the possible downside risk for shares A; for that reason, he/she has created a hedging position in shares B. Nevertheless, shares A are not necessarily a perfect substitute for shares B and shares B may be mispriced, so it is very difficult to eliminate all fundamental risk (see Barberis and Thaler, 2003).

Noise trade risk

Let assume, that for noise trade risk the pre-requisite of perfect substitutes holds. The interpretation of De Long et al. (1990a) is based on the idea that arbitrageurs cannot fully reverse the mispricing caused by noise traders. This is because arbitrageurs are active in the short run and are risk averse (i.e. they are exposed to noise trade risk). Noise traders do not make decisions upon fundamental analysis and (falsely) believe that they have special information[13] about the future price of an asset that other traders are lacking. The interaction between fully and partially rational investors deflects asset prices from their fundamental values. Shleifer and Vishny (1997) explain the activity of arbitrageurs operating in the short term as described in De Long et al. (1990a). Arbitrageurs have short horizon because they often manage funds of various investors and lenders. Their performance is judged according to short term returns, thus it leads to focusing on short term horizons. The next reason is separation of brain and capital which means that resources are separated from agents involved in arbitrage, i.e. a relatively small group of arbitrageurs specialized in such trading manage the money of other investors and this possibly creates agency relationship. Thus, the

[13] Based, for instance, on technical analysis, the use of momentum, various recommendations, etc. See for example the literature survey by Menkhoff and Taylor (2007) or Bask and Fidrmuc (2009), which are focused on technical analysis and noise traders and applied on the exchange rates.

specialized arbitrageurs may avoid some extremely volatile positions which could be labelled as arbitrage due to the risk of losses resulting from volatile and extreme positions regardless of the attractive return profile of the transactions.

Synchronisation risk

Abreu and Brunnermeier (2002, 2003) answer the question regarding the persistence of bubbles by means of limited arbitrage caused by synchronisation risk. The synchronisation problem involves different views among rational arbitrageurs leading to (non-) synchronisation of the timing of the correction of the mispricing, that is, the rational arbitrageurs are not sure when their colleagues will take advantage of arbitrage and try to time this moment while riding the bubble. Thus, they are aware of the existence of the bubble and know that it will burst at some future point in time. By timing, they delay arbitrage and thus cause the temporary persistence of the bubble. If they timed their positions and jointly exerted pressure to sell, they would have sufficient strength to burst the bubble. Clearly, this is delicate timing game concerning when behavioral traders will be overwhelmed by rational arbitrageurs.

1.4 Specific characteristics of asset markets

The tools for identifying asset market bubbles are often based on the assumption that market prices deviate from the fundamental asset value. For identification purposes, it is necessary to bear in mind the specific attributes of those markets.[14] These include different trading liquidity, frequency and volumes, transaction costs, market rigidities, lags in data as well as lags caused by legal procedures, etc. To identify bubbles in a particular segment of the asset market, it can be helpful to consider developments in other segments of the market and other indicators such as monetary aggregates and credit and investment indicators. This can be helpful especially in case of real estate markets, which are closely related with credit growth.

In the case of empirical analysis, it is necessary to take into account the specific characteristics of financial time series. Such series contain certain features that can affect the robustness of the empirical tests. Not only are exchange rates and stocks more volatile than macroeconomic variables, they can also show conditional heteroscedasticity, leptokurtic distributions, volatility clusters, stationarity and asymmetry in response to positive and negative movements in profit ratios.

The degree of misalignment or the presence of bubbles on asset markets can be determined by means of ratios which generally use very narrow set of fundamentals or by applying a model approach based on a wider set of fundamentals. Price ratios (e.g. price to earnings, price to income) give an initial idea about an asset market, but they suffer from numerous shortcomings, in particular: (i) the

[14] Real estate market, foreign exchange market and stock exchange market.

alarm ratio indicating overvaluation or the existence of a bubble is ambiguous and volatile, i.e. comparing the ratio with its own historical values may be misleading, crucially dependent on the time horizon used; (ii) direct developments in interest rates are not taken into account; (iii) ratios have a narrower focus for assets for which returns can be achieved only through increases in their price (exchange rates, gold, commodities); (iv) time series have short histories, especially in the case of transition economies, so a long-term view of their evolution cannot be taken. Overall, price ratios are useful for getting a basic idea about price development in respect of earnings or affordability in a particular asset market. Moreover, the modification of the ratios expressed as earnings to price can be compare with the yield of other financial instruments (e.g. bond yields) to get a rough picture about the relative yield between financial instruments. Generally, though, it is appropriate – for both financial and non-financial assets – to combine a number of approaches to identifying bubbles in order to cover factors indirectly associated with asset prices (structural changes in the economy, demographic factors, etc.)

1.5 Options for the empirical identifying of bubbles

The range of techniques suitable for identifying the occurrence of bubbles is limited by the features of bubbles (asymmetrical dynamics, non-linearity, sudden and difficult-to-identify changes in investor sentiment, bad vs. good asset pricing, news and its incorporation into the price etc.). The success of econometric tests is ambiguous, since the tests' results differ. Gurkaynak (2005) states in the conclusion of his empirical study that for every test that finds a bubble, there is another that disputes it. Moreover, he points out that we are still unable to distinguish bubbles from time-varying or regime-switching fundamentals. In our opinion, however, the primary question is whether the heterogeneity of the results of empirical testing is based on inadequately specified models or whether bubbles are more a psychologically and behaviorally determined phenomenon that is very difficult to explain on the basis of fundamentals. This is consistent with a thorough knowledge of asset price determinants and should lead, in combination to expert judgment, to the reliable evaluation of forming bubbles.

Identification of bubbles is not just about the confirmation of the existence of the bubble[15], but also as mentioned in the section on the classification of bubbles, about specification of the formation process. Salge (1997) describes the specification of the bubble formation process as direct tests (see, for instance, the intrinsic bubble of Froot and Obstfeld, 1991).[16] A more general approach for bubble identification, so-called indirect tests, differs from the direct test in sense

[15] The effort to diagnose bubbles *ex ante* has even involved the use of tools taken from theories of complex systems (e.g. Sornette, 2003).

