The influence of the macroeconomic trilemma on monetary policy - A functional coefficient approach for the Taylor rule

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Abstract

The aim of this work is to get a deeper understanding of how the macroeconomic trilemma influences national monetary policy. If the theoretical structure of the trilemma holds, countries which allow their exchange rate to float more freely should be able to put a higher weight on national monetary policy targets. Therefore a panel data framework is used to investigate the potential differences of the coefficients in a Taylor rule-like reaction function. A dynamic panel model with an interaction dummy variables and a functional coefficient model is used to investigate the connections between exchange rates, capital openness and independent monetary policy.

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List of Abbreviations

AB	Arellano-Bond
ADF	Augmented Dickey-Fuller
CPI	Consumer Price Index
DW	Durbin-Watson
ECB	European Central Bank
GMM	Generalized Method of Moments
GDP	Gross Domestic Product
HP	Hodrick-Prescott
iid	independent and identically distributed
IMF	International Monetary Fund
OLS	Ordinary Least Squares

List of Symbols

β	Estimated coefficient
D	Dummy variables
Δ	Difference operator
E	Expectation operator
γ	Structural parameter
HP	Variable index: HP trend of variable
i	Country index: domestic country
j	Country index: base country
L	Lag operator
m	Time index: month
Ω	Information set
ρ	Interest rate smoothing parameter
t	Time index: quarter
y	Time index: year

1 Introduction

1.1 Research problem

On September 6 2011, the Swiss National Bank announced their intention to peg the Swiss franc against the Euro at a minimum exchange rate of 1.20 francs per Euro and to "enforce this minimum rate with the utmost determination and [be] prepared to buy foreign currency in unlimited quantities" (SNB 2011). This measure was taken to fight the recent appreciation of the Swiss franc, which constituted a thread to the export oriented Swiss economy. The Swiss franc had gained more than 30 percent versus the Euro over the preceding twelve months, even though the Swiss National Bank had lowered the interest rate to zero percent (Verschuur and Wille 2011).

In economic theory this should have led to a reduction of capital inflow, which was the main reason for the appreciation of the Swiss franc. Though investors seemed more concerned about the financial stability of the euro area and continued to place funds in Switzerland, which they considered stable. This caused the Swiss National Bank to take unorthodox measures and announce the first peg since the Bretton Woods currency system in 1973. However, the decision was not without controversy. One month before the announcement, even the President of the Swiss National Bank, Philipp Hildebrand, had said that "a fixed and permanent peg of the Franc to the Euro isn't compatible with our constitutional and legal mandate to conduct an independent monetary and exchange rate policy." (Verschuur and Wille 2011)

This trade-off for Switzerland is a recent example of a phenomenon which has become well known in the economic literature as the "macroeconomic trilemma". It describes the impossibility of simultaneously reaching three objectives of open economies: an open capital market, a stable exchange rate and the ability to conduct an independent monetary policy.

Unrestricted capital mobility is important to attract foreign investments and ensure optimal allocation of resources. By stabilizing the exchange rate, countries can try to "import" a credible monetary policy or sustain price stability with important trade partners. Finally, an autonomous monetary policy enables a country to achieve domestic goals through an additional policy-channel.

Although all three of these goals are potentially beneficial for a country's economy, the macroeconomic trilemma implies that only two of them can by realized at the same time while one has to be given up. A growing number of studies have investigated whether the theoretical implications of the trilemma can be confirmed empirically. While most of this confirmed a trade-off between the three components, the empirical measurement of these is difficult (cf. Obstfeld et al. 2005, p. 423). There are no generally accepted definitions for the independence of monetary policy, the openness of the capital market and the stability of the exchange rate. For this reason there is still much uncertainty about the relationships between the underlying components of the trilemma.

Different approaches to capture the state of economies in the trilemma have been developed. In these, sovereign monetary policy has mostly been defined as the ability of a central bank to set interest rates independent from interest rates of a regionally important economy, referred to as the base country. The closer the domestic interest rate is following the guidelines from the base country, the smaller the ability to use monetary policy for domestic purposes. While this is non-controversial, the approach of capturing monetary policy independence through interest rate pass-through has one major disadvantage: It only covers the extent to which the macroeconomic trilemma potentially allows countries to carry out an independent monetary policy. However, it neglects the actual intentions behind the design of monetary policy. Several authors have referred to this shortcoming:

> *It must be acknowledged that we cannot speak to the ways in which intent of the monetary authorities underlies the preceding evidence on interest-rate independence.*
>
> Obstfeld et al. (2005, p. 435)

> *It would be ideal to model the interest rate process more formally and see if countries were pursuing particular policies.*
>
> Shambaugh (2004, p. 18)

It is important to get a deeper insight into the ways in which central banks operate under diverse conditions to understand how the trilemma influences national monetary policy. Until now it has not been clear whether interest rate pass-through or co-movement was intended to stabilize the exchange rate or might be the result of common shocks in the context of international business cycle transmission (cf. Obstfeld et al. 2005, p. 435).

This study addresses this problem by modeling the process of interest rate determination via a monetary policy rule. Therefor a Taylor type rule (Taylor 1993) is used, as is common in the economic literature. In the Taylor rule, inflation and economic output are the two components that determine the interest rate. Both are domestic quantities. Hence, the Taylor rule can be seen as a model for a sovereign monetary policy. The size and significance of the reaction parameters display whether and the extent to which central banks approach domestic economic goals. Then, by distinguishing different states of the other two components in the macroeconomic trilemma, it will be investigated how exchange rate stability and capital openness influence the reaction of interest rates towards domestic targets.

If a central bank has ceased to perform a sovereign monetary policy in favor of an open capital market and stable exchange rates, it should not be able to pursue inflation or cyclical targets by means of its interest rate. However, most studies have shown that countries generally do not decide to abandon one of the three objectives of the trilemma completely (cf. Herwartz and Roestel 2010, p. 15f; Durringer 2009, p. 40; Shambaugh 2004, p. 33; Obstfeld, Shambaugh, and Taylor 2005, p. 433). So, by using a Taylor rule to determine domestic monetary policy preferences, it can be investigated where central banks set their priorities. For example, whether they are more willing to give up exchange rate stability to approach economic growth or price stability. The design of domestic monetary policy along with the choice of positioning in the trilemma then allows for drawing conclusions for the central bank's loss function.

For the empirical analysis in this study, a panel data framework is used to investigate the potential differences of the coefficients in a Taylor rule for different states of financial integration and exchange rate volatility. The dataset contains 20 OECD countries in a time sample from 1980 to 2009. This choice is motivated by the attempt to gather a panel dataset which offers enough observations for multiple trilemma configurations for a group of countries with similar and comparable monetary policies and economic conditions. Different measures for the trilemma variables from previous studies are compared to get more robust and diverse results. Furthermore, several of the previous studies used very rigid measures to distinguish the trilemma positioning of countries. In Obstfeld et al. (2005) and Shambaugh (2004) it is investigated, whether countries match conditions which classify them as pegs or nonpegs with regard to their exchange rate respectively as having capital barriers or not. This approach, though it is restrictive, is applied by using a dynamic panel model with interaction dummy variables for the potential peg status of a country and the existence of capital barriers as a benchmark if there are significant differences for the estimated coefficients. However, as Herwartz and Roestel (cf. 2010, p. 1f) pointed out, this approach might not consider the diverse aspects of the trade-off relationship between the trilemma components as well as their country- and time-specific heterogeneity. To accommodate for this objection the monetary policy reaction function is also estimated via a functional coefficient model, as suggested by Herwartz and Roestel (2010, p. 11ff). This offers a more flexible approach to investigate the connections between exchange rates, capital openness and independent monetary policy.

1.2 Structure

The structure of this work is as follows. In the next section, the theoretical background and previous studies on the macroeconomic trilemma are reviewed as well as the basic development in the literature regarding monetary policy rules. As there are various studies which are related to these topics, the review focuses on recent and relevant research. The important elements of this literature overview are then collated to draw implications for the research problem of this study. The choice of research methods, outlined in the introduction, will be justified and specified more explicitly. Section four covers the empirical research of the study. It is composed of three parts. First the estimation of a Taylor rule for each individual country will be examined. The estimated policy coefficients are compared to analyze whether patterns of monetary policy for countries with similar trilemma strategies can be identified. Secondly, a dynamic panel model with distinctions concerning the trilemma setup is applied to the Taylor rule. This will serve as a benchmark for the effect of the trilemma on monetary policy. In the last part, a Taylor rule is estimated in a functional coefficient model, where the policy parameters depend on the state of exchange rate flexibility and capital openness. Each part covers the specification of the respective empirical model with the related econometric approach and estimation problems. Also the used data will be described and a definition of the variables is given. This covers the components of the Taylor rule and the constituent parts of the macroeconomic trilemma: exchange rate stability and openness of the capital market. For the empirical analysis the descriptive statistics and time series properties are discussed as well as the results of the different regression specifications. Finally, the last section summarizes the results and conclusions, points to potential shortcomings and gives direction for further research on the topic.

2 Monetary policy and the macroeconomic trilemma - Theoretical background and empirical evidence

In this section, the previous literature on the topic of the research problem will be reviewed. First, the principles of the trilemma phenomena are described and an overview on the recent empirical findings is given. Following this, the Taylor rule is described as a model for monetary policy.

2.1 The macroeconomic trilemma

2.1.1 The theory behind the macroeconomic trilemma - A two-course menu for open economies?

Gregory Mankiw has felicitously explained the term "trilemma" in his article on the macroeconomic trilemma in the New York Times:

> *Yes, trilemma really is a word. It has been a term of art for logicians since the 17th century, according to the Oxford English Dictionary, and it describes a situation in which someone faces a choice*

among three options, each of which comes with some inevitable problems.

Mankiw (2010)

As mentioned in the previous section, in the macroeconomic context, the trilemma states that of the three preferable targets – a souvergein monetary policy, full financial integration and a stable exchange rate – policy makers in open economies can only reach two.

Each of the goals has potential beneficial effects for an open economy. With an independent monetary policy, policy makers are able to attend to domestic economic matters by additional instruments. Thus, monetary policy instruments have been seen as more efficient than fiscal policy instruments for many issues, because monetary policy generally takes effect faster and is more target-oriented. Full financial integration provides a country with the unlimited access to the international capital markets. This is a major requirement to attract foreign investors. In addition it gives nationals the opportunity to place funds in profitable investments abroad. Both support local gain of wealth and an optimal allocation of resources. A stable exchange rate also supports foreign investments, because strong exchange rate volatility represents a risk for their returns. Investors have more planning reliability and can save insurance against exchange rate fluctuations. Furthermore, it helps to maintain price stability, because exchange rate changes affect domestic prices via the prices of import goods.

Economic theory states that one of the goals has to be given up. So in theory the macroeconomic trilemma leaves a country with three choices:

1. Stabilize the exchange rate and free the capital flow, but give up independent monetary policy.

2. Stabilize the exchange rate and conduct an independent monetary policy, but restrict the capital flow.

3. Liberate the capital market and conduct an independent monetary policy, but let the exchange rate float.

In the first situation, policy makers can not achieve domestic economic goals by monetary policy. If, for example, they would try to lower the inflation rate by raising the central banks interest rate, they would induce a rise of capital inflow via the open capital market. This is because the higher interest rate makes investments in the country more profitable. The foreign investors need to change their currency into the domestic currency to be able to place funds in the country. This creates an appreciation pressure on the domestic currency, which is not compatible with a stable exchange rate. To avoid the appreciation, policy makers could implement capital barriers (second option). The inflow of capital would thus be prevented by completely shutting down international capital transactions or by increasing the costs for foreign investors, counterbalancing the gains from the increased interest rate. Alternatively, choosing the third option, they could give up the fixed exchange rate. In this case, the currency would react to the higher demand on the capital market and would appreciate.

The phenomenon of the macroeconomic trilemma was first introduced by Robert Mundell in the 1960s[1] (cf. Aizenman & Ito 2012, p. 2; Durringer 2009, p. 3). Using an extension of the classic IS-LM model, he showed how the choice of the exchange rate regime and the capital mobility have an impact on the outcome and effectiveness of monetary policy for small open economies. Parallel to Mundell the model was also developed by Marcus Flemming and has been known as the Mundell-Flemming model henceforth. The analysis of the trilemma phenomenon is strongly simplified in the model, but benefits from the intuitiveness of the IS-LM framework.

Various further research has been conducted on the macroeconomic trilemma, in which multiple peculiar names were used to describe the phenomenon. It has been labeled as *Mundell's triangle of incompatibility* (Deblock 2003), *The incompatible trinity* (Krugman 2000) , *The triad of incompatibilities* (Fischer and Reisen 1993), *The holy trinity* (Rose 1996), *Impossible theorem* (Isard 1995), *Impossible trinity* (Fischer 2001; Ghosh et al. 2003; Joshi 2003; Hsing 2012) and finally *The trilemma*, introduced by Obstfeld and Taylor (1998); Obstfeld, Shambaugh, and Taylor (2005).[2] The term *trilemma* seems to be predominantly used in recent studies (for example in Aizenman, Chinn, and Ito (2008, 2010a,b);

[1] See for example Mundell (1960, 1961, 1963).
[2] This list is mostly taken from Durringer (2009, p. 3).

Aizenman and Ito (2012); Herwartz and Roestel (2010); Schoenmaker (2011); Popper, Mandilaras, and Bird (2011)). Derived from the common word *dilemma*, it is both intuitive and catchy; and clarifies the fact that it applies to a problem with three choices.

2.1.2 Monetary policy and the macroeconomic trilemma

The extent to which monetary policy is really possible under different trilemma configurations and its effectivity have been subject of discussion in the literature. Many studies were able to demonstrate empirically, that there is a trade-off between the three trilemma components. However, as the methods of the researches vary, few generally accepted facts were developed so far.