[16] Direct tests pertain mainly to the stock market (often testing the relationship between dividends and share prices) and are sensitive to misspecification of the model, e.g. the omission of an important determinant

of not directly specifying the bubble formation process (e.g. cointegration methods and specification tests). Indirect tests are designed to purely confirm or to refute the existence of a bubble. Further, this part of the chapter discuses the basic techniques for identifying bubbles also from the field of indirect tests, which consists mainly of (a) trend curves, statistical filters and price ratios, (b) empirical methods and models, and (c) specification tests.

1.5.1 Trend curves, statistical filters and price ratios

The statistical approach to identifying misalignment of asset prices compares the time series trend with actual development. This approach can be used not only to get an initial idea of the degree of misalignment, but also to determine asset price bubbles forming through asset price booms. For the trend approach one needs long[17] historical time series which are not necessarily available, especially in emerging or developing countries. Nevertheless, it is not necessarily the case ex ante that these results will be less successful than those obtained using much more sophisticated approaches. Univariate filters such as the Hodrick-Prescott (HP) filter or Band-Pass (BP) filter can be used to calculate the trend, and are used in many studies.[18]

Goodhart and Hofmann (2008) follow the approach of Borio and Lowe (2002) and Adalid and Detken (2007) to defininge aggregate asset price booms. A house price-boom is defined as a persistent deviation of real house prices from a smooth trend, calculated on a one-sided HP filter with a (high) smoothing parameter of 100,000. A boom is defined as a positive deviation of house prices from this smooth trend of more than 5 per cent lasting at least 12 quarters. Adalid and Detken (2007) follow a similar procedure to Goodhart and Hofmann (2008). A boom is defined as a persistent deviation from an HP trend (with smoothing parameter of 100,000) of more than 10 per cent lasting at least 4 quarters. Bordo and Jeanne (2002a, b) focus on the growth rate of asset price series to define booms.[19] A boom is defined as where the 3-year (from t–2 to t) moving average growth rate of the (real) asset price exceeds the series average by a factor of 1.3 times the series standard deviation. When this condition is met, then a boom is declared in periods t–2, t–1 and t.

Price ratios (price to earnings, price to income) too could enter into statistical filtering. The divergence of the actual ratio from the long-run development expressed by the trend may signal misalignment. The judgment about the exist-

[17] Approximately 30–40 years of real estate market is suitable for the trend analysis.

[18] Having regard to the underdevelopment of some markets, especially in transition (developing) countries, which show strong growth, that cannot be seen as a bubble (base effect).

[19] Detken and Smets (2004) argue that the use of an asset price gap (as in methods 1-3) is preferable to the growth rate for defining a boom, as the price gap allows the concept of accumulated financial imbalances to be stressed – reducing the weight of periods of rapid asset price growth directly following an asset price collapse. It also allows sustained periods of only slightly above average growth to cumulate into a boom in levels space.

ence of the bubble is based on the distance between actual value of the ratio from the estimated trend by a number of standard deviations. Hume and Sentence (2009) investigate credit booms defined as deviations of credit to GDP ratios from an expanding HP filter as used in Gourinchas, Valdes and Landerretche (2001). An expanding HP filter extends the sample over which the filter is applied by one period as each successive period is added to the sample, such that for any point in time the trend is calculated only on data up to, and not beyond, that point in time. Hume and Sentence (2009) use a smoothing parameter of 100, a standard smoothing parameter for annual data. They define a boom (so setting its threshold) as occurring when the data series deviates from its trend by more than one standard deviation, and set limit thresholds – determining when the boom begins and ends- as half a standard deviation.

1.5.2 Empirical methods and models

Diba and Grossman (1988) tested share prices in relation to dividends. By means of unit root tests and cointegration analysis, they observed the order of integration of these time series and whether there is an explosive element in the asset price time series. If the growth rate of the asset price is not more explosive than that of the key fundamental, a bubble is not present. If it were present, it would generate an explosive element in the relevant price. Classic unit root tests[20] and subsequent cointegration analysis are associated with methodological problems, i.e. standard linear econometric methods are not necessarily sufficient to determine the non-linear behaviour of an asset price component, particularly in the case of periodically collapsing bubbles (see, for example, Evans, 1991). Subsequently, the tests have been extended to cover the possibility of testing for a unit root in a model with a time-varying auto-regressive coefficient and in regime-switching models (for example Van Norden, 1996, and Van Norden and Vigfusson, 1998). This line of testing was chosen mainly because of the time-varying risk premium, which can be a source of excessive fluctuations, causing complications when testing for the presence of a bubble in traditional tests, i.e. those that do not take account of the time-varying variable. Proving the non-stationarity of a time series does not necessarily imply the presence of an asset price bubble.

Beyond the narrow set of fundamentals mentioned above, one can apply an approach taking advantage of a wide set of fundamentals linked to a particular market, using a deeper structure of causalities. This approach seems to be applicable for identifying determinants especially for the real estate market, which is an issue of special interest. Modelling both the demand and supply sides of the market brings valuable insight in to determination of value and thus indirectly judgments about potential misalignment. Methodologically there exists a variety of possible estimation techniques, e.g. VECs, classical and panel data regres-

[20] See, for example, the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test or the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test.

sions, etc. Subsequently, provided that the model is specified correctly, it is able to map non-standard movements on the market and partly or fully explain asset price movements using determinants.

Further, there exists a broad spectrum of structural-reach models, which can be used for a deeper understanding of the processes behind the formation of bubbles. Based on the findings of the current financial crisis a variety of theoretical models related to asset price bubbles were introduced. For example Barlevy (2008) offers a model in which credit plays an essential role in allowing for speculative bubbles that can be used to explore these claims. Dubecq, Mojon and Ragot (2009) set up a model where asset price bubbles due to risk shifting can be moderated by capital requirements, under imperfect information. Interesting empirical work was done by Alessi and Detken (2009), who find that global measures of liquidity are among the best performing indicators. They display forecasting records which provide useful information for policy makers interested in timely reactions to growing financial imbalances.

1.5.3 Specification tests

The basic idea of specification tests is that they compare estimates for discount factors that are taken from differently defined formulations of forward-looking asset price models and subsequent performance of a specification test. The following model formulations can be compared (see, for example, Taylor and Sarno, 2002[21]). The first one is based on the equation:

$$s_t = \lambda_0 E_t s_{t+1} + v_t + \varpi_t, \tag{1.5}$$

where the current asset price s_t over time is an additive function of the expected discounted value of the asset in the subsequent period $\lambda_0 E_t s_{t+1}$ (containing the discount factor λ_0), the present fundamentals v_t and the error term ω_t.

An alternative estimate of the discount factor, derived from a purely fundamental asset model[22], can be specified as follows:

$$\tilde{s}_t = \sum_{i=0}^{\infty} \lambda_1^i E_t v_{t+1} + \varpi_t. \tag{1.6}$$

In the case of the alternative estimate, a simplifying assumption is made regarding the fundamentals, namely that they are determined by an AR(1)[23] process. The estimated discount factors are subsequently compared using the Haus-

[21] The authors apply this approach to the exchange rate.

[22] The choice of specific fundamental model will greatly affect bubble identification results. A bubble may be rejected either because it really does not appear in the data or, in the worse case, because the model is misspecified (an important variable has been omitted).

[23] AR(1): $v_t = \kappa v_{t-1} + u_t$, where coefficient $|\kappa| < 1$ and u_t denotes white noise.

man specification test[24] (Hausman, 1978). If the discount factor estimates differ insignificantly, no bubble is found in the data.

1.6 Conclusion

Asset price bubbles have become a popular topic among both the public and experts and there is wide discussion about whether they really exist or whether they constitute just an error in the valuation of assets. The ambition of the authors was not to contribute to a concrete debate about the existence of bubbles. The aim of the chapter is to classify and distinguish different types of asset price bubble and to point out the methods available for identifying asset overvaluation which can be potentially used for identifying bubbles. Identifying bubbles seems to be not an easy task, not only doing so in time (especially ex ante) but also in terms of distinguishing fundamental and non-fundamental determinants and interpreting their value. It is therefore difficult to confirm with any degree of certainty the existence of a bubble, since it is no trivial task to determine the fundamental value of an asset or a bubble-generating deviation.

To conclude, we identify the following major issues related to identifying equilibrium asset price movements. Firstly, continuous monitoring of asset prices is necessary for early identification of unbalanced booms, which can later grow into asset price bubbles. Secondly, we recommend the use of the full spectrum of empirical tools in their optimum order ranking from simple to complex, i.e. from trend curves and statistical filters (such as Hodrick-Precsott or Band-Pass filters) through empirical methods and models (unit root tests, cointegration, specification tests) to deeply structured models (which are contextualised in a complex understanding of the economy). In other words, when we identify a possible unsustainable growth of assets by simple techniques such Hodrick-Prescott filter, it would be logical to pursue a deeper analysis based on structural models to identify the crucial factors and determinants of the asset price movements. Thirdly, we argue that disequilibrium asset prices is a necessary but not sufficient condition for discerning a bubble in a given asset. Finally, we would remark that specifics across markets and countries have to be borne in mind, since in underdeveloped markets sharp increases of monitored assets may not imply the creation of a bubble.

[24] Two discount factors are obtained from the estimates of equations (5) and (6), λ_0 from equation (5) and λ_1 from equation (6). The null hypothesis of the test states that both discount factor estimates are consistent (variance close to zero), but λ_1 is more efficient (has smaller asymptotic variance) than λ_0. The alternative hypothesis states that one or both discount factor estimates are inconsistent.

Chapter 2

Misalignment of Exchange Rates: The Case of the Czech Republic

By Luboš Komárek and Martin Motl

The second chapter discusses the approaches and options for the identification of the equilibrium exchange rate. It focuses mainly on the outcomes of the behavioral (BEER) and fundamental (FEER) models of the equilibrium exchange rate of the Czech koruna, which are presented in real terms. The results of both models of the equilibrium exchange rate (BEER and FEER) showed a significant long-term appreciation trend, due mainly to faster growth in labour productivity in the Czech Republic compared to the euro area. The results also confirmed the estimates of exchange rate overvaluation up to mid-1997 and in 1998, 2008, and 2011. However, since 2009 the models suggest a significant slowdown in the appreciation of the equilibrium exchange rate, due mainly to a decline in investment flows and the slowing domestic growth rate of labour productivity compared to the euro area.

2.1 Introduction

Equilibrium exchange rates play a significant role not only in modern macroeconomics, but also in the conduct of practical economic policy. Exact determination of the equilibrium value of the exchange rate – as in the case of other assets, in particular shares and property – is non-trivial, as it is difficult to distinguish between fundamental and non-fundamental exchange rate determinants.[25] Estimates of the equilibrium rate are important to the central bank for four main reasons. First, they provide knowledge necessary for effective conduct of independent monetary policy. Knowledge of the rate of equilibrium evolution of the currency and the deviation of the current exchange rate from the equilibrium

[25] See also Horváth and Komárek (2007).

rate[26] is a valuable piece of information for indicating exchange rate misalignments (bubbles) and the probable future exchange rate path. The second, closely related reason is the evaluation of the appropriate setting of the monetary conditions.[27] The third reason of a macroeconomic nature is the assessment of the economy's price competitiveness, in which the exchange rate plays a crucial role. The fourth reason is the necessary knowledge of equilibrium exchange rate estimates in the process of fixing the exchange rate upon entering a monetary union, and in the discussion of the pros and cons of such a step. For countries entering the euro area, this involves above all setting the central rate (before entering ERM II) and the conversion rate (before entering the euro area).[28] In this context, ECB (2003) states that *...the central rate should reflect the best possible assessment of the equilibrium exchange rate at the time of entry into the mechanism. This assessment should be based on a broad range of economic indicators and developments while also taking account of the market rate*. However, the communication of European institutions in this area is vague, with no clear definition of the methods recommended for estimating the equilibrium exchange rate and no description of other related procedures.

This chapter is structured as follows. Section 2.2 focuses on broadly defining individual equilibrium exchange rate concepts. Section 2.3 discusses econometric methods for estimating equilibrium exchange rates. Section 2.4 describes the application of two methods for estimating the equilibrium exchange rate, including empirical results for the koruna-euro exchange rate. Based on the experience of selected euro area members, these methods were used in the pre-entry negotiations for setting the central rate and the conversion rate. The concluding section contains a summary and recommendations.