One of the most ambitious researchers on the trilemma are Aizenman, Chinn, and Ito (2008, 2010a,b); Aizenman and Ito (2012). They tried to capture the trilemma setup of countries via three indices for monetary independence (based on the correlation between domestic and base interest rate), exchange rate stability (based on the standard deviation of the exchange rate to the base country's currency) and financial integration (based on a measure by Chinn and Ito (2008, 2006), which uses information about capital restrictions in the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions*) (cf. Aizenman et al. 2008, p. 6f). In the absence of a known specific form of the trade-off relationship, they analyze whether the three variables add up to a constant in a simple linear regression model.[3] The results show that the variables are indeed linearly related and that there is a trade-off between them. A change of one variable leads to a change in the opposite direction of the weighted average of the other two variables (cf. Aizenman et al. 2008, p. 13). They also tested, the performance of different trilemma strategies regarding the goals of economic policy output and inflation. According to their findings, countries with higher exchange rate stability experience higher output volatility but a lower inflation level. More monetary independence is related to higher inflation levels (the latter may be a strategy to monetize a countries debt) and lower output volatility. An

[3]The model has the form $1 = \alpha_j MI_{i,t} + \beta_j ERS_{i,t} + \delta_j KAOPEN_{i,t} + \varepsilon_t$, with MI for monetary independence, ERS for exchange rate stability, KAOPEN for financial integration and ε as the residual term.

open capital market leads to lower inflation and helps reducing exchange rate volatility. Furthermore, different combinations of realized trilemma goals lead to different results, indicating that the trade-off between the trilemma choices is carried forward to the feasibility of economic targets. This makes it difficult to suggest strategies for an optimal trilemma configuration (cf. Aizenman et al. 2008, p. 16ff; Aizenman et al. 2010a, p. 25; Aizenman et al. 2010b, p. 34).

Durringer's (2009) results confirm the trilemma relation, using a different approach to capture its components by indices. However, he suggests taking some additional control variables (inflation, current account) into account. Like Aizenman et al. (2008), he also finds that some countries achieve overall better results for the three trilemma variables. This indicates, that the trilemma trade-off is not strictly binding in the sense that one component has to take place for another (cf. Durringer 2009, p. 39f; Aizenman et al. 2008, p. 14).

The first usage of the term *macroeconomic trilemma* can be found in Obstfeld and Taylor (1998). Together with J. C. Shambaugh they established this notation in multiple studies. To analyze the phenomenon, Obstfeld, Shambaugh, and Taylor (2005, 2004) test how much the interest rates of countries are determined by the interest rates of a base country. In contrast to Aizenman et al. the ability to independently set the interest rate, as a measure for monetary independence, is modeled directly and not simply captured via the correlation of interest rates. They distinguish the countries in groups of pegged and not pegged economies as well as economies with and without capital controls. To investigate the differences of the interest rate pass-through for different combinations and time samples, they use a panel error correction model approach by Pesaran, Shin, and Smith (2001).[4] The results of Obstfeld et al. (2005) show that pegs have a substantial higher interest rate pass-through and hence less independence for monetary policy. In addition, the adjustment towards the base country's interest rate level is faster and a higher share of the interest rate movement can be explained by the model (via $\mathbf{R}^2$).

Furthermore, they find that neither nonpegs have fully autonomous interest rates or completely floating exchange rates, nor do pegs experience full interest rate pass-through. For nonpegs this could be explained by the so called

[4] The model by Pesaran, Shin, and Smith (2001) allows for uncertainty regarding the integration of interest rates and is used in other studies on the topic as well.

fear of floating (Calvo and Reinhart 2002). It states that countries try to avoid strong exchange rate fluctuations, regardless of the exchange rate regime. The absence of full interest rate pass-through can be an indication of flexible exchange rate bands (which eases the effects of a fixed exchange rate) and arbitrary costs (cf. Obstfeld et al. 2005, p. 39f; Obstfeld et al. 2004, p. 14ff).

The concept of classification for pegs and nonpegs in Obstfeld et al. (2004, 2005) was developed and used previously by Shambaugh (2004). It applies to whether a country stays in a specific exchange rate band for a certain amount of time. Shambaugh (2004) also investigated the trilemma via the channel of interest rate pass-through, founded on the idea of interest rate parity. His results are consistent with those of Obstfeld et al. (2004, 2005), even when controls for other possible impacts (time effects, international trade and foreign debt) are taken into account (cf. Shambaugh 2004, p. 32f).

Herwartz and Roestel (2010) use a similar approach to Shambaugh (2004) to determine the independence of domestic monetary policy in the context of the trilemma. They criticize Shambaugh (2004) and others for not accounting for domestic economic conditions (deviations from long run output, inflation and exchange rate) when estimating the dependency of the domestic interest rate on the interest rate of base country. In a pooled panel model, Herwartz and Roestel (2010) find that general results of Shambaugh (2004) can be confirmed but that the omission of domestic control variables leads to an upward bias for the estimated pass-through parameter. This could be a sign for the effect of synchronized business cycles (Herwartz and Roestel 2010, p. 9), contrary to Shambaugh's statement, that common economic shocks are not responsible for the results (Shambaugh 2004, p. 23).

Moreover, Herwartz and Roestel (2010) raise concerns over the restrictive method of dividing countries into clear-cut groups (pegs vs. nonpegs, capital controls vs. no capital controls). They state that a continuous measure for exchange rate volatility and capital openness is needed to get a more detailed insight into the trilemma trade-off. This requirement is achieved by using a semiparametric functional coefficient model for the estimation of the interest rate pass-through. In this model the parameter estimation is additionally dependent on the state of exchange rate volatility and financial integration. They are thereby able to analyze the effect of various policy combinations on monetary independence. The results of the semiparametric regressions confirm that countries with fixed exchange rate and open capital markets experience close to complete interest rate pass-through, whereas more flexible exchange rates and restricted capital openness can facilitate substantial freedom for independent monetary policy. More important, the trade-off seems to be not linearly. Countries have the option to stabilize exchange rates to some extent without loosing much monetary sovereignty (cf. Herwartz and Roestel 2010, p. 14ff).

Despite these general confirmations on the trilemma phenomenon, there are also studies which have doubts regarding the gains of monetary independence for certain trilemma policies. Frankel, Schmukler, and Serven (2004) use a very similar approach to Shambaugh (2004), but find that regardless the exchange rate regime the interest rate pass-through is very high for all 46 analyzed countries and even complete since the nineties. At the most, floating countries have little and only temporary independence for monetary policy, indicated by a slower adjustment speed towards the base country's interest rate. Only two bigger countries (i. e. Germany and Japan) seemed to be able to set interest rates self-governed to some extent (cf. Frankel et al. 2004, p. 726). However, in his study Shambaugh (2004) criticizes some of the methodical approaches of Frankel et al. (2004). He claims that Frankel et al. (2004) did not properly account for the integration of the interest rate, oversimplified the choice of the base country by using the United States for every country and overlooked the effect of some outliers in the data. Without these shortcomings the results would be more in line with his findings (cf. Shambaugh 2004, p. 10f).

While basic methodology to investigate the effect of the trilemma on monetary policy is very similar in most studies, Mukherjee (2010, 2011) focuses on the connection between the trilemma and the monetary policy function of central banks. Therefore the key note of his approach is closely related to the approach of this study. Mukherjee (2011) analyzes how capital openness affects the behavior of inflation targeting central banks concerning exchange rate fluctuation. For this purpose he estimates an monetary policy function where the central bank sets its interest rate with respect to inflation, the output gap, exchange rate fluctuation and capital openness, using a dynamic panel model approach for 22 inflation targeting countries. The results suggest that the response of the interest rate to exchange rate fluctuations declines with more capital openness and becomes insignificant in the upper region.[5] With limited capital openness, however, countries can maintain monetary independence and controlled exchange rate flexibility at the same time. Furthermore, Mukherjee (2011) finds that inflation targeting countries are able to stabilize inflation better that non-inflation targeting countries, although the latter experience lower exchange rate volatility (cf. Mukherjee 2011, p. 7ff).

2.1.3 The change of the trilemma setup in history

One strand of the literature has focused on the historical aspect of the phenomenon of the macroeconomic trilemma. The main question here is how the configuration of the trilemma was chosen over different time periods. Obstfeld et al. (2005) distinguish three periods with fundamentally different approaches handling the trilemma:

1. The Gold Standard era
2. The Bretton Woods era
3. The Post Bretton Woods era

During the system of the gold standard, bank money creation was limited by the gold reserves of a country, because there was a guaranteed fixed conversion rate between a currency and gold. The era was characterized by globalized markets, high capital mobility and fixed exchange rates. Hence, the ability of countries to conduct an independent monetary policy was restricted. In the Bretton Woods era, a system of fixed exchange rates was applied with the US Dollar as the lead currency, which was backed by gold. Central banks had to maintain the exchange rate - but due to strict limitations for capital markets they could also conduct an autonomous monetary policy. After the Bretton Woods system was given up, exchange rates became flexible in principal and the capital market became more and more liberated, which offered the opportunity for a sovereign monetary policy (cf. Obstfeld, Shambaugh, and Taylor 2005, p. 424). However, different strategies

[5] Capital openness is measured via the index by Chinn and Ito (2008).

for different countries can now be observed. The USA let their exchange rate float in favor of a sovereign monetary policy. China restricts the international flow of capital in the country to be able to hold the exchange rate at a stable and low level and to be monetary independent. Finally, the example of Switzerland in the introduction shows a third path; a fixed exchange rate but the loss of monetary independence to the European Central Bank (Mankiw 2010).

When distinguishing between different time periods, Obstfeld, Shambaugh, and Taylor (2005, p. 429ff) found that interest rate pass-through was the highest under the gold standard, followed by the Post Bretton Woods period. During the Bretton Woods system no positive pass-through of interest rates was observed, indicating that capital controls were truly effective. However the pass-through coefficient as well as the $\mathbf{R}^2$ from the regressions are always clearly smaller than one (max. 0.61 resp. 0.41). This indicates that also under very different monetary systems and exchange rate regimes countries do not have to give up souvereign monetary policy completely. This is true, mostly because capital markets are not totally perfect and exchange rates are generally not completely fixed but are allowed to vary and adjust in small ranges.

Durringer (2009, p. 4f) emphasizes the role of the trilemma configuration and economic conditions as an explanation for crises and failures of monetary systems. He argues, that the rising pressure on policy makers by more organized workers to approach the problem of unemployment led to the collapse of the gold standard system - because the waiving on actively using monetary policy was no longer tenable. The Bretton Woods system also failed, because the ongoing process of globalization necessitated free capital transactions. After the Bretton Woods system, no new system was implemented which could entirely fail. However, crises occurred when policy makers tried to take advantage of all three trilemma components[6].

Popper, Mandilaras, and Bird (2011, p. 19) studied the stability of trilemma configurations over time. They found that policy combinations including a stabilization of exchange rates are the least stable ones and that there is a trend

[6]For example the European crisis with the German reunification in 1992-93 or the Asian crisis in 1997.

towards a "middle solution" for many countries.[7] This finding is confirmed in several other studies as well (cf. Aizenman et al. 2008, p. 26).

2.1.4 Country types and their positioning in the trilemma

In addition to historical differences, there are also differences in the trilemma configurations among countries and country types. As Aizenman and Ito (2012, p. 3) point out, developing and emerging countries are much more vulnerable to international economic shocks. Thus, it is more important for them to have a optimized trilemma policy. In the eighties, most developing countries followed a trilemma strategy with closed capital markets, fixed exchange rates and souvereign monetary policy. Thereafter they moved towards more financial integration (cf. Aizenman et al. 2008, p. 1). Overall, Aizenman et al. (2008, p. 26) find that between 1970 and 2006, there has been a trend for developing countries towards a "middle ground" solution with controlled exchange rate flexibility, a medium level of financial integration and some freedom for monetary policy.[8].

In contrast, industrialized countries broadly moved towards stabilized exchange rates and high capital mobility with limited monetary independence (cf. Aizenman et al. 2008, p. 26). Herwartz and Roestel (2010, p.8ff) confirm this finding with a different approach in their research. They analyzed interest rate pass-through for small open industrialized countries. For all countries, their findings show that there is a considerable dependency of domestic interest rate on the interest rate of a base country, although this dependency varies with the capital openness and exchange rate flexibility.

The difference between developed and developing countries is also analyzed by Durringer (2009, p. 28f). Using indices for the three trilemma components, the study shows that developed countries achieve higher and more stable scores regarding their trilemma performance. Developing countries on the other hand

[7] Popper et al. (2011) use a data set which covers 177 countries over a time periode from 1970 till 2008.

[8] Aizenman et al. (2008, p. 26f) also emphasize the role of holding a large amount of international reserves. Results show, that the reserves serve as a backing for stable exchange rates, while still being able to conduct independent monetary policy to some extend (see also Obstfeld, Shambaugh, and Taylor 2008, p. 1f). Though, the influence of international reserve holding on the trilemma is not an issue in this research and will not be further discussed.

experienced higher volatility and lower scores, though their performance has notably enhanced since the seventies.

2.2 The Taylor rule

The idea in the research problem of this study is to specify monetary policy in the context of the macroeconomic trilemma explicitly via a monetary policy function. There is very extensive literature on this strand of economic research. This section reviews the basic and relevant research.

The most popular monetary policy rule is the so called Taylor rule presented by Taylor (1993). It assumes, that the central bank sets the interest rate to achieve price stability as well as stable and adequate economic growth. Therefor Taylor (1993) proposes the following linear policy function:

$$i_t^* = \bar{i} + \overline{\pi} + \gamma_\pi(\pi_t - \overline{\pi}) + \gamma_x x_t \tag{1}$$

where

- i_t^* is the target interest rate derived from the monetary policy rule.
- $\bar{i}$ is the long run equilibrium interest rate, i. e. the target interest rate when inflation and output are at their target levels.
- $\overline{\pi}$ is the inflation rate target.
- π_t is the actual inflation rate at time t.
- x_t is the deviation of output from its potential equilibrium level (output gap) at time t.
- $\gamma_\pi > 1, \gamma_x > 0$.

The central bank sets the interest rate according to deviations from the inflation and output targets. The requirements for the reaction parameters γ_π and γ_x ensure that the interest rate changes appropriately to bring back inflation and output to their desired levels (cf. Clarida, Gali, and Gertler 1999, p. 68f).