2.2 Equilibrium exchange rate concepts

Long-term exchange rate behaviour is most often considered from the perspective of purchasing power parity (PPP). However, as the PPP theory implies a constant real exchange rate, any changes in the real exchange rate are regarded under this theory as deviations from the equilibrium rate – see, for example, Holman (1993a,b) or Mandel and Tomšík (2008). The PPP theory is viewed as the final measure of the relative value of individual currencies, but not as an appropriate measure of the equilibrium exchange rate in a world of long-term

[26] By comparison with advanced economies, converging economies face a complication, as their equilibrium exchange rate path oscillates from the equilibrium appreciation path.
[27] The monetary conditions index (real and nominal) in simpler aggregate stylized models usually has two components, namely an exchange rate component (the deviation of the exchange rate from the estimated equilibrium exchange rate) and an interest rate component (the deviation of interest rates from equilibrium interest rates). A weighted average of these deviations (the monetary conditions index gap) indicates the phase of the monetary cycle, i.e., whether monetary policy is easy or tight overall.
[28] See, for example, Buiter (2004), Hochreiter and Tavlas (2004), De Grauwe and Schnabel (2005).

convergence, various real shocks, and fluctuations in capital flows. There is a strong consensus in the economic literature that PPP is not a suitable measure for calculating the equilibrium exchange rates of developing or transition economies. These countries very often experience relatively marked appreciation trends, which, however, the PPP theory is unable to explain. By contrast, a very well known phenomenon purporting to explain such real appreciation is the Balassa-Samuelson (BS) effect. This effect shows that differences in labour productivity between individual countries, which subsequently generate differences in the prices of tradable and non-tradable goods, are very important for the evolution of real exchange rates. However, other factors that may contribute to trend appreciation of the real exchange rate can be identified. They include, for example, trend appreciation of the real exchange rate calculated on the basis of movements in prices of tradable goods and administered (regulated) prices. However, the empirical evidence for the BS effect is usually statistically insignificant – see, for example, Flek, Marková, and Podpiera (2002), Holub and Čihák (2003), Égert (2003b), Cincibuch and Podpiera (2004) or Égert and Podpiera (2008).

As with the PPP theory, real trend appreciation is a long-term phenomenon that is important for economic policy makers but not sufficient for understanding changes over the usual decision-making horizon. Therefore, a number of approaches have appeared over the last twenty years attempting to capture the determinants of the equilibrium real exchange rate (ERER) and estimate its value using models of various complexity. If we apply the fundamental distinction used in economics, i.e., between positive and normative concepts, we can identify the following two categories among the above approaches (Figure 2−1). The first category of models (normative concepts) enters into the model relationships the *desired* results (exchange rate paths) which the models are intended to arrive at from the current situation, and back-calculates the levels of the variables needed to attain this goal. By contrast, the second category of models (positive concepts) enters into the model relationships the current variables and policies, on the basis of which it determines the equilibrium future value of the selected variable.[29]

[29] The explanations below are simplified and abstracted from a discussion of the conditions of construction of model approaches. A detailed discussion of these approaches, including the derivations of their mathematical apparatus, is included, for example, in Frait and Komárek (1999a,b), MacDonald (2000) or Égert (2003a).

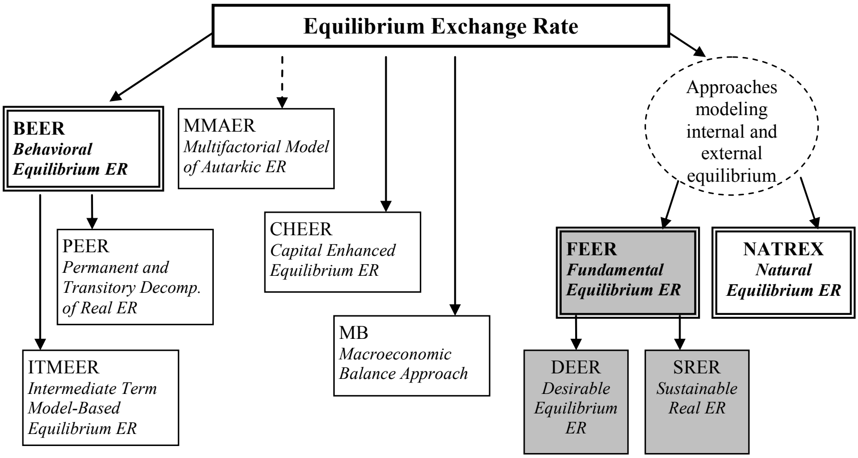

Figure 2–1 Equilibrium exchange rate concepts[30]
Note: The BEER, FEER, and NATREX approaches are the main concepts for calculating the equilibrium exchange rate. The other approaches can mostly be understood as modifications of them. The approaches highlighted in grey are normative, while the others are positive; ER denotes exchange rate.

2.2.1 Normative concepts

Normative concepts include the Fundamental Equilibrium Exchange Rate (FEER) and the Desirable Equilibrium Exchange Rate (DEER). The FEER model is the foundation of the normative concepts; it was created by Williamson (1983, 1994). It is a multi-equation approach to the estimation of the equilibrium real exchange rate corresponding to the simultaneous internal and external equilibrium of the economy.[31] Internal equilibrium is usually defined as the level of output consistent with full employment (or the natural unemployment rate) and with low and sustainable inflation. External equilibrium is usually defined as a situation in the economy where the balance of payments (or its current account) is in balance. Thus, the equilibrium exchange rate does not correspond to the PPP theory, but is consistent with a broader definition of macroeconomic equilibrium which may better suit the needs of economic policy makers. The FEER concept is thus based on an effort to gain distance from short-term cyclical conditions or temporary factors and focus on fundamental factors which will very likely prevail in the medium term. The calculation of the FEER requires an

[30] The DARER (*Debt-Adjusted Real Exchange Rate*) approach is intentionally not listed, as it is more a modification of the standard calculation of the real exchange rate taking into account the evolution of the current account of the balance of payments and the evolution of net FDI than a *true* calculation of the equilibrium exchange rate – see for example Frait and Komárek (2008).
[31] The first application of the FEER model to the exchange rate of the Czech koruna was performed by Šmídková (1999) and Šmídková et al. (2002).

explicit estimate of sustainable fiscal policy with full employment and the setting of a target for the current account (the normative aspect).

2.2.2 Positive concepts

The positive concepts include in particular the Natural Equilibrium Exchange Rate (NATREX) and the Behavioral Equilibrium Exchange Rate (BEER), which are the two most commonly used positive approaches. The NATREX is a medium- to long-term real exchange rate determined by real fundamental factors, and it changes as those factors change.[32] The factors include savings, investment, productivity, labour capitalization, and net external debt (and for smaller countries the exogenous terms of trade, world interest rates, and foreign direct investment), which affect desirable long-term capital flows and change the level of the equilibrium exchange rate. The actual real exchange rate subsequently adapts to the equilibrium rate. Unlike the FEER approach, the NATREX is a positive concept. It is an equilibrium exchange rate determined by real fundamental factors and existing economic policies. However, these policies are not necessarily optimal, hence the NATREX is not an optimal real exchange rate. The NATREX is also based on explicit modeling of the equilibrium real exchange rate according to the evolution of its determinants.

The BEER model is similar to the NATREX but focuses more on the concept of misalignment (because current fundamental determinants differ from sustainable or desirable determinants – in line with the FEER model) as the difference between the current and equilibrium values of the real exchange rate based on sustainable long-term levels of the fundamental determinants. This model brings into line a set of macroeconomic variables according to the economic theory using a single-equation cointegration relationship. The Permanent Equilibrium Exchange Rate (PEER) model is mentioned within the BEER approach. It enables a real exchange rate misalignment to be broken down into short-term deviations, random errors, and deviations in fundamental factors from sustainable levels. This means that the PEER model decomposes the long-term cointegration vector (*fitted values*) into a permanent part and transitory part. The permanent part is interpreted as the equilibrium exchange rate. The approach introduced by Wadhwani (1999) (Intermediate Term Model-Based Equilibrium Exchange Rate, ITMEER) is a modification of the BEER/PEER model.

Other variants of equilibrium exchange rate models include the Macroeconomic Balance (MB) model, which has also been used relatively often by the International Monetary Fund. This approach circumvents the normative aspect of the FEER approach using a direct estimate of the sustainable current account deficit/surplus, which is based on the balance of savings and investment. From this point of view, the MB approach is similar to the NATREX. In his review, MacDonald (2000) also mentions the Capital Enhanced Equilibrium Exchange

[32] The first estimates of the model in its simplified form were performed by Frait and Komárek (1999b) and Škop and Vejmělek (2009).

Rate (CHEER) approach, which includes the nominal exchange rate, the price level, domestic and foreign interest rates, and capital flows.

2.3 Methods for empirically estimating equilibrium exchange rates

The main techniques for identifying exchange rate misalignments, or asset price misalignments in general, include (a) trend curves and statistical filters, (b) unit root tests and cointegration, and (c) structurally rich models (see also Figure 2–2).

2.3.1 Trend curves and statistical filters

The simplest – but purely statistical – approach to the identification of exchange rate misalignments is to compare the time series trend with the actual values. This approach can be used to obtain an initial idea of the approximate degree of misalignment – see, for example, Csajbók (2003). It is not necessarily true ex ante that the results of this simple non-economic method will be less successful than those obtained using more sophisticated methods. To calculate the trend, one-dimensional filters such as the Hodrick-Prescott (HP) filter with an appropriate smoothing coefficient (according to the periodicity of the time series) or the Band-Pass (BP) filter can be used. The advantage of the BP filter is that it can isolate the cyclical component of the time series from the non-cyclical component (see, for example, Baxter and King, 1995, or Christiano and Fitzgerald, 2003), but the filtering assumes knowledge of the order of integration of the time series. This is determined using unit root tests, which, however, can yield contradictory results.

2.3.2 Unit root tests and cointegration

Using unit root tests and cointegration analysis, Diba and Grossmann (1988) tested the order of integration of time series to determine whether an explosive component is present in the time series of an asset price. A misalignment (bubble) is not present unless the rate of growth of the asset price is more explosive than the evolution of the key fundamental.[33] Classical unit root tests and subsequent cointegration analysis may therefore not be sufficient to determine the non-linear nature of the behaviour of an asset price component, especially in the case of periodically collapsing bubbles (see, for example, Evans, 1991). Advanced tests enable testing for a unit root in models with a time-varying autoregression coefficient and in regime-switching models (see, for example, Van Norden, 1996, and Van Norden and Vigfusson, 1998).[34] The above techniques

[33] If it were present, it would generate an explosive component within the relevant price.

[34] This direction of testing was chosen mainly because of the time-varying risk premium, which can be a source of excessive fluctuations, causing complications in testing for the presence of a bubble in classical tests, i.e., those which do not account for a time-varying

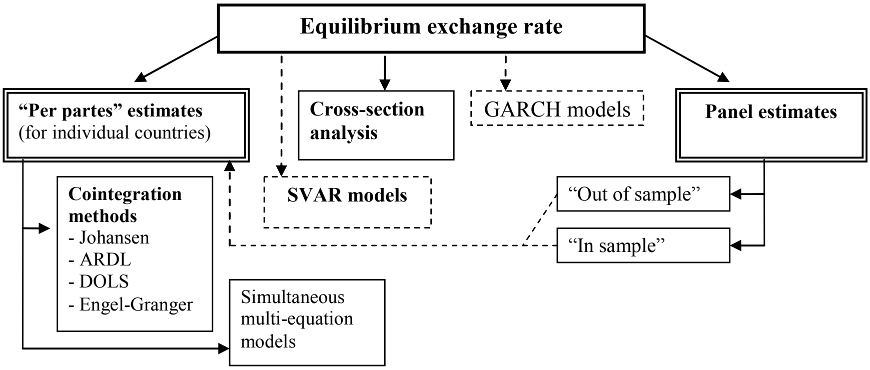

Figure 2–2 Empirical methods used to estimate equilibrium exchange rates
Note: Estimates for individual countries are the most common way of calculating equilibrium exchange rates.

form the basis for estimating the equilibrium exchange rate using the FEER approach.

2.3.3 Structurally rich models

The use of structurally rich models that reveal asset price determinants (ideally using supply and demand factors) can be regarded as an advanced technique for identifying misalignments (or bubbles). These models aim to confirm or refute the existence of a bubble. However, they do not directly specify the process of emergence of the misalignment (bubble). The information content of these models may be is affected by misspecification of the model and by problems linked with small data samples.