The theoretical background of the Taylor rule is depicted in Clarida, Gali, and Gertler (1999)[9]. The background of optimal monetary policy rules is derived from a dynamic general equilibrium framework. The model contains an aggregated supply function, which is determined by the real interest rate, and a Phillips curve, wherein inflation is related to the output gap.[10] The former is obtained from an Euler equation, derived from the household's optimization of consumption and saving. The latter is deduced from the price setting of firms, under the assumption that only a fraction of them adjust their prices according to the current informations (nominal price rigidity). In this setting the central bank minimizes its quadratic loss function. It contains the central banks targets for inflation and output deviation. The solution of this minimization problem yields the monetary policy function for a welfare optimizing interest rate. The actual values for the parameters depend on the weights of the policy targets in the loss function. For deviations of inflation the central bank has to adjust the interest rate by more than one-to-one ($\gamma_\pi > 1$), because inflation is only effected indirectly via the output gap. The output gap responds to the real interest rate. If the nominal interest rate is changed by less than a larger magnitude, the real interest rate and therewith output will not be adjusted in the desired direction, which brings back inflation back to its target value[11] (cf. Clarida et al. 1999, p. 7ff).

Besides the normative implications of the Taylor rule, that it is consistent with a theoretical optimal monetary policy configuration, Taylor (1993) also contributes the empirical usefulness of his rule. He showed that with a parameter setup of $\gamma_\pi = 1.5$, $\gamma_x = 0.5$, $\overline{r} = 2$ and $\overline{\pi} = 2$ the Taylor rule is able to provide a good fit for the interest rate policy of the Frederal Reserve between 1987 and 1992. The choice of the parameter values is based on the results of research on

[9]For a detailed discussion of the Taylor rule and its background see also Taylor (1999)

[10]The two functions have the following form:

$$\begin{aligned} x_t &= \mathbf{E}_t x_{t+1} - \varphi[i_t - \mathbf{E}_t \pi_{t+1}] + g_t && \text{Aggregated supply function} \\ \pi_t &= \lambda x_t + \beta \mathbf{E}_t \pi_{t+1} + u_t && \text{Phillips curve} \end{aligned}$$

where

- g and u are disturbance terms.
- $\mathbf{E}_t$ is the operator for the expected value in time t.

[11]See also prior footnote.

the topic, rounded to straightforward simple numbers for an easy discussion (cf. Taylor 1993, p. 199ff; Clarida et al. 1999, p. 70).

While the simplicity of the original Taylor rule makes it illustrative and easy to test, it has also been criticized for this attribute. Especially the assumption that the central bank only considers the development of prices and output from the past till the present for its interest rate decision and ignores the expected future development is a major shortcoming. One of the most important enhancements of the Taylor rule that corrects this issues, was developed by Clarida, Gali, and Gertler (1998a). The main difference in their approach is that the central bank tries to target the future economic development. Thus, the monetary policy rule considers informations about expected development of inflation and output. They propose the following functional form for a forward looking Taylor rule:

$$i_t^* = \bar{i} + \gamma_\pi(\mathbf{E}[\pi_{t+k}|\Omega_t] - \overline{\pi}) + \gamma_x \mathbf{E}[x_{t+q}|\Omega_t] \tag{2}$$

where

- $\mathbf{E}$ is the expectation operator.
- Ω_t is the information set at time t about the development of the inflation rate in $t+k$ and output gap in $t+q$. The interest rate choice by the central bank is based on this informations.

Function (2) has the advantage that it models a central bank which determines the interest rate with respect to the expected development and not to past values. Clarida et al. (1998a, p. 5) point out that this is more consistent with how central banks declare their monetary policy activity. It is called forward looking, because it takes into account the foresighted character of monetary policy, in contrast to the original Taylor rule, which is also called backward looking for this matter. In addition, the policy rule by Clarida et al. (1998a) contains the backward looking Taylor rule as a special case. If lagged inflation and output gap represent a sufficient statistic for their future development, then function (2) collapses to the original Taylor rule (cf. Clarida et al. 1998a, p. 5).

Furthermore, Clarida et al. (1998a, p. 7) state that the above form of the policy rule is too restrictive to accurately describe the progress of interest rates. They are not always adjusted immediately to full extent, because central banks smooth the adjustment to prevent destabilizing interest rate shocks and loosing credibility. For the actual interest rate Clarida et al. (1998a) propose the following form of interest rate smoothing:

$$i_t = \rho(L)i_{t-1} + (1-\rho)i_t^* \tag{3}$$

where

- i_t is the actual interest rate at time t.
- $\rho(L) = \rho_1 + \rho_2(L) + \rho_3(L^2) + \ldots + \rho_p(L^{p-1})$.
- ρ is the partial adjustment parameter, which determines the degree of smoothing.
- $\sum_{j=1}^{p} \rho_j = \rho$.
- L is a lag operator.

The final form of the policy function is therefore:

$$i_t = [\bar{i} + \gamma_\pi(\mathbf{E}[\pi_{t+k}|\Omega_t] - \overline{\pi}) + \gamma_x \mathbf{E}[x_{t+q}|\Omega_t]](1-\rho) + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \ldots + \rho_p i_{t-p} \tag{4}$$

This functional form has become very popular in the economic literature and has been used in multiple studies. It has shown to provide an increased economic performance over the original Taylor rule.

Basically the Taylor rule applies theoretically to a closed economy. The theoretical implications for a monetary policy rule in an open economy are displayed by Clarida (2009) in a two-country open economy model. The feedback relations between domestic and foreign economic variables are manifold as well as complicated and are not discussed in detail. Clarida's general results suggest that open economies put more weight on inflation targeting and less on output. On the other hand, central banks have to react to inflation shocks by smaller magnitude. In response to a higher inflation rate, a rise of interest rates will lead to an appreciation of the nominal exchange rate (as described in section 2.1.1), which damps down inflation (cf. Clarida 2009, p. 130f).

Empirically it is not controversial that the exchange rate has an impact on inflation and output and therefore influences interest rates indirectly. Thus, considering the role of the exchange rate directly in the policy function can be a reasonable approach for open economies. Especially as it has been pointed out in the previous section, that most countries do not abandon one of the trilemma goals completely. Many studies include the exchange rate in some form into the monetary policy functions. A discussion about the efficiency of exchange rate targets in policy rules can be found in Taylor (2001). As Clarida (2009, p. 131) points out, there are different ways to specify a theoretical optimal monetary policy rule, expressed in terms of the endogenous variables. It can be done with or without the exchange rate and even without the inflation rate. So in the context of the macroeconomic trilemma, monetary policy rules in the form of function (4) are still valid, typically under the assumption that a country allows its exchange rate to float and has an open capital market.

3 Implications of the literature for the research problem

The review of several studies on the macroeconomic trilemma has shown that the structure of the theoretical phenomenon empirically holds. Though, the proposition that a country has to choose two of the three trilemma goals does not. Central banks generally are able to and do choose strategies which incorporate all three components. Therefore, with regard to monetary policy it can be said, that most countries generally have at least some freedom for independent policy. The way this freedom is used by central banks has been rarely analyzed and will be a topic for this study. This presents a desirable extension to the research so far, which mainly focused on interest rate pass-through. If countries have some monetary independence, but are limited to some extent by the trilemma framework, it is interesting if there is a common way in which countries use their independence. Clarida (2009, p. 130) points out, that in a theoretical open economy model central banks put a higher weight on inflation targeting. This presents a testable hypothesis for this matter. Do open countries (i. e. with an open capital market and a floating exchange rate) put higher weight on inflation targeting than less open economies? It is also possible that a country tries to give up some capital openness and exchange rate stability intentionally to be able to target economic output more strongly (for example in the case of an expected major economic downturn). In general, a country with more monetary independence should be able to put higher weights on domestic economic goals than a country which puts higher weights on the other two trilemma components.

This research will try to find some answers on the raised questions. To analyze monetary policy a Taylor rule will be used. It has some advantages over the previous methods to investigate monetary independence. The prevalent approach to capture independence of monetary policy via interest rate pass-through suffers from two major drawbacks. First, the extent to which domestic interest rate is not determined by the base country's interest rate only displays the possibility to conduct an independent monetary policy. How this possibility is used can not by analyzed. Second, the approach can not distinguish precisely between intentional interest rate adjustments to the base country's interest rate and interest rate co-movement, which arises from business cycle linkages and common shocks. Though, the latter can be eased by using appropriate control variables. By using a Taylor rule, the first issue can be dispelled. It directly shows how policy makers adjust the interest rate subject to domestic economic targets. As described, the typical elements of the Taylor rule are the inflation rate and the output gap. However, also other possible goals for monetary policy are possible. As the trilemma suggests, the exchange rate should be considered as well. Though, Clarida (2009, p. 130f) states that there are different correct ways to specify a monetary policy rule for an open economy, with or without including the exchange rate. Thus, also the estimation of a simple Taylor rule should provide consistent results in the context of the trilemma trade-off. Nevertheless, it is advisable to control whether the results change when the exchange rate is included in the Taylor rule. The second issue is clearly resolved as well. The Taylor rule explicitly includes the inflation rate and the output gap, both business cycle related, and models the corresponding response of the interest rate.

As shown, using the Taylor rule presents a promising approach to get a more detailed view on the trilemma phenomenon. The size and significance of the estimated coefficients in the Taylor rule directly display the responsiveness of the central bank to domestic economic matters. In Mukherjee (2011) the

Taylor rule has been used before in this context. He analyzed how the capital openness influences the possibility or attempts of the central bank to control the exchange rate. In this research however, the effect of both other trilemma components on the design of monetary policy will by investigated. Therefor different states of financial integration and exchange rate flexibility have to be distinguished, to be able to analyze the corresponding differences in monetary policy. Shambaugh (2004) and Obstfeld et al. (2005) use dummy variables to organize observations into pegged and non pegged exchange rates as well as open and restricted capital markets. This clear-cut categorization has the disadvantage that it does not allow for "middle solutions" of the trilemma as they are found to be prevalent among many countries in the literature. Furthermore, it is not clear what restrictions central banks are facing regarding the trade-off relation between the trilemma variables. Aizenman, Chinn, and Ito (2008) suggest that there is a linear trade-off between the trilemma variables. Herwartz and Roestel (2010) on the other hand find, that with a more sophisticated approach there is evidence for nonlinearities in their relationship. Durringer (2009) supports this finding and states that some countries achieve an overall better trilemma performance than others. Thus, an approach as in Shambaugh (2004) can only be a first benchmark for the estimation. Generally, a more flexible approach as in Herwartz and Roestel (2010) is preferable to get a more detailed insight in the relation between the macroeconomic trilemma and monetary policy.

Because the distinguishing of different states of the macroeconomic trilemma requires a large number of observations, a panel model approach is used in this study. Of course it can not be assumed that different countries conduct an exactly equal monetary policy, even besides the differences arising from different trilemma strategies. Nonetheless, significant differences between the coefficients of the Taylor rule in a panel model for different trilemma configurations can be seen as a consistent measure for patterns in monetary policy for open economies. To ensure that monetary policy is as similar as possible among the used countries, only industrialized countries and observations after 1980 are selected for the data sample. As reviewed in section 2.1.4, developed countries show similar patterns in their trilemma strategies over the recent past. Furthermore, they generally have independent central banks, which focuses on price stability.

In a first step, a Taylor rule will be estimated separately for each country in the data sample to compare the policy coefficients and analyze whether patterns can be identified, which can be traced back to the trilemma setup. Therefore, averages of different trilemma measures for the countries are presented. Then, a dynamic panel model is applied on the Taylor rule with interaction dummy variables to distinguish between different trilemma strategies. This model serves as a benchmark for the third approach, where a Taylor rule is estimated in a functional coefficient model, based on the approach by Herwartz and Roestel (2010). This method provides the ability of a highly differentiated analysis of monetary policy in the context of the macroeconomic trilemma.

In previous studies different measures for the three trilemma components have been applied. To some extent these measures differ considerably. To get robust results of the influence of exchange rate flexibility and capital openness on monetary policy, approaches from different studies will be applied and compared. A detailed variable definition and discussion is given in the next section.

4 Taylor rule for single country regressions - Patterns by attributes?

For the empirical analysis of the monetary policy in the single countries, a baseline specification of a backward looking Taylor rule like in function (1) and a forward looking Taylor rule in the form of function (4), as suggested by Clarida et al. (1998a, p. 4ff), will be used and compared. Therefor the models will be transferred into computable empirical models.

4.1 Empirical models

4.2 The backward looking Taylor rule

The backward looking Taylor rule in function (1) can be reshaped in the following form:

$$i_t^* = \bar{i} + (1 - \gamma_\pi)\overline{\pi} + \gamma_\pi \pi_t + \gamma_x x_t \tag{5}$$

To be able to get a consistent estimation, interest rate smoothing as shown in function (3) is applied to function (5). Furthermore, a disturbance term is added to the function. It captures unsystematic interest rate movement. Clarida et al. (1998a, p. 7f) explain the origin of the disturbance with two arguments. First, it displays temporary deviations from the systematic monetary policy rule by the central bank. This can arise from diverse economic shocks or a lack of political independence of the central bank. It is also possible that the central bank is following its policy rule but does not have perfect control over the interest rates. This might be the case, if the demand for central bank reserves suddenly rises and interferes with the ability to handle this demand, while keeping the interest rate at the desired target.

The empirical model for function (5) with interest smoothing and a disturbance term can be written as:

$$i_t = [\bar{i} + (1 - \gamma_\pi)\overline{\pi} + \gamma_\pi \pi_t + \gamma_x x_t](1 - \rho) + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \ldots + \rho_p i_{t-p} + \upsilon_t \quad (6)$$

This function can be estimated using an ordinary least squares (OLS) regression. The disturbance term υ captures unsystematic shocks on the interest rate, so it is appropriate to assume that it is independent and identically distributed (iid) and uncorrelated with the regressors. Therewith, the model meets the assumptions for an OLS regression and can be estimated in the following form:

$$i_t = \beta_0 + \beta_\pi \pi_t + \beta_x x_t + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \ldots + \rho_p i_{t-p} + \upsilon_t \quad (7)$$

with:

- $\beta_0 = [\bar{i} + (1 - \gamma_\pi)\overline{\pi}](1 - \rho)$
- $\beta_\pi = \gamma_\pi(1 - \rho)$
- $\beta_x = \gamma_x(1 - \rho)$

For simplicity the model follows the common approach that the inflation rate target $\overline{\pi}$ and the equilibrium interest rate $\bar{i}$ are both constant over time as in Clarida et al. (1998a, p. 4). The number of lags of the interest rate in the equation depend on how strong a central bank is smoothing the interest rate adjustment. If the lags are not considered correctly, the estimated residuals υ tend to show first order autocorrelation (cf. Kuzin 2006, p. 1674).