From the perspective of the economic theory behind equilibrium exchange rates, it is appropriate to estimate the equilibrium exchange rate in real terms (cf. PPP theory, BS effect); the equilibrium obtained can then be converted into nominal terms. From the practical point of view, it must also be determined (i) whether the estimate should be made on a bilateral or effective basis, (ii) which price index should be used – most often the consumer price index (CPI) or producer price index (PPI) is used,[35] and (iii) whether the parameters should also be calibrated for the equilibrium exchange rate model or whether they should be obtained solely from an empirical estimate of the model.

variable. This is because the proven non-stationarity of a time series does not necessarily indicate the presence of a bubble in the asset price.

[35] Another option, which is often limited by data availability, is to use unit labour costs (ULC).

2.4 Estimates of the equilibrium exchange rate of the CZK

As the majority (over 75%) of Czech foreign trade turnover is with euro area countries, the subject of analysis of the equilibrium exchange rate estimates in real terms (the Equilibrium Real Exchange Rate, ERER) will be the bilateral exchange rate of the Czech koruna against the euro. All foreign variables contain data for the euro area (sections 2.4.1 to 2.4.3).

2.4.1 Statistical methods

Figure 2–3 shows two types of exchange rate misalignment obtained by applying the Hodrick-Prescott (HP) filter and the Band-Pass (BP) filter to the CZK/EUR real exchange rate deflated by the PPI[36] in manufacturing (for direct comparability with the results of the BEER and FEER models in sections 2.4.2 and 2.4.3). The calculations were performed using quarterly data for 1995Q1–2011Q4. The risk of estimation bias at the end of the data sample was taken into account by including longer time series approximating the outlooks for the input variables. The results of the filters (when comparing with the ERER models presented below and the path from the core prediction model) can illustrate the basic trends, bearing in mind the well-known problems of these simple filtering methods at the beginning and the end of the data set.

a) HP filter and BP filter b) Misalignment of HP filter and BP filter

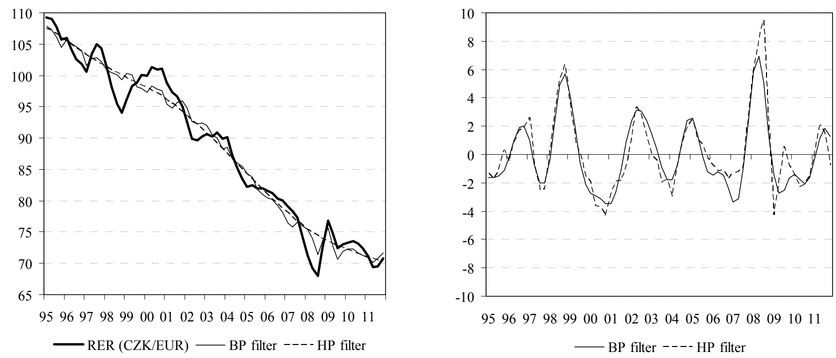

Figure 2–3 Real bilateral exchange rate of the koruna against the euro using the HP filter and the BP filter
Note: For misalignment, (+) denotes overvaluation and (–) denotes undervaluation.
Source: Authors' calculations using CNB, CZSO, and Bloomberg data

[36] Compared to its euro area counterpart, the PPI for the Czech Republic has a significantly higher weighting of energy-intensive items. This could mean that the real exchange rate is biased at times of strong energy price growth. As an alternative, the calculation could therefore be performed on the basis of unit labour costs (ULC).

2.4.2 BEER (Behavioral Equilibrium Exchange Rate)

The essence of the BEER model is the initial determination of a set of relevant variables that affect the real exchange rate from the perspective of economic theory. Those variables are then used as explanatory variables of the model. A detailed discussion of the effects of individual fundamental factors on the real exchange rate can be found, for example, in Faruquee (1995), Clark and MacDonald (1998), Frait and Komárek (1999a, b and 2001), Égert (2003a), and Komárek and Melecký (2005).

Stronger growth in average productivity in the home economy than in the foreign economy will lead, ceteris paribus, to higher domestic inflation.[37] However, in the case of economies with a floating exchange rate, such as the Czech Republic, this price effect is dampened by real appreciation. Moreover, productivity growth may also be captured in nominal appreciation. Appreciation pressures should also emerge as a result of strong inflows of foreign direct investment (privatization, new infrastructure projects), facilitating rapid restructuring primarily in the tradable goods sector. Growth in the value of the domestic currency over the longer term (real appreciation) should also lead to growth in the home country's net foreign assets, e.g. through growth in foreign assets owned by residents. The external terms of trade, defined as the ratio of the home country's export and import prices, are another fundamental variable. If they improve, then, ceteris paribus, domestic prices will rise. This, in turn, will cause the real exchange rate to appreciate. The attractiveness of the domestic currency on international markets also reflects the real interest rate differential, which primarily affects the real exchange rate via its nominal dimension, i.e., the nominal exchange rate. If the home economy shows a positive real interest rate differential (and if the differential increases), demand for the domestic currency rises, its value increases (nominal appreciation), and the real exchange rate again appreciates. However, following the logic of the uncovered interest parity condition, a positive interest rate differential should give rise to expectations of future depreciation. At the same time, if the economy faces a relatively high ratio of external debt to GDP, confidence in the domestic currency will fall, leading to both nominal and real depreciation. The other most commonly monitored variables include the openness of the economy (the sum of exports and imports relative to GDP) and the ratios of net exports, investment, and government and private consumption to GDP.

---

[37] This is especially true of transition countries with a fixed exchange rate and a large industrial sector, where labour productivity growth in the tradable goods sector is faster than in the non-tradable goods sector. This productivity growth differential is then reflected in different price growth in the two sectors, with prices in the non-tradable goods sector rising faster than in the tradable goods sector owing to lower labour productivity therefore being a potential source of inflation pressures. Distinguishing between the market and administered components of inflation is also important.