To test whether central banks consider exchange rate deviations from its trend level and interest rate differentials from the base country's interest rate when they determine the interest rate, a specification which includes additional explanatory variables is also estimated. The Taylor rule is then written as:

$$i_t = \beta_0 + \beta_\pi \pi_t + \beta_x x_t + \beta_\varrho \varrho_t + \beta_\tau \tau_t \rho i_{t-1} + \upsilon_t \tag{8}$$

where:

- ϱ_t is the deviation of the exchange rate from its long-run trend.
- τ_t is the difference of the domestic real interest rate and the real interest rate of the base country.
- $\beta_\varrho = \gamma_\varrho(1 - \rho)$
- $\beta_\tau = \gamma_\tau(1 - \rho)$

The measures for the exchange rate deviation from its trend level and the real interest rate differential are described in detail in the next section on data and definition of variables. This approach is analogous to the additional variables in the policy rule estimation by Mukherjee (2011, p. 5). Their use is motivated by the attempt to capture the practice of central banks in the face of an open capital market and maintaining a stable exchange rate. Theoretically, if the exchange rate is above (below) its trend, a central bank which tries to stabilize the exchange rate has an incentive to raise (lower) the interest rates to strengthen (weaken) the domestic currency. To avoid exchange rate fluctuations in the first place, a central bank can also react directly to interest rate differentials with respect to the base country (cf. section 2.1.1).

4.3 The forward looking Taylor rule

Additional to the backward looking version, also a forward looking Taylor rule on the basis of Clarida et al. (1998a, p. 4ff) will be estimated. Forward looking Taylor rules have shown a better econometric performance for explaining monetary policy. However, the comparison of both variants provides a useful robustness analysis for the results. Furthermore, both variants are needed in the following sections. Therefore, it is required to ensure comparability of their results.

As for the backward looking Taylor rule, the time invariant components of function (4) are gathered and a disturbance term is added:

$$i_t = [\bar{i} - \gamma_\pi \bar{\pi} + \gamma_\pi \mathbf{E}[\pi_{t+k}|\Omega_t] + \gamma_x \mathbf{E}[x_{t+q}|\Omega_t]](1-\rho) + \rho_1 i_{t-1} + \ldots + \rho_p i_{t-p} + \upsilon_t \quad (9)$$

To be able to estimate this monetary policy rule, the terms $(1-\rho)\gamma_\pi \pi_{t+k}$ and $(1-\rho)\gamma_x x_{t+q}$ are added and subtracted from function (9). Thus, the model can be rewritten as:

$$i_t = [\gamma_0 + \gamma_\pi \pi_{t+k} + \gamma_x x_{t+q}](1-\rho) + \rho_1 i_{t-1} + \ldots + \rho_p i_{t-p} + \varepsilon_t \qquad (10)$$

where

- $\gamma_0 = \bar{i} - \gamma_\pi \bar{\pi}$.
- $\varepsilon_t = -(1-\rho)[\gamma_\pi(\pi_{t+k} - \mathbf{E}[x_{t+q}|\Omega_t]) + \gamma_x(x_{t+q} - \mathbf{E}[x_{t+q}|\Omega_t])] + \upsilon_t$.

The error term ε consists of the forecast errors for the inflation rate and the output gap (i. e. the difference between their actual and their expected value) as well as the disturbance term for unsystematic interest rate movements (υ). It is assumed that the forecast errors are not systematically biased and their magnitude does not vary over time. Furthermore, they are orthogonal to the variables in the information set Ω_t. The properties of υ have already been discussed for the backward looking Taylor rule. Hence, because the error term ε is a linear combination of the forecast errors and υ, ε it is iid.

The regression model in the form of function (10) can not be estimated by the OLS method. It is exposed to an endogeneity problem, because the explanatory variables π_{t+k} and x_{t+k} depend on the dependent variables i_t. Thus, they are correlated with the residual term, which is a violation of the requirements for the OLS method. To be able to estimate function (10), a vector of instrument variables $\mathbf{z}_t$ is specified, which are known when the central bank sets its interest rate i_t ($\mathbf{z}_t \in \Omega_t$). They represent the informations on which the central bank refers its decision to. The instruments are to be correlated with the regressors and uncorrelated with the residual term.[12] Then, $\mathbf{z}_t$ can be used to compute the coefficients of the forward looking Taylor rule, using the Generalized Method of Moments (GMM). The GMM is especially useful in this context, because it allows to estimate nonlinear regressions with instrument variables and does not need to make assumptions for the covariance structure of the residual term regarding heteroscedasticity and autocorrelation.[13] The moment conditions for the GMM estimator are:

$$\mathbf{E}\{[i_t - [\gamma_0 + \gamma_\pi \pi_{t+k} + \gamma_x x_{t+q}](1-\rho) + \rho_1 i_{t-1} + \ldots + \rho_p i_{t-p}]\mathbf{z}_t\} = 0 \tag{11}$$

As for the backward looking Taylor rule, the two additional variables for exchange rate deviations from its trend and real interest rate differentials with respect to the base country are added in an additional specification[14]. In contrast to the inflation rate and the output gap, informations on interest rates and exchange rates are directly available. Here it is assumed that economic agents are primarily geared to these present informations. Thus, also the central banks make their decisions with regard to them and accordingly the exchange rate gap and interest rate differential at the time t are included in the forward looking Taylor rule.

The weighting matrix used to minimize the moment conditions and the estimated standard errors are robust toward heteroscedasticity and autocorrelation in the residuals. To be able to estimate all four coefficients in function (10), at least four instruments are necessary. For this matter, three lags of the independent variables are used as instruments (i. e. nine altogether).[15] This overidentification makes it possible to test the validity of the used instruments with Hansen's J-test (cf. Greene 2003, p. 548f). Finally, the target horizon of the central bank for the inflation rate and the output gap, to which it sets the interest rate, is assumed to be one quarter ($q = k = 1$).

In the following section, the data and the variables which are used to estimate the proposed models will be explained.

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[12] Let $\beta = (\gamma_0\ \gamma_\pi\ \gamma_x\ \rho_1\ \ldots\ \rho_p)'$ be a vector of the parameters of the model and $\mathbf{x}_t$ a vector of the regressors. Then $\mathbf{z}_t$ fulfills the conditions $\mathbf{E}[\upsilon_t|\mathbf{z}_t] = 0$ and $\mathbf{E}[\mathbf{x}_t|\mathbf{z}_t] \neq 0$.

[13] For details on the GMM estimator see Hansen (1982).

[14] Analogous to (8).

[15] When exchange rate stability or capital openness are added to the equation the number of parameters increases to six and the number of instruments increases to 16.

4.4 The components of the Taylor rule and the trilemma - Data and variable definitions

4.4.1 Country and time sample selection

The basic selection criteria for the data used in this research, have already been discussed in section three. All time series have a quarterly frequency, as in many other studies on the topic (Herwartz & Roestel 2010; Clarida et al. 1998a). It offers a relatively large number of observations with enough meaningful variation in the data, while not being exposed too much to outliers of short frequency. The data set consists of data for 20 industrialized OECD countries; Australia, Austria, Belgium, Canada, Denmark, the Eurozone, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, Thailand and the United Kingdom. This choice is motivated by the attempt to gather a panel data set of countries with preferably similar economic conditions and monetary policies. In addition, there is a good availability of data for these countries. The time horizon of the data reaches from 1980:Q1 till 2008:Q4. During the 1980s many developed countries started to fight high inflation rates, prevalent in the 1970s (cf. Clarida et al. 1998b, p. 1042f). Even though not all countries officially announced inflation targeting as the major assignment for their central banks, it is assumed that monetary policy was targeted in the same direction since then. This assumption is also supported by the data for the development of inflation rates (cf. Figure 1). The cutoff after 2008 is motivated by the start of the financial crisis. It caused considerable disturbance for all economies and is therefore excluded. Of course many countries in the sample are members of the Eurozone, with a joint monetary policy by the European Central Bank (ECB). These countries are only considered until 1998:Q4, because in 1999 the responsibility for monetary policy was assigned from national central banks to the ECB.

The data used in this study is taken from the IMF's International Financial Statistics database and the datastream database. A detailed overview for the definitions, sources and symbols of the variables is given in Table 4. The single country regressions and the panel regressions in the following sections are estimated using STATA 11.2, while the functional coefficient model in the last section is estimated in GAUSS 10.

4.4.2 The Taylor rule variables

For the basic Taylor rule, data for the interest rate, inflation rate and the output gap are needed. As a proxy for the short-term nominal interest rate, the policy instrument of the central bank, the money market rate or, if not available, the treasury bill rate is used. Actual policy rates are frequently not available and these two interest rates are commonly used for this purpose (see for example Obstfeld et al. 2005, p. 425; Mukherjee 2011, p. 5; Herwartz & Roestel 2010, p. 6). Inflation is measured via the change of the consumer price index (analogous to Clarida et al. 1998a, p. 1045). For the output gap the difference of the real gross domestic product (GDP) index and its trend is estimated. The trend displays the potential output and is calculated using the Hodrick-Prescott (HP) filter with 1600 for the smoothing parameter, as suggested by Hodrick and Prescott (1997, p. 4). To avoid inaccurate trend determination at the beginning and the end of the time series pre- and post-sample observations are used for its estimation. Where no data was available for the real GDP index, the few missing observations were filled with data on the industrial production index. For some countries there are breaks in the output time series, mostly because new base years for the index estimation. To avoid incorrect estimations of the HP trends, the HP filter is applied before and after the breakpoints. The trend is recomposed thereafter, to get a time series without the breakpoint.[16] The data on output and inflation is seasonal adjusted. For some countries no seasonal adjusted time series were available. For those the adjustment was carried out manually, using the Tramo-Seats method in Eviews 5.0 (Gomez & Maravall 1996, cf.). Finally, single observations with strong outliers for interest rates for single countries were dropped. Most of those interest rate spikes seem to be associated with the European currency crisis in the mid nineties.

The extended specifications for the Taylor rule also comprehend variables for an exchange rate gap and the real interest rate difference with respect to the base country. The former is measured as the deviation of the exchange rate from

[16] Thus procedure has to be applied to Austria, Belgium, Germany, Ireland, Italy and New Zealand.

its long-run trend. Hereby, the exchange rate is defined as the units of domestic currency per one unit of the base country's currency. Its trend is again computed using an HP filter with 1600 for the smoothing parameter. If countries try to peg or stabilize their exchange rate, the trend of it can be seen as an approximation of the targeted exchange rate level. If the exchange rate is above (below) its trend, it indicates that the domestic currency's value is lower (higher) than desired. The real interest rate differential is estimated as the difference between the domestic (i) real interest rate and its counterpart from the base country j, where the real interest rate is the nominal interest rate minus the inflation rate. The two variables are written as:

$$\varrho_{it} = e_{ijt} - e_{ijt}^{HP} \tag{12}$$

resp.

$$\tau_{it} = (r_{it}) - (r_{jt}), \tag{13}$$

where:

- e_{ijt} is the exchange rate, defined as the units of domestic currency from country i per one unit of the base country's (j) currency.
- e_{ijt}^{HP} is the HP trend of e_{ijt}.
- r_{it} is the real interest rate in country i at time t.
- $r_{it} = (i_{it} - \pi_{it}^{e})$, where π_{it}^{e} displays the inflation expectations in time t. It is approximated by the annual CPI inflation rate (π_t), assuming static formation of expectations.

Henceforth, the subscript i denotes the domestic country, while j denotes the associated base country. For the choice of the associated base country for the analyzed countries this study follows the approach by Shambaugh (2004, p. 13f, 44f: Table XI). He uses official peg classifications of countries and, if these do not exist or do not match with the actual exchange rate, judgment by reference to historical regional dominant countries. For all European countries the base country is Germany. For all other countries, Germany and the Eurozone it is the USA, except for New Zealand, which is assigned to Australia.

Further, the subscript t denotes the time index of variables. As this study uses data on a quarterly frequency, it refers to the current quarter. However, some of the variables use data on a monthly or annual frequency. For those variables the subscripts m resp. y are used.

4.4.3 The trilemma variables

To be able to identify possible patterns among the estimated policy parameters, averages of different trilemma variables of the countries will be presented in connection with the regression results. The trilemma variables are taken from Aizenman et al. (2008), whose approach has also been used in many other studies, and from Herwartz & Roestel (2010). These studies provide commonly used measuring methods which are nevertheless sufficiently different to supply additional informations. Furthermore, their definition is suitable for the latter estimations.

Herwartz & Roestel (2010) define exchange rate flexibility as the sum of squares of the differential of the log of the exchange rate between country i and the associated base country j for all month m in the previous quarter t:

$$\varphi_t^{fx} = \sum_{m \in t-1} (\Delta \ln e_{ij,m})^2. \tag{14}$$

Higher values indicate a less stable exchange rate. This kind of approximation of exchange rate flexibility is used in most studies on the macroeconomic trilemma. Though, it is not without controversial. The lack of variation in the exchange rate can be a result of active stabilization policy, but it can also result from a lack of shocks on the exchange rate. This can be addressed by controlling if the exchange rate variation is associated with active use of policy variables. Though, it will be analyzed whether the exchange rate flexibility influences the monetary policy, it is problematic to simultaneously test whether the flexibility is a result of monetary policy (cf. Levy-Yeyati & Sturzenegger 2005, p. 1606f; Shambaugh 2004, p. 13).

The measure for exchange rate flexibility by Aizenman et al. (2008) is based on the annual standard deviation of the monthly exchange rate. It is normalized to an index between zero and one, using the following formula:

$$\iota_{it}^{FX} = \frac{0.01}{0.01 + \sigma(\Delta(log\ e_{ij}))}. \tag{15}$$

Higher values of the index indicate a more stable exchange rate. As suggested by Aizenman & Ito (2012, p. 15f) this measurement is adjusted with regard to some conditions by Shambaugh (2004, p. 14) to prevent a downwards bias towards overrated flexibility. First, if the exchange rate stays in a small band it is considered as fixed and the value one is assigned. The same applies, when the exchange rate stays totally fixed in eleven out of twelve month. Finally, if there are two re- or devaluations in three months, then they are considered as one event, and if the remaining ten months experience no exchange rate movement, then that year is considered to be a year of fixed exchange rate.

The measures for the openness of the capital market are substantially different from each other. In Herwartz & Roestel (2010) capital openness is estimated as the squared differential of the real interest rate in country i and the real interest rate in the associated base country j. The idea is based on the concept of real interest rate parity (Pipatchaipoom & Norrbin 2006, p. 3). Ceteris paribus countries with high financial integration should experience a smaller real interest rate difference to other countries. The variable is written as:

$$\varphi_{it}^{cap} = (r_{it-1} - r_{jt-1})^2. \tag{16}$$

This is a more indirect approach to approximate capital mobility than the one of the capital openness index by Chinn & Ito (2006, 2008), which is most commonly used in other studies. It is based on the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions. The index exploits informations on reported "multiple exchange rates, restrictions on current account transactions, on capital account transactions, and the requirement of the surrender of export proceeds" (Aizenman et al. 2008, p. 7). The original values are normalized to an index between zero and one, where higher values indicate more capital openness.[17] Unfortunately, it is only available at an annual fre-

[17] The original index has a range from -1.83 to 2.5. It is normalized by subtracting the minimal from the actual value, divided by the range of the index.

quency.[18] Since both variables offer a very different measure, both will be used and compared.

In most studies, monetary policy independence is analyzed by the central bank's ability to set the interest rate independent of the interest rate in the base country. Aizenman et al. (2008) try to capture this classification via an index, based on the correlation between the interest rates. It is defined as:

$$\iota_{iy}^{MI} = 1 - \frac{corr[i_{iy}, i_{jy}] - (-1)}{1 - (-1)}. \tag{17}$$

The index ranges from zero to one as well, where higher values indicate more monetary independence. Even though monetary policy is modeled directly in this study, this index will be used in single country regressions to analyze whether higher coefficients are associated with higher monetary independence.

4.5 Descriptive statistics and time series analysis

Before turning to the regression analysis, a closer look on the data is important to get an overview on the characteristics of the different variables. In Table 2 a histogram is given for the pooled data of the variables used for the Taylor rule estimation. Is is noticeable that the data for the output and exchange rate gap as well as for the real interest rate differential are very symmetrically distributed. For the former two this is not surprising. They are estimated as the variables deviation from a flexible trend, which should be symmetrical by construction. That the real interest rate differential is also centered symmetrically around zero indicates, that the countries in the sample generally try to keep a similar interest rate level. This could be done intentionally, when countries orientate themselves at the interest rate condition of a base country, or when countries face similar business cycles. In any case it is in line with the findings on previous studies on interest rate co-movements. As seen by the histogram as well as the mean in Table 5, there seems to be a tendency for more allowance for positive differences, i. e. for a higher interest rate than in the base country. For example this could

[18] The capital openness index for many countries is updated frequently and can be downloaded free of charge. Unfortunately, it is not available for the Eurozone.

Table 1: Mean of variables by decade

	1980s	1990s	2000s	Overall
Interest rate	10.61	6.73	3.45	7.09
Inflation	6.70	2.64	2.27	3.89
Output gap	0.017	-0.095	0.42	0.11
Exchange rate gap	-0.002	-0.009	0.004	-0.004
Real interest rate difference	0.13	1.22	0.02	0.49
Exchange rate flexebility	0.0011	0.0009	0.0011	0.0010
Exchange rate stability index	0.65	0.65	0.53	0.62
Capital openness	0.45	0.20	-0.20	0.21
Capital openness index	0.65	0.88	0.91	0.79
Monetary independence index	0.44	0.46	0.45	0.45

be explained with a generally lower risk premia in base countries.

⟨*Figure 2 and table 5 here*⟩

The inflation rate and more so the interest rate are not symmetrically distributed. Both distributions have tails toward high values. This results mainly from the data in the 1980s. Back then many countries were still engaged with bringing down high inflation from the 1970s. Table 1 gives an overview for the mean values of the variables per decade. It shows that inflation and interest rates have been substantially reduced since then. Additionally, their volatility became lower. This indicates that in general monetary policy was able to stabilize the price development in the analyzed countries.

The downward trend for inflation and interest rate leads to a common problem in the estimation of monetary policy rules; the question whether the time series are stationary or not. Theoretically, interest rates are bounded from below by the value zero and it is also not reasonable to assume that they can rise to infinity. Therefore they can not be pure unit root processes. Nevertheless, in finite samples unit roots can often not be rejected. Table 6 presents the results of the Augmented Dickey Fuller (ADF) test for the inflation and interest rate.

While for the inflation rate a unit root can be rejected for 15 from 20 countries, the interest rate is only tested as stationary for two countries. However, many studies point out the low power of unit root tests. Following Clarida et al. (1998a, p. 9), for the single country regression it will be assumed that the interest rate time series are stationary.[19] For the later regressions corresponding panel unit root tests suggest that the issue is eased in the panel framework. The variables output and exchange rate gap are tested to be stationary for all countries, as it is expected with regard to their construction. For the interest rate differential the ADF test barely fails to reject the presence of a unit root for five countries. Here stationarity is assumed as well, referring to the low power of the ADF test.

To be able to compare the estimated policy coefficients with the trilemma setup of a country, the mean of five trilemma variables for each country is displayed in tables 7 and 8. The distribution of the variables is given in the histograms in table 3.

⟨*Figure 3 here*⟩

The two measures for exchange rate flexibility indicate that the countries in the sample generally have a stable exchange rate. For the variable exchange rate flexibility the majority of the values is concentrated at almost zero and shows little variation.[20] The exchange rate stability index on the other hand reports the value one for most countries and thereby stable exchange rates as well, but has more variation over the range of the lower values. The mean of the two variables does not change considerably over time. In connection with the means by country in the regression tables, this shows that countries have chosen different strategies regarding this element of the trilemma configuration.

Openness of capital markets shows some amount of variation for both measures. Further, both variables indicate a significant change over time toward very high openness, indicating that financial integration is a general trend for all countries in the sample. But again, there are differences between the countries. Despite of the general trend countries seem to have chosen different practices for

[19]It is also reasonable to assume that some of the non-stationarity is captured by possible cointegration between the inflation rate and the interest rate, in spite of the fact that the ADF test suggest a different level of integration.

[20]There are some single outliers for the exchange rate flexibility variable. Since they seem to be random over countries and time those values over 0.04 are dropped for the analysis (less then ten overall).

this field as well.

Finally, the index for monetary independence shows a very short range of values. The majority of the data lies between 0.4 and 0.5. This is also true over time and between countries. If interest rate co-movement captures the degree of independence of monetary policy correctly, this indicates that the countries all have a similar amount of freedom for sovereign policy. The development over time is contrary to the results of Aizenman et al. (2008, p. 57). They find that industrialized countries experienced a drop of monetary independence until the mid-'90s to a value between 0.1 and 0.2. Table 2 presents the correlation be-

Table 2: Correaltion between trilemma variables

Variables	φ^{FX}	ι^{FX}	φ^{cap}	ι^{cap}	ι^{MI}
φ^{FX}	1.00				
ι^{FX}	-0.4	1.00			
φ^{cap}	0.08	-0.13	1.00		
ι^{cap}	0.10	-0.23	-0.22	1.00	
ι^{MI}	0.11	-0.22	0.08	0.01	1.00

tween the different trilemma variables. A comparison of the variables shows that the exchange rate stability index on one hand and the exchange rate flexibility variable on the other hand clearly measure the same. Although, as correlation is significantly smaller than one, the different definitions of the variables seem to produce varying information from their basis; the change of exchange rate. Because the index assigns high values to stability, whereat for the other variable this indicates higher flexibility, the correlation is negative. For the variables for capital openness the correlation is much lower. This is not surprising, since the idea behind the measures is a different one. Still the correlation lies at 0.22, indicating that the information in both measures points in the same direction.

The correlation matrix contributes only limited information for the relationship between the trilemma components. The correlation between the exchange rate stability index and the capital openness variables indicate that there is some amount of trade-off between the two. Yet, this is not supported by the exchange rate flexibility variable. For the monetary independence index, little connection is found with capital openness, but exchange rate stability is negatively correlated to a certain extent. These results of the correlation analysis can be confirmed by the comparison of the means of the variables for the different countries (see table 7). In general countries with a monetary independence above the average show lower exchange rate stability (e. g. Germany, Japan, Australia). On the contrary, very high exchange rate stability is associated with lower monetary independence (e. g. Austria, Belgium, Netherlands). For the openness of capital markets the overview does not show a clear pattern in connection with monetary independence. But the trade-off with exchange rate stability can be observed in some cases (e. g. UK, Japan, New Zealand).

4.6 Estimation results

The results for the single country regressions on the basis of the Taylor rule specifications (7), (8) and (10) are presented in table 7 and 8. Estimating separate Taylor rules for the countries, before the connection of the policy parameters with the trilemma components is econometrically analyzed, is of use for three reasons. First, it provides a differentiated overview for the data characteristics, before the data is pooled together. Second, the comparison of the results with the different trilemma configuration of the countries allows a first descriptive analysis of possible relationships between monetary policy and the trilemma components. This is a good benchmark for the later panel estimations. Finally, it can be analyzed whether the approach of pooling the data is useful at all. If monetary policy would be fundamentally different across the countries, it would be inappropriate and senseless to apply a panel model on the data (cf. Shambaugh 2004, p. 25).

⟨*Table 7 and table 8 here*⟩

Table 7 provides the results for the backward looking Taylor rule estimation by OLS. The regression model includes only one lag of the dependent variable for interest rate smoothing, although the Durbin Watson (DW) statistic in the table indicates first order autocorrelation for over the half of the regressions. However, adding two or three lags does not seem to solve this problem. Especially the second specification with additional explanatory variables suffers from serial correlated residuals. Therefore, the results must be treated with caution. The forward looking GMM regression performs better in this regard.

The estimated coefficients show the expected signs and reasonable values. Structural policy parameters can be calculated by dividing the corresponding β by $(1-\rho)$. Below the test statistics the structural inflation parameter is presented. It is generally greater or near one. The output gap coefficient is positive in all estimations. Both matches the theoretical expectations as discussed in section 2.2. The parameters are mostly tested to be significant different from zero, but as many regressions have autocorrelated residuals, the reported significance levels for the parameters are not always reliable. For the smoothing parameter values between 0.8 and 0.9 are reported for the most part. Accordingly, only 20 to 10 percent of the change of the interest rates is assigned to the interest rate target i^*. This is in line with the results from other empirical studies with quarterly data (for example Clarida et al. 1998b, p. 1045ff).

The effect of exchange rate deviations is not clear among the analyzed countries. For exchange rate stabilization it would be theoretically expected, that if the exchange rate is above (below) its trend (i. e. the value of the currency is lower (higher) than desired), the central bank raises (lowers) the interest rate to adjust the exchange rate. Of course this requires that the exchange rate is actually a target of the central bank and that the central bank has the monetary independence as well as the necessary power to influence the exchange rate. However, of the estimated coefficients, eight show a positive sign (3 significant) whereas twelve are negative (4 significant). The prevailing negative coefficients are found as well in the forward looking specification and are counterintuitive at first sight, because it encourages a presumably undesired trend. However, a possible explanation lies in the exchange rate's counterpart for the base country. A domestic exchange rate, which lies above its trend, might indicate that the currency of the base country is stronger than desired. If the central bank in the base country decides to lower the interest rate in face of the low exchange rate, it can be better for small countries to go along with the higher interest rate, because they would experience a massive appreciation if they would try to lean against the base interest rate. For the real interest rate differential most countries have a positive sign,which is also often significant. As for the exchange rate deviation this is not the expected sign, as positive sign implies a reaction on interest rate differences which does intensify prevailing disparities.[21]

[21] It must be pointed out, that the counterintuitive results for the two variables can arise from

The $\mathbf{R}^2$ suggests a high explanatory power of the model specifications (over 0.9 for the most). The specifications with the additional explanatory variables do not much gain for the $\mathbf{R}^2$. However, the information criteria by Akaike and Bayes (AIC, BIC) favor this specification for most countries.

As mentioned, the DW statistic indicates first order serial correlation for many of the OLS regressions. The GMM regressions perform better in this regard. A Portmanteau test (Q statistic) only rejects the null hypothesis of no autocorrelation in 14 of the 40 regressions. Again, additional lags of the interest rate did not eliminate this issue in most cases. Hence, only one lag is considered in the regressions as well. Previous research has found, that forward looking monetary policy rules are able to capture monetary policy more accurately. In addition, the structural policy parameters can be estimated directly. Thus, the estimated results are more reliable. For the most part the GMM regressions supports the findings from the OLS estimations.[22]

The parameter for inflation is almost always significant positive and greater or near one. The output gap on the other hand is only significant in half of the regressions. Interest rate smoothing is generally found to be significant in a range between 0.7 and 0.95. Negative values for exchange rate deviations are even more dominant than in the backward looking models. In 16 of the regressions it is negative, whereof six are significant. Finally, interest rate differentials are significant positive for ten countries and negative coefficients are always found to be insignificant. Further, the values are often very high (in three times greater than 1 and additional three times greater than 0.9). The Hansen J-test on overidentifying restrictions suggests that the used lagged variables are appropriate instruments for the estimation by GMM.