The process of selection of the fundamental determinants entering the BEER model was influenced by well-known empirical experience and published recommendations. Consistency of the results of the parameters with economic theory and their statistical significance were the decisive factors in the assessment of the variants of the equation estimations. The following real exchange rate equation represents the results of the estimates and various specifications of the model:

$$RER = f(DPROD; NFA; THFK; NX), \quad (2.1)$$

where RER is the real CZK/EUR exchange rate (deflated by the PPI in manufacturing[38]), DPROD is the labour productivity differential between the Czech Republic and the EMU, NFA is the ratio of the Czech Republic's international investment position to GDP at current prices, THFK is the ratio of real investment to real GDP, and NX expresses the ratio of net exports to GDP at current prices. The resulting estimate of the equation using seasonally adjusted quarterly data for 1996Q1–2011Q4 is:

$$RERt = -\,0.1123\ DPROD_t - 0.0261\ NFA_t - 0.4582\ THFK_{t-1} - 1.4613\ NX_t + 156.3$$

$$(0.0378)^{***} \qquad (0.0034)^{***} \qquad (0.0832)^{***}$$

$$(0.2802)^{***}$$

$$(R^2 = 0.9917 \qquad S.E. = 1.1159 \qquad D\text{–}W = 1.94)$$

All the estimated parameters of the equation are statistically significant at the 1% level. Misalignment estimates can be constructed for both the short and long run. In the short run (see Figures 2–4 and 2–5), the macroeconomic fundamentals are generally subject to more economic shocks, leading to higher volatility of the equilibrium exchange rate path. Alternatively, the long-run equilibrium exchange rate path can be estimated by approximating the time series of the variables entering the model using the HP filter.

2.4.3 FEER (Fundamental Equilibrium Exchange Rate)

The equilibrium exchange rate estimate according to the FEER model is based on the concept of the partial internal and external equilibrium of the economy. Internal equilibrium is consistent with the potential output path calculated using the Cobb-Douglas production function. External equilibrium is presented as a sustainable evolution of the ratio of the Czech Republic's current account deficit to GDP at the 5% level.[39] The core version of the FEER model contains a block

[38] The real exchange rate also indicates the competitiveness of the economy. The PPI index in manufacturing was therefore used to adjust it for price effects in the BEER and FEER models, as this index is also a suitable price proxy for the categories of goods making up the core of Czech foreign trade.

[39] Fixing the sustainable level of the current account deficit relative to GDP (at 5% in accordance with the accepted convention) for the entire monitored period is a simplifica-

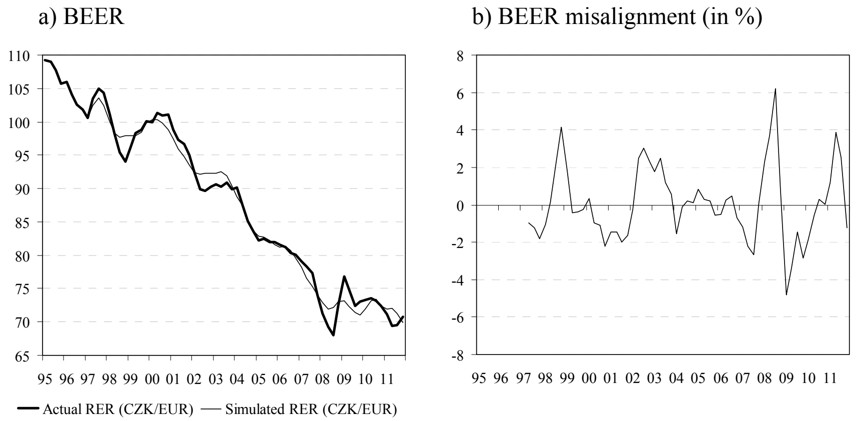

Figure 2–4 Estimate of the equilibrium real exchange rate and its misalignment according to the BEER model
Note: For misalignment, (+) denotes overvaluation and (–) denotes undervaluation.
Source: Authors' calculations using CNB, CZSO, Bloomberg, Datastream, and AMECO (European Commission) data

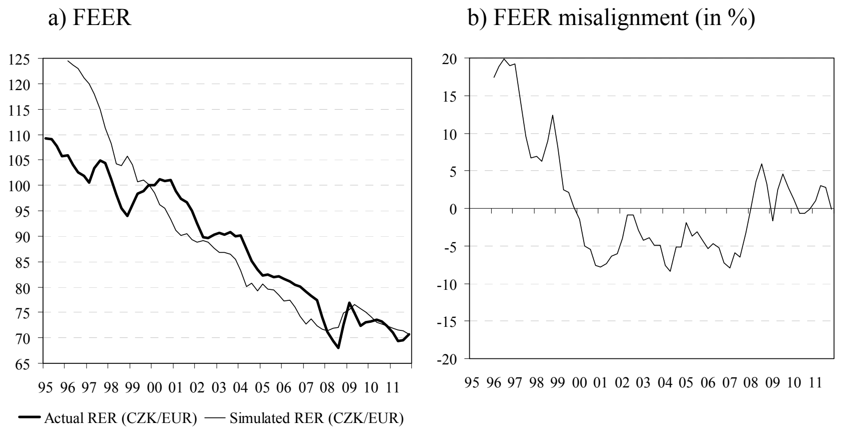

Figure 2–5 Estimate of the equilibrium real exchange rate and its misalignment according to the FEER model
Note: For misalignment, (+) denotes overvaluation and (–) denotes undervaluation.
Source: Authors' calculations using CNB, CZSO, Bloomberg, Datastream, and AMECO (European Commission) data

---

tion, as the long-run sustainable level may change over time, especially at times of strong FDI inflows.

of foreign trade equations (i.e., export and import equations) as well as other supplementary equations (identities) ensuring simultaneous attainment of the internal and external equilibrium of the economy. The foreign trade equations[40] assume the existence of a functional dependence between exports and imports, or between domestic and external demand and the exchange rate:

$$\textit{Exports:} \quad lnX = f(lnMEMU; lnRER; lnDPROD), \tag{2.2}$$

$$\textit{Imports:} \quad lnM = f(lnDD; lnRER; lnX), \tag{2.3}$$

where X represents real exports of goods and services, M is real imports of goods and services, DD is real aggregate domestic demand, $MEMU$ is real imports of euro area goods and services, RER is the real CZK/EUR exchange rate (deflated by the PPI in manufacturing), $DPROD$ is the ratio of labour productivity in the Czech Republic to that in the EMU.