From the three countries with a significant positive parameter for exchange rate deviations, Austria and the Netherlands show noticeable high values. These outliers can might be explained by the range of values for this variable. Both

an endogeneity problem. The parameter signs could be explained by the impact of the interest rate on the variables. Ceteris paribus, a raising interest rate leads to a positive change of the interest rate differential and a negative for the exchange rate. The parameter signs do also not change for the forward looking Taylor rule, where the variables are instrumented. Overall, other variables should also be taken into account to get a better idea on the influence of foreign interest rates and the exchange rate in monetary policy rules.

[22]The GMM regressions for Thailand do not converge and can not be presented for this reason.

countries present a mean of -0.0001 for it and have very low absolute values for minimum and maximum. This indicates, that they are very stable pegs and show an instant and strong reaction toward exchange rate deviations. The high coefficient value is maybe a result from the low values margin. This is also supported by the exchange rate stability variables. They report a near maximal value for stability.

It is puzzling as well, that the policy rule estimations for the ECB show insignificant and even negative coefficients for the inflation rate. The ECB is known to have a structural inflation target. But as it was implemented in an era of stable prices, this result can be an outcome of a lack of variation in the inflation data for the sample.

One objective of the analysis of the single country regressions was to analyze whether the country sample is suited to be pooled to a panel dataset. From a descriptive point of view this can be approved. The results suggest that the countries pursue an inflation targeting monetary policy and also pay attention to the output gap. Further, interest rate smoothing is applied on a similar level. Regarding exchange rate deviations and interest rate differentials, results are mixed between countries. Moreover, their effect is often counterintuitive. However, the impact on other coefficients seem to be small for the most part, which indicates that their consideration or exclusion from the estimation does not influence the consistence of the model. For the comparably of the forward and the backward looking Taylor rule variants, the results seem to be robust with regard to the estimation technique. Although, there are some differences, the estimates are overall quite similar.

The second objective was to check if connections between policy parameters and the trilemma variables can be found. This turns out to be complicated on a purely descriptive basis. For most connections there can also be found counterexamples. This does not come as a surprise, as trilemma strategies and monetary policy can be arranged in divers and complex variations. Especially domestic policy targets can be hardly linked with exchange rate stability or capital openness using this raw practice. This supports the approach of this study that the analysis should be carried out using a differentiated method. For exchange rate deviations and interest rate differentials on the other hand some patterns can be identified. Four of the six countries with significant negative coefficients for exchange rate deviations have a relative flexible exchange rates. A possible explanation would be, that these countries do not follow a tight exchange rate target. The reaction on interest rate differentials can be linked to two different variable characteristics. Four countries with a significant positive parameter have a relative low capital openness (AUS, ITA, NOR, SWE). Three other countries have a very high exchange rate stability (BEL, DEN, NEL). For the latter the strong response to the base interest rate can be a strategy to maintain high exchange rate stability. The connection to lower capital mobility is not initially intuitive and might be related to the discussed argument that following the base interest rate is not necessarily immediately stabilizing the exchange rate. Rather it reflects fear of floating, while directly reactions on exchange rate deviations are a sign of serious pegging. however, as the effect of the interest rate differential is not as expected, the implications should be treated with caution.

The monetary independence index will not be of further interest in this study, since monetary policy is modeled directly. Still, for the descriptive analysis it can be noted that higher values are associated with relative high significant coefficients for inflation or output gap, even though the values for the index are very similar among the countries. Apparently, the ability to conduct an active monetary policy is associated with monetary independence.

5 A benchmark for monetary policy under different trilemma strategies – A panel model analysis of the Taylor rule

A proper econometric analysis of the macroeconomic trilemma requires a large number of observations. Otherwise it is not possible to identify patterns in the data. Therefore, the data used for the separate regressions is pooled together to a panel dataset. For panel data models it is required that the coefficients of the investigated relationships are identical over all countries. The descriptive analysis of the single country regression results suggests, that this requirement is fulfilled to a necessary degree. The countries seem to conduct a related monetary policy. However, when a Roy-Zellner test on poolability is applied to the data, as suggested by Baltagi (2001, p. 56ff) and described in Vaona (2008), it just barely rejects the equality of the coefficients. As policy differences with respect to the macroeconomic trilemma are the research object of this study, this does not contradicts the panel approach. On the contrary, equality would likely imply that the countries are too similar to identify those differences. It can be seen as a verification of the choice of countries, that the test on poolability fails, but fails just barely. Additionally, there already have been some allusions to the trilemma variables with regard to differences in among the parameters. By all means, the use of a panel model constitutes a reasonable approach to investigate the research problem of this study.

5.1 Development of an empirical panel model

To identify structural differences in monetary policy which are related to the macroeconomic trilemma, the forward looking Taylor rule, analogous to the single country specifications, is used for the panel regressions. Two examples for panel data studies on monetary policy rules can be found in Mukherjee (2010) and Belke & Potrafke (2009).[23] Both point to the problem of the lagged dependent variable as a regressor in the model, which makes it a dynamic panel model. In dynamic panel models, lagged dependent variables tend to be correlated with the residual term. As described in Baltagi (2001, p. 129ff), this leads to biased estimates of the parameters for fixed effects (FE) and random effects (RE) models. In a simple dynamic panel model with RE in the from of:

$$y_{i,t} = \delta y_{i,t-1} + \beta x_{i,t} + u_{i,t} \qquad i : 1, \ldots, N; t : 1, \ldots, T, \tag{18}$$

with:

$$u_{i,t} = \mu_i + \nu_{i,t} \tag{19}$$

where μ_i $IID(0, \sigma_\mu^2)$[24] and $\nu_{i,t}$ $IID(0, \sigma_\nu^2)$. It can be easily seen, that when $y_{i,t}$ is a function of μ_i, the same is true for $y_{i,t-1}$. Hence, $y_{i,t-1}$ is correlated

[23]Belke & Potrafke (2009, p. 27ff) present a survey with some previous studies on monetary policy, which used panel approaches for the Taylor rule.

[24]μ_i varies randomly among individuals but not over time. It captures unsystematic heterogeneity among the individuals.

with the residual term of the model. Also in a FE model this problem persists, even though a within transformation eliminates μ_i from the equation.[25] The within transformed lagged dependent variable is computed as $(y_{i,t-1} - \overline{y}_{i,-1})$, where $\overline{y}_{i,-1} = \frac{1}{T-1}\sum_{t=2}^{T} y_{i,t-1}$. Analogous the within transformed residual is written as $(\nu_{i,t} - \overline{\nu}_i)$. The average over all residuals $\overline{\nu}_i$ contains $\nu_{i,t-1}$ as one element; the residual term of the untransformed panel model in $t-1$. Hence, the lagged dependent variable, which contains $y_{i,t-1}$, and the residual term, which contains $\nu_{i,t-1}$, are correlated by construction. Of course this correlation vanishes as the observations over time rise. The remaining bias for the estimates with regard to the observations over time is called the Nickell-Bias (Nickell 1981). Belke & Potrafke (2009, p. 16) refer to the Nickell-Bias and the large size of T in their study to justify their use of a simple FE model. Mukherjee (2010, p. 7) on the other hand uses data on a yearly frequency and therefore decided to apply a panel data estimation method developed by Arellano & Bond (1991), which is especially suited for panel datasets with a small T and eliminates the correlation between residuals and explanatory variables.

5.1.1 Dynamic panel model estimators

In this study observations per country normally lie between 70 and 110. By means of panel data analysis this numbers can be referred to as high. Nevertheless, a dynamic panel model estimator will be used for the regressions, to avoid possibly biased estimators.[26]

There are different methods besides the one by Arellano & Bond (1991). An overview for estimation techniques can be found in Baltagi (2001, p. 1329ff). The idea and practical application of two popular estimators – the already mentioned AB estimator and an estimator outlined by Arellano & Bover (1995) and fully developed by Blundell & Bond (1998) – is given in Roodman (2006).[27] In the following, a short review of the principals behind the two estimators is given.

[25] Note that in the FE model μ_i is no more the individual specific part of the residual term, but a individual specific constant.

[26] As pointed out by Judson & Owen (1999, p. 7ff) estimators can still be substantially biased even for a higher T.

[27] Roodman (2006) also describes the Stata command `xtabond2`, which implies these regression techniques and is used for the estimations in this section.

Even though only the second estimator will be used, the description of the AB estimator offers the foundation for it and provides a more intuitive introduction for the principal idea of dynamic panel estimators.

The principal idea behind the AB estimator is to take the first difference of a dynamic panel model in levels like in equation (18). This eliminates the individual specific effect and the model can be written as:

$$\Delta y_{i,t} = \delta \Delta y_{i,t-1} + \beta \Delta x_{i,t} + \Delta \nu_{i,t} \qquad i : 1, \ldots, N; t : 1, \ldots, T. \tag{20}$$

Then the AB estimator uses lags of the explanatory variables in levels as instruments for the regressors in first differences to avoid correlation between $\Delta y_{i,t-1}$ and $\Delta \nu_{i,t-1}$. Theoretically the number of lags that can be used as instruments increases with each additional observation. The AB estimator uses this approach, which renders him especially useful for panel datasets with small T and large N. As for the Taylor rule equation, other regressors are not always strictly endogenous but predetermined. This means, they are correlated with past realizations of the residual term.[28] In this case these regressors must be instrumented with appropriate lags as well, because $\Delta \nu_{i,t}$ includes the first lag of the residual term which would lead to an endogeneity problem. The instruments are then used for a GMM estimation of the differentiated model (cf. Baltagi 2001, p. 131ff):

$$W'\Delta y = W'\Delta y_{-1}\delta + W'\Delta X\beta + W'\Delta\nu, \tag{21}$$

where y is a vector of the dependent variable, y_{-1} is a vector of the lagged dependent variable, X is a matrix of exogenous and predetermined explanatory variables, ν is a vector of the residual term and $(\delta\ \beta)'$ is a vector of parameters. The GMM estimator for $(\delta\ \beta)'$ is then writen as:

$$\begin{pmatrix} \hat{\delta} \\ \hat{\beta} \end{pmatrix} = ([\Delta y_{-1}, \Delta X]' W V^{-1} W' [\Delta y_{-1}, \Delta X])^{-1} ([\Delta y_{-1}, \Delta X]' W V^{-1} W' [\Delta y]), \tag{22}$$

where $W = (W_1' \ldots W_N')'$ is the matrix of instruments and $V = W'(I_N \otimes G)$". W_i

[28] Shocks in the past had an influence on the interest rate. This again effects the regressors of the equation (inflation, output gap, exchange rate).

has the form:

$$\begin{pmatrix} (y_{i1}, x'_{i1}, x'_{i2}) & & & & 0 \\ & (y_{i1}, y_{i2}, x'_{i1}, x'_{i2}, x'_{i3}) & & & \\ & & . & & \\ & & & . & \\ & & & & . \\ 0 & & & & (y_{i1}, ..., y_{iT-2}, x'_{i1}, ..., x'_{iT-1}) \end{pmatrix}.$$

$(I_N \otimes G)$ refers to the structure of the variance matrix of the differenced residual term $(E[\Delta\nu_i \Delta\nu_i'] = \sigma_\nu^2 (I_N \otimes G))$.[29] The matrix G has the form:

$$\begin{pmatrix} 2 & -1 & 0 & ... & & 0 & \\ -1 & 2 & -1 & ... & & & \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ & & & ... & -1 & 2 & -1 \\ & 0 & & ... & 0 & -1 & 2 \end{pmatrix}$$

The AB estimator has one disadvantage, pointed out by Blundell & Bond (1998, p. 120ff). When the dependent variable of the regression is close to a random walk, lagged explanatory variables in levels perform poorly as instruments for the regressors in difference in the model. To increase the efficiency of the estimation they developed an estimator, where the explanatory variables are kept in levels and the instruments are transformed in differences. This approach does not eliminate the fixed effects (μ_i) from the model like for the AB estimator, it makes the instruments exogenous to them. Technically, if ω_{it} is a set of instrument variables for country i in observation t, the following condition must hold: $E[\Delta\omega_{it}\mu_i] = 0 \; \forall \; i, \; t$. This is fulfilled if $E[\omega_{it}\mu_i]$ is time invariant. The available instruments depend again on whether ω is strictly exogenous ($E[\omega_{it}\nu_{it}] = 0$), predetermined ($E[\omega_{it}\nu_{it-1}] \neq 0$) or endogenous ($E[\omega_{it}\nu_{it}] \neq 0$). In the latter case $\Delta\omega_{it-1}$ and previous lags are valid sets of instruments because neither ω_{it-1} nor ω_{it-2} are correlated with ν_{it}, given that ν is not serial correlated. Otherwise also $\Delta\omega_{it}$ can be used (cf. Roodman 2006, p. 26f).

[29] This is the one-step variant of the estimator. For the two-step estimator V is build from the estimated residuals from the one-step estimation.

The estimator for the approach by Blundell & Bond (1998) is called the *system GMM* estimator, in contrast to the *difference GMM* estimator by Arellano & Bond (1991). It is analogous to (22), whereas the variables in the equation enter in levels. Appropriate lagged differences of the explanatory variables as well as additional, in contrast to the AB estimator even time invariant, variables can be used for the instrument matrix W. The a priori estimate of the covariance matrix structure is more complicated than for the AB estimator. Here V is a block diagonal matrix of the following form:

$$\begin{pmatrix} MM' & M \\ M' & I \end{pmatrix},$$

where M is a transformation matrix and $MM' = I$ (cf. Roodman 2006, p. 27ff).[30]

5.1.2 A dynamic panel model for the Taylor rule

The basis for the estimation in this section is the Taylor rule in the from of equation (10). As a panel model it is written as:

$$i_{i,t} = [\gamma_0 + \gamma_\pi \pi_{i,t+1} + \gamma_x x_{i,t+1}](1-\rho) + \rho_1 i_{i,t-1} + \ldots + \rho_p i_{t-p} + \varepsilon_{i,t} \quad i: 1, ..., 20, \quad (23)$$

resp.

$$i_{i,t} = [\gamma_0 + \gamma_\pi \pi_{i,t+1} + \gamma_x x_{i,t+1} + \gamma_\varrho \varrho_t + \gamma_\tau \tau_t](1-\rho) + \rho_1 i_{i,t-1} + \ldots + \rho_p i_{t-p} + \varepsilon_{i,t}. \quad (24)$$

To identify possible differences in monetary policy with respect to the conducted trilemma strategy, all observations are divided in periods of a pegged resp. non-pegged exchange rate and of open resp. restricted capital markets, analogous to studies like Shambaugh (2004); Obstfeld et al. (2005); Herwartz & Roestel (2010).