Both equations were estimated using the VEC (Vector Error Correction) model[41] on seasonally adjusted quarterly data for 1996Q1–2011Q4. All the estimated parameter values forming cointegration vectors are consistent with economic theory and are as follows:

Exports:

$$lnX_t = 1.13\ lnMEMU_t + 1.52\ lnRER_t + 1.84\ lnDPROD_t - 17.06$$

$$(0.006)^{***} \qquad (0.147)^{***} \qquad (0.111)^{***}$$

$$R^2 = 0.88 \qquad S.E. = 0.034$$

Imports:

$$lnMt = 0.74\ lnDDt - 1.41\ lnRERt + 0.24\ lnXt + 5.93$$

$$(0.249)^{***} \qquad (0.221)^{**} \qquad (0.098)^{**}$$

$$R^2 = 0.73 \quad S.E. = 0.049$$

The complete FEER model was created by adding to the behavioral equations of real exports and imports the identities of net exports and real GDP and the identities defining internal and external equilibrium:

Identities:

$$NX_t = X_t - M_t \tag{2.4}$$

$$NX_t^N = P_t^X NX_t + M_t \left(1 - \frac{P_t^M}{P_t^X}\right) P_t^X \tag{2.5}$$

$$Y_t = DD_t + NX_t \tag{2.6}$$

$$Y_t^{GAP} = Y_t - Y_t^{EQ} \tag{2.7}$$

[40] These equations are subsequently linked via the net exports identity.
[41] Only the adjusted long-run parts of the equations (cointegration vectors) are used to estimate the equilibrium exchange rate.

$$Y_t^N = Y_t P_t^Y \tag{2.8}$$

$$CA_t^{EB} = CA_t^{EQ}\, Y_t^N \tag{2.9}$$

$$CA_t^{GAP} = NX_t^N - CA_t^{EB} \tag{2.10}$$

where NX is real net exports, NX^N is nominal net exports, P^X describes export prices, P^M is import prices, P^Y is the GDP deflator, Y is real GDP and Y^N nominal GDP, CA^{EB} is the sustainable current account balance, CA^{EQ} is the constant threshold for long-run sustainability of the current account deficit relative to GDP, Y^{GAP} is the deviation of real GDP from the target (internal equilibrium of the economy), Y^{EQ} is potential GDP calculated on the basis of the Cobb-Douglas production function, and CA^{GAP} is the deviation of the current account balance from the target (external equilibrium).

The model was solved using the Winsolve program as an optimization task minimizing the squares of the variables Y^{GAP} and CA^{GAP} over the entire period within the boundaries of the individual model equations. For simultaneous attainment of internal and external equilibrium (two targets), two instruments were defined, namely, the real exchange rate (RER) and aggregate domestic demand (DD). This approach is in line with Tinbergen's rule of economic policy instruments and targets (see Tinbergen, 1952).[42]

The results of both equilibrium exchange rate models (BEER and FEER) demonstrated a strong long-run appreciation trend (see also Figure 2–6), due mainly to faster productivity growth in the Czech Republic than in the euro area. The results of the estimates also revealed that the exchange rate of the koruna was overvalued[43] until mid-1997 as well as in 1998, 2008, and 2011. From 2009 onward, however, the models indicate a slowdown in equilibrium appreciation, due mainly to a drop in investment inflows and a slowdown in domestic labour productivity growth compared to the euro area. Outside the FEER model, the resulting slowdown in equilibrium appreciation can also be linked with an acceleration of the Czech Republic's external debt.

Unlike in the BEER and FEER models, the equilibrium exchange rate is not modeled directly in the CNB's core prediction model. Real equilibrium exchange rate appreciation (expressed in consumer prices) is described indirectly as the difference between growth in domestic and foreign export-specific technology. In an open economy, prices of tradable goods under certain assumptions rise more slowly than prices in the non-tradable goods sector as a result of faster technological progress in the tradable goods sector. This is known as the Baumol-Bowen effect and results in consumer price inflation being higher than

[42] Tinbergen's rule of economic policy instruments and targets states that in the long run it is impossible to pursue two mutually dependent monetary policy targets using one instrument (interest rate changes).

[43] Overvaluation is a close synonym for excessive appreciation, which leads to a loss of price competitiveness.

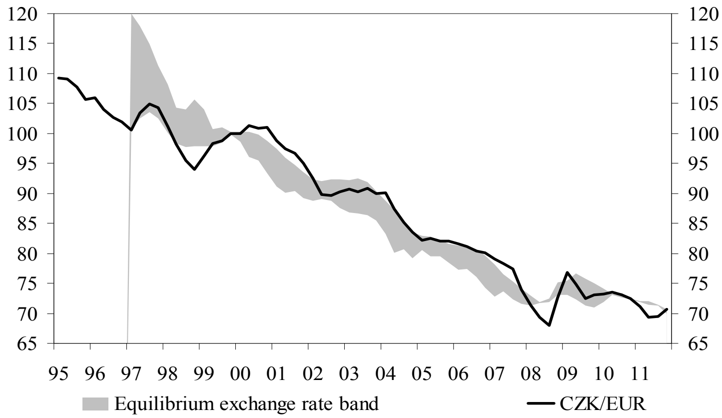

Figure 2–6 Equilibrium real exchange rate band according to the BEER and FEER models
Source: Authors' calculations using CNB, CZSO, Bloomberg, Datastream, and AMECO (European Commission) data

import price inflation. In the CNB's core prediction model, this inflation differential is captured using growth in export-specific technology. The same process also takes place abroad. Assuming that both economies are at long-run equilibrium and therefore have constant terms of trade, real exchange rate appreciation is described as the difference in the growth rates of export-specific technology. This is known as the Harrod-Balassa-Samuelson effect.

2.5 Conclusion

The importance of equilibrium exchange rate estimates and the need to analyze them cannot be overlooked, especially in a small and open economy like the Czech Republic. The sensitivity to deviations of the actual exchange rate from its equilibrium level rises with the degree of openness. Identifying equilibrium exchange rate movements is thus a similar issue to that of identifying asset price misalignments (bubbles) – it is difficult to determine them not only ex ante, but also ex post. Nevertheless, several positive and normative approaches to the estimation of equilibrium exchange rates have been formulated. In addition to simple statistical methods, two approaches were applied to estimate the CZK/EUR equilibrium exchange rate, one based on positive economics (BEER) and the other on normative economics (FEER). Estimates using the BEER and FEER models can be regarded as fundamental in the area of equilibrium exchange rate estimation. Anecdotal evidence across the new Euro Area members from Central and Eastern Europe indicates that these models were required by European authorities in the euro adoption process (before ERM II entry and before euro area entry itself). However, the need to analyze the equilibrium exchange rate level is no less important for countries that are not attempting to enter a monetary union. An equilibrium exchange rate band can periodically be constructed from the results of BEER and FEER model estimates. This band can be used for more robust analyses of past economic developments and exchange rate outlooks.