[30] The definition of M depends on the desired transformation for the data, orthogonal deviations or differences. For the latter M consists of -1's on the diagonal, 1's to the right of the -1's and 0 elsewhere. Hence MM' is equal to G for the AB estimator. For orthogonal deviations MM' is equal to I, like in the covariance structure for the system GMM estimator above. Orthogonal deviations can be used instead of differences. Instead of taking the first difference of the variables, the average of all future available observations of a variable is subtracted from its level. (cf. Roodman 2006, p. 24). The two-step estimation uses the estimated residuals from the one-step estimation for the estimation of the covariance matrix, similar as for the the AB estimator.

Shambaugh (2004, p. 13) suggest two different approaches to determine whether a country stabilizes its exchange rate. Typically, countries officially declare their ambitions to peg the exchange rate and for example the IMF keeps track of the declared status of its member nations. Although this *de jur* classification offers a usable guideline, it may fails to capture the *de facto* status of a country. Officially floating countries can try to stabilize their exchange rate, for example due to fear of floating. On the other side there can be countries which declare to peg but actually show little effort toward it. The other possibility is to declare criteria which classifies a country as a peg. Shambaugh (2004, p. 13f) analyze whether the exchange rate of countries stay in a 2% band. Herwartz & Roestel (2010, p. 7) distinguish whether the exchange rate flexibility for a country is higher or lower than the contemporaneous cross sectional median over all countries. The same approach is applied for capital openness. In this regard Shambaugh (2004, p. 19f) relies on information by the IMF on capital market restrictions for a binary coding.

For this study the approach by Herwartz & Roestel (2010) is adopted. It is applied on the trilemma variable for exchange rate flexibility ($\varphi^{FX}, \varphi^{cap}$) and capital openness as used by Herwartz & Roestel (2010) and the corresponding indices by Aizenman et al. (2008) (ι^{FX}, ι^{cap}), already presented for the single country analysis. Additionally the approach of a exchange rate band by Shambaugh (2004) is conducted. The classification criteria are used to construct dummy variables which assign the value one to observations with a stable exchange rate resp. an open capital market. The explicit definitions of the criteria is given in the next section.

The dummy variables are used to build interaction terms between the dummy variables and the regressors, which extend equation (23) to:

$$\begin{aligned} i_{i,t} = [&\gamma_0 + \gamma_{\pi,1}\pi_{i,t+1} + (D\gamma_{\pi,2})\pi_{i,t+1} + \gamma_{x,1}x_{i,t+1} + (D\gamma_{x,2})x_{i,t+1}](1-\rho) \\ &+ \rho_1 i_{i,t-1} + \ldots + \rho_p i_{t-p} + (D\rho_D)i_{i,t-1} + \varepsilon_{i,t}. \end{aligned} \tag{25}$$

The extension for (24) is analogous. D stands for the corresponding dummy variable for exchange rate stability, capital openness or for a combination of both to capture the combined effect of a stable exchange rate and open capital markets. To limit the number of additional parameters that need to be estimated, only the first lag of the interest rate enters the equation multiplied with a dummy variable.[31] The interaction terms measure the difference of monetary policy subject to the macroeconomic trilemma. In theory, it would be expected, that countries with a more stable exchange rate or resp. and an open capital market have less freedom to target domestic policy goals like inflation or output. Therefore $\gamma_{\pi,2}$ and $\gamma_{x,2}$ are expected to be negative. With regard to the interest rate differential it could be expected that countries with a more stable exchange rate or an open capital market care more about keeping that difference small (ergo $\gamma_{\tau,2} < 0$). The same is true for the parameter for the exchange rate gap.

To estimate equation (25), the one step system GMM estimator is used. As tested for the single country regression and pointed out by Shambaugh (2004, p. 8), interest rate series are close to unit roots in finite samples. Therefore the dependent variable in the model is close to a random walk (cf. Libanio 2005, p. 146), which makes the system GMM estimator the more efficient choice (cf. Baltagi 2001, p. 143). Blundell et al. (2000, p. 82) also show that the system GMM estimator reduces the bias of estimates in finite samples.

Lags of the explanatory variables in first differences are used as instruments for the explanatory variables in first differences in the model. As the dataset for this study provides a large number of observations over time, it is not recommended to make use of the method to expand the number of instruments with each additional observation. As pointed out by Roodman (2006, p. 13), this can cause numerical problems, because the number of elements in the estimated variance matrix of the moments rise quadratic to the number of instruments, which rise with the dimension of T. For the estimations in this study three lags of all explanatory variables are used.[32] All of the explanatory variables are assumed to be not strictly exogenous but predetermined, because they are all potentially influenced by past interest rate shocks.[33] Three lags of the interest

[31] The parameter ρ_D is found to be insignificant in most specifications. The same is true for interaction terms with additional lags.

[32] The estimation of the model using the AB method is computationally intensive and can cause the PC to refuse the memory needed to consider a higher amount of lags as instruments. However, the results seem to be hold for specifications with more instruments.

[33] It is also possible that the explanatory variables are endogenous instead of predetermined, implying that contemporary interest rate shocks also have a significant impact on them. In this case the lags of the differentiated explanatory variables used as instruments must be shifted one additional period back. However, the effect on the estimates is negligible.

rate are included to model interest rate smoothing by central banks. Less lags fail to prevent autocorrelation of the residuals. Additionally, robust standard error estimation is used to get consistent results for any pattern of autocorrelation and heteroskedasticity within the panels.

5.2 Classification of dummy variables for the trilemma status

The dummy variables for stable exchange rates and an open capital market make use of the trilemma variables which already served some insights for the relation between monetary policy and the macroeconomic trilemma in the single country regressions. Herwartz & Roestel (2010) approach to distinguish observations at the median of trilemma variables is easy to apply and can be carried out for other measures, like those from Aizenman et al. (2008), as well. Though, with regard to the distribution of the data, as seen in figure 3, that the majority of countries in the dataset are similar positioned in the trilemma. Most observations show a relative stable exchange rate and an open capital market. To account for these characteristics in the data, observations are additionally distinguished at the 25% resp. 75% quantile. Only for the capital openness index (ι^{cap}) this classification can not be used, because for over the half of the observations one maximum value is assigned. Therefore this maximum is used to indicate highly open capital markets. For the other variables the additional criteria implies stricter requirements that have to be fulfilled. The dummy variables are formally defined in table 3. Additional to the exchange rate stability dummies on the basis of φ_{it}^{FX} and ι_{it}^{FX} the classification procedure by Shambaugh (2004) is applied to construct a dummy variable ($D_{iy}^{FX,1\%}$). It is based on whether the exchange rate stays in a band of one percent during one year. To prevent that one time fluctuations of the exchange rate dominate the classification for a year of otherwise stable exchange rate, any year with an exchange rate change of zero for eleven out of twelve month is also considered as stable. Shambaugh (2004) uses an exchange rate band of two percent in the baseline specification for his research. However, he points out that the difference between the results for a one and a two percent band do not differ substantially (cf. p. 14). The smaller band is used to account again for the overall stable exchange rates for the countries used in this study.

Table 3: Trilemma dummy variables

Symbol	Definition	Quantity of the attribute
$D_{it}^{FX,\varphi\ 50q}$ =	1 if $\varphi_{it}^{FX} < Median(\varphi_t^{FX})$	for 953 quarters
	0 else	for 994 quarters
$D_{it}^{FX,\varphi\ 25q}$ =	1 if $\varphi_{it}^{FX} <$ 25% $quantile(\varphi_t^{FX})$	for 456 quarters
	0 else	for 1491 quarters
$D_{it}^{FX,\iota\ 50q}$ =	1 if $\iota_{it}^{FX} \geq Median(\iota_t^{FX})$	for 1000 quarters
	0 else	for 959 quarters
$D_{it}^{FX,\iota\ 75q}$ =	1 if $\iota_{it}^{FX} \geq$ 75% $quantile(\iota_t^{FX})$	for 538 quarters
	0 else	for 1421 quarters
$D_{iy}^{FX,1\%}$ =	1 if $max\ /\ min(\Delta log\ e_{im}) \leq \|0.02\|\ \forall\ m \in y$ or $\Delta log\ e_{im} = 0$ for 11 of 12 $m \in y$	for 1388 quarters
	0 else	for 571 quarters
$D_{it}^{cap,\varphi\ 50q}$ =	1 if $\varphi_{it}^{cap} < Median(\varphi_t^{cap})$	for 992 quarters
	0 else	for 1079 quarters
$D_{it}^{cap,\varphi\ 25q}$ =	1 if $\varphi_{it}^{cap} <$ 25% $quantile(\varphi_t^{cap})$	for 459 quarters
	0 else	for 1612 quarters
$D_{iy}^{cap,\iota\ max}$ =	1 if $\iota_{iy}^{cap} > max(\iota^{cap})$	for 1307 quarters
	0 else	for 904 quarters

The exchange rate (e_{im}) always refers to the exchange rate between domestic country i and its base country j.

Note that ($D_{iy}^{FX,1\%}$) as well as ι_{iy}^{cap} are defined on a yearly basis (y) and not on a quarterly (t) like the rest. This leads to less variation in the assigned observation status. On the other hand it can prevent too much and therewith meaningless fluctuation of the status.

By construction the dummies using the approach by Herwartz & Roestel (2010) and those using the indices by Aizenman et al. (2008) show similar quantities of assigned zeros and ones, but they also have a similar distribution of the assigned values over the observations. The dummy on the basis of Shambaugh (2004) classifies much more observations as such with a stable exchange rate.

5.3 Results from the panel estimations with interaction dummy variables for the trilemma state

In this section the results of the dynamic panel regression models with different interaction dummy variables for the trilemma state of countries are presented. Table 9 includes the estimations with the dummy variables for exchange rate stability, the regressions in table 10 contain dummy variables for the openness of capital markets and for the estimations in table 11 to 13 the exchange rate stability dummies are combined with either one capital openness dummy.

⟨*Table 9 to 13 here*⟩

The interest rate smoothing is similar for all used dummy variables. In all of the specification without additional variables each of the interest rate lags is highly significant. Overall the smoothing parameter ρ sums up to approximately 0.9. For the specifications including exchange rate deviations and the interest rate differential the smoothing parameter is marginally lower and lies between 0.75 and 0.8. In non of theses specifications the second interest rate lag is significant, but testing for serial correlation of the residuals suggests to take three lags into account nonetheless. The coefficients for inflation and output gap are almost always highly significant and have the expected sign and magnitude. For the specification with additional explanatory variables the inflation coefficient tends to be higher, while the output gap coefficient tends to be lower. Exchange rate deviations always enter with a negative sign, but the effect is never significant. Interest rate differentials on the other hand are always significant positive, indicating that central banks generally include the interest rate of the base countries in their own interest rate decisions. However, the sign is once again contrary to theoretical considerations.

All of these estimates coefficients in the upper part of the tables report the reaction of central banks in case of relative flexible exchange rates (table 9), some capital market restrictions (table 10) or the combination of both (table 11 to 13). The coefficients combined with the dummy variables (and the subscript 2) measure the difference in the reaction for states of relative stable exchange rates resp. highly open capital markets. These differences vary for both dummy type and dummy specification, indicating that the theoretically consideration of a more active monetary policy, in the case of less emphasize on the other two goals of the macroeconomic trilemma, does not hold in general.

Interest rate smoothing is significantly positive different for stable exchange rates in two specifications and one time for open capital markets. This does not represent strong evidence for a structural difference. However, in table

12 and 13 the parameter is significant negative in four resp. six specifications. The negative sign indicates, that countries with high capital openness and a stable exchange rate take their past interest rate realizations less into account. A possible explanation for this behavior could be, that their credibility with regard to monetary policy is backed up by these factors and therefore has to be implemented by a smooth interest rate development to a smaller degree.

The parameter change for inflation is in most specifications negative. With respect to more stable exchange rates it is always negative and significant for both specifications using the dummy variables on the basis of the median of the exchange rate stability index (ι^{FX}) and a 1%-band for exchange rate changes (i. e. $D^{FX,\iota\ 50q}$ and $D^{FX,\ 1\%}$). Moreover, the estimated structural parameter γ_π show that for less stable exchange rates the parameter is clearly above the value 1, whereas for more stable exchange rates it is often near or even below 1.[34] Even if it is slightly above 1, values below 1 are typically in the range of one standard deviation, whereas this is not true when exchange rates are less stable. This holds for most specifications without exchange rate deviations and interest rate differential, even if the difference is not significant. When the additional variables are considered, the difference is mostly marginal as long as the coefficient is not significant. For more open capital markets the difference is never significant negative, except once in specification (6) on table 10 and never for dummy variables combinations except (2) on 13, both include the dummy on the basis of the capital openness index. Oddly it is significant positive for (5) (6) and (7) on table 13. Also the whole results for this dummy combinations differ substantially from the rest and are therefore treated with caution.

For the state of exchange rate stability the results can be seen as evidence that countries that stabilize their exchange rate have problems to conduct a proper inflation targeting policy. That three of five dummy variables do not produce significant coefficients can be a result of their construction. On one hand the exchange rate stability index and the criteria regarding the exchange rate band produce more stable classifications than the exchange rate flexibility variable φ^{FX}. The latter switches the classification approximately twice as much. On the other hand $D^{FX,\varphi\ 25q}$ and $D^{FX,\iota\ 75q}$ make stricter requirements and thereby maybe exclude to many observations. This could also explain the insignificance of

[34]see specification (5) on table 9, (3), (5) and (7) on table 11, (1) –(4) on table 13.

the coefficient for the combined dummy variables, because for monetary openness the results suggest no link for policy restrictions with regard to inflation targeting.

Also the difference for the reaction toward the output gap is mostly negative, as it would be expected. With regard to more stable exchange rates it is found to be significant only for specifications (1) and (3).[35] However, the capital openness seems to be more relevant. On table 10 the coefficient is significant negative for specifications (2) and (4) (and almost for (3)). When the capital openness dummies are combined with the exchange rate stability dummies, the effect seems to intensify. For combinations with $D^{FX,\varphi\ 50q}$ it is only significant for the two specifications with $D^{FX,\varphi\ 25q}$ ((7) and (8) on table 11). For combinations with $D^{FX,\varphi\ 25q}$ however, the coefficient is significant negative in six observations. This indicates that central banks, which stabilize the exchange rate and face a highly open capital market, are substantially restricted in their ability to influence the domestic business cycle.

A different pattern is only found for most of the specifications with the capital openness dummy on the basis of the capital openness index ι^{cap} in table 13. Here the reaction toward inflation is significantly higher for more stable exchange rates in combination with high capital mobility in six of the specifications and also with regard to the output gap in four specifications. Even more striking is the size of the interaction term for exchange rate deviations. Its size ranges from approximately 90 to over 150. This suggests, that the estimation are maybe influenced by outliers in the data. It is noticeable that observations for the Netherlands are the most frequent ones among the countries for all dummy combinations equal to 1. From the single country regression it is known that the coefficient of exchange rate deviations for the Netherlands had a value of 449.1. It seems like these observations tend to dominate the estimations for dummy variable combinations with ι^{cap}, which results into deviating and probably not representative estimators.

For the other specifications the difference in the reaction on exchange rate deviations for different states of exchange rate stability and capital openness is found to be insignificant, except for two specifications (specification (2) on table 9 and table 12).

[35] It is also significant in specification (10), but with a positive sign, which seems counterintuitive.

Finally, the interaction dummy variable for the real interest rate differential is significant positive for all specifications, except on table 13. This suggests that countries with more open capital markets and stable exchange rates react more intense to interest rate conditions in their base country. This confirms the findings from previous studies. However, as the reaction seems destabilizing again. The relation should be captured differently in further research.

The validity of the estimated coefficients depend on the assumption that the residuals are not serial correlated. Otherwise, lagged explanatory variables, which are correlated with lagged residuals would be also correlated with future realizations of the error term and therewith not adequate as instrument variables. On the lower part of the regression tables a AB test-statistic on autocorrelation. It uses first differences of the residuals to eliminate serial correlation due to μ_i. Therefore first order autocorrelation is expected by construction, since $\Delta\nu_{it} = \nu_{it} - \nu_{it-1}$ and $\Delta\nu_{it-1} = \nu_{it-1} - \nu_{it-2}$ both include ν_{it-1}. Second order autocorrelation should not occur. This is true for all specifications, as indicated by the test-statistics $ar1$ and $ar2$ and the corresponding p-values. The null hypothesis for the test is that there is no autocorrelation of the particular order (cf. Roodman 2006, p. 27, p. 31ff).

The tables also supply two tests for the validity of the instruments. However, both have a shortcoming. The Sargan test is not robust to serial correlation and heteroskedasticity, while the Hansen test can be weakened by too many instruments. The test hypothesis for both imply that the instruments are valid. The Hansen test fails to reject the test hypothesis at p-value of 1 for all specifications. The Sargan test generally suggests that the instruments for the specifications without exchange rate deviations and interest rate differential are valid, but rejects this hypothesis for the specifications with the additional variables. It is hard to tell which test suffers from his shortcoming in this regard. Adding additional lags does generally not enhance the Sargan test-statistic. Since the instrument setup is quite common for these kinds of monetary policy rules, it is assumed, that the instruments are valid (cf. Roodman 2006, p. 11f).

6 A functional coefficient approach for the Taylor rule

Overall the results from the dynamic panel model estimation have shown, that the connections between monetary policy and the macroeconomic trilemma can be diverse. The effects do not seem to follow the simple rule, that less realization of exchange rate stability and capital openness lead in general to a more active monetary policy. However, the results provide evidence that this can give central banks more freedom. How this freedom is used, differs with respect to the trilemma element which is neglected by a central bank and presumably also to what extent it is neglected. When both trilemma components are combined, the effect becomes even more unclear. It is unlikely that the real structure behind the trilemma relations can be captured adequately with dummy variables. Dummy variables only allow a restrictive distinguishing of states; either the exchange rate is flexible or it is not for example. To overcome this shortcoming, in this section the estimation of the Taylor rule is conducted using a semi parametric functional coefficient model, which allows for a smooth transition between the trilemma states.

6.1 A functional coefficient model approach for the Taylor rule

The method used in this section follows the regression model of Cai et al. (2000). They take a simple multivariate regression function and define a functional coefficient model of the following form:

$$E[Y|\mathbf{X} = \mathbf{x}, \mathbf{U} = \mathbf{u}] = \sum_{k=1}^{m} \alpha_k(\mathbf{u}) x_k, \tag{26}$$

where $\mathbf{x}$ is a vector of m explanatory variables, $\mathbf{u}$ is a set of other explanatory variables and $\alpha_k(.)$ is a functional coefficient, associated with x_k (cf. Cai et al. 2000, p. 941). The principal idea behind this approach is that the variable y depends on the explanatory variables in $\mathbf{x}$. The structure of this dependency however additionally depends on the other explanatory variables in $\mathbf{u}$. This structure of the regression model makes it an ideal choice for analyzing the research problem of this study. It can be estimated how central banks set their interest rates subject to the determinants of the Taylor rule and how this relation differs subject to the state of the trilemma variables. The functional coefficient model combines elements of standard parametric regressions (linear relation between y and $\mathbf{x}$ via the parameters α) and nonparametric estimation techniques (the functional form of $\alpha_k(.)$ is not predetermined, besides that it is a smooth function) and therefore referred to as a semiparametric regression (ct. Härdle et al. 2004, p. 4).

For the practical application of the technique a generalized panel model version of (26) as in Herwartz & Xu (2010) and Herwartz & Roestel (2010) is used. It is written as

$$y_{it} = x_{it}'\beta(\omega) + \nu_{it}, \tag{27}$$

where y_{it} is the dependent variable, x_{it} is a vector of explanatory variables, ω is a set of additional explanatory variables (referred to as factor variables henceforth) for the functional coefficient and $\beta(.)$ is a vector of functional coefficients. The assumption in this study is, that the reaction of central banks indicates its independence to conduct a monetary policy aimed at domestic targets and that it changes subject to the state of the trilemma. Therefore, ω can consist of the two other trilemma components, exchange rate stability and capital openness. For the estimation of the model this is a favorable number, because unspecified functional relations in nonparametric models suffer from the so called *curse of dimensionality* (cf. Härdle et al. 2004, p. 4). It states that the statistical precision of nonparametric functional estimations strongly decreases with the number its explanatory components. This implies that the amount of necessary observations to identify the correct relationship in such a model quickly becomes unrealistic. Two variables are still a reasonable number for reliable results from a panel dataset. Additionally, with two factors driving the parameter values, the results are still presentable in three dimensional form and therewith clearly analyzable.

The estimation of (27) is carried out using a multivariate version of the Nadaraya Watson estimator (Nadaraya 1965; Watson 1964) as used in Herwartz & Xu (2010, p. 48) and Herwartz & Roestel (2010, p. 20). The estimator is then defined as:

$$\hat{\beta}(\omega^{(1)}, \omega^{(2)}) = \mathcal{X}^{-1}(\omega)\mathcal{Y}(\omega), \tag{28}$$

where

$$\mathcal{X}(\omega) = \sum_{i=1}^{N}\sum_{t=1}^{T} x_{it}x'_{it}K_h(\omega_{it}^{(1)} - \omega^{(1)})K_h(\omega_{it}^{(2)} - \omega^{(2)}), \tag{29}$$

$$\mathcal{Y}(\omega) = \sum_{i=1}^{N}\sum_{t=1}^{T} x_{it}y_{it}K_h(\omega_{it}^{(1)} - \omega^{(1)})K_h(\omega_{it}^{(2)} - \omega^{(2)}) \tag{30}$$

and $\omega^{(1)}$ as well as $\omega^{(2)}$ can be measures for exchange rate stability or capital openness. The estimator (28) can be seen as a local state specific pooled least squares estimator. For (29) and (30) a finite amount of states for $\omega^{(1)}$ and $\omega^{(2)}$ is defined, that covers the whole relevant range of different trilemma states. Then, observations for $x_{it}x'_{it}$ resp. $x_{it}y_{it}$ are weighted with respect to the distance of the corresponding trilemma measure to a specific state. Observations which are nearer to this state are included in the estimation of the corresponding coefficient with a higher weight than those which are farther away. Those which are too far away are excluded. Therefore, the estimator is referred to as *local*. As a result it is possible to estimate the effect of explanatory variables in the Taylor rule for diverse combination of different states of exchange rate flexibility and capital openness.

The weighting of the observations is carried out via the multiplicative kernel functions $K_h(\omega_{it}^{(1)} - \omega^{(1)})$ and $K_h(\omega_{it}^{(2)} - \omega^{(2)})$. Kernels are generally used in non- and semiparametric estimation techniques as weighting functions. In detail the kernel functions are defined as $K_h(.) = \frac{1}{h}K(\frac{\cdot}{h})$. $K(u)$ marks the kernel function. Its form specifies how it weights the corresponding observations with regard to the state of $\omega^{(1)}$ and $\omega^{(2)}$. For this study a quartic kernel function is used, following Herwartz & Roestel (2010, p. 20) ($K(u) = \frac{15}{16}(1 - u^2)^1 I(|u| \leq 1)$)[36] The symbol h denotes the bandwidth of the kernel function. It defines the range of observations that should be taken into account for the weighting. The choice of the bandwidth is critical element for the estimation. A higher bandwidth includes a higher range of observations in the estimation. This leads to a higher smoothing of the estimator. The more observations are included, the more equal are the estimations for the different states. The extreme example would be to include all observations for all states, which would return the normal

[36] $I(|u| \leq 1)$ denotes an indicator function, taking the value 1 if the absolute value of its argument is equal or less than 1. This insures the cut-off of values of the factor variables that are too far away from a specified state.

OLS estimator, because every observations is included with the same weight in (29) and (30). A lower bandwidth allows for more state dependent effects. However, if it is set too low, the estimation becomes vulnerable to outliers in the data and unstable in regions with smaller number of observations (cf. Härdle et al. 2004, p. 51ff). As bandwidth selection criteria Scott's rule of thumb is used (Scott 1992), analogous to Herwartz & Roestel (2010). Scott's rule of thumb is defined as $h_{scott} = N^{-(1/d+4)}\hat{\sigma}_\omega$, where N is the number of total observations, d is the number of regressors and $\hat{\sigma}_\omega$ is the empirical standard deviation of the corresponding factor variable. Obviously, the suggested bandwidth raises with the number of explanatory variables and declines with more observations. Also similar to Herwartz & Roestel (2010), the kernel function is premultiplied with the canonical bandwidth of 2.0362 for quartic kernels. This ensures equivalence over other kernels (cf. Härdle et al. 2004, p. 54f).[37]

Theoretically $x_{it}x'_{it}$ and $x_{it}y_{it}$ in (29) and (30) could be replaced with their equivalences from the system GMM estimator used in the previous section. However, this results into substantial numerical problems and produces very irregular estimates. Therefore a FE approach for a backward looking Taylor rule will be used in this section. This is justifiable against the background of the results in the fourth section. Further, T is large for the countries in the panel dataset, which leads, as argued by Belke & Potrafke (2009), to an acceptable small Nickell-Bias. For the estimation the additional explanatory variables for exchange rate deviations and the real interest rate differences are neglected. The former was insignificant in general and the latter showed an unclear effect. Since the estimation results for the two kinds of specifications (with and without the additional variables) of the panel models were quit similar, this seems to be statistical justifiable.

To eliminate the FE from the data, a within transformation is carried out for the variables in y_{it} and x_{it}. Three lags of the interest rate are included as explanatory variables, since this helped to eliminate autocorrelation in the residuals for the dynamic panel models in the last section. The dependent variable is again the interest rate i_{it} while $x_{it} = (\pi_{it},\ x_{it},\ i_{it-1},\ i_{it-2},\ i_{it-3})'$.

[37] With the selected bandwidth the estimates still tend to be instable in some data regions. Therefore the bandwidth is additionally multiplied with a constant factor of 1.5 (see Herwartz & Roestel (2010, p. 20) for a similar approach).

6.2 The factor variables for the macroeconomic trilemma components

As factor variables for the state of the macroeconomic trilemma, the same variables as in the previous sections are used. However, to ensure cross sectional comparability, the variables should be transformed into a standardized from. The indices for exchange rate stability and capital openness already fulfill this requirement. The adherence to a exchange rate band is not suitable for this method and is dropped as a measure. For the other two variables the standardization suggested by Herwartz & Roestel (2010, p. 11ff) is applied.

The exchange rate flexibility variable φ^{FX} is standardized in two different ways. For both variants φ^{FX} is logarithmized to improve the distributional features of the variable. Otherwise most of the observations for φ^{FX} are near zero as seen in figure 3. To avoid creating invalid values when taking the logs, zero is assigned to the logarithmized variable where the $\varphi_{it}^{FX} = 0$ (cf. Herwartz & Roestel 2010, p. 11). The logarithmized variable is defined as $\varphi_{it}^{FX*} = ln(\varphi_{it}^{FX})$.

First the variable is standardized with respect to the realized exchange rate flexibility of the country over time. The factor variable is then written as:

$$\omega_{it}^{FX_i,\ \varphi} = \frac{(\varphi_{it}^{FX*} - \overline{\varphi}_i^{FX*})}{\sigma_i(\varphi_i^{FX*})}, \tag{31}$$

with

$$\overline{\varphi}_i^{FX*} = \frac{1}{T}\sum_{t=1}^{T}\varphi_{it}^{FX*}, \quad \sigma_i(\varphi_i^{FX*}) = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(\varphi_{it}^{FX*} - \overline{\varphi}_i^{FX*})^2}.$$

The second standardization is defined as the contemporary exchange rate flexibility against the other countries. It is written as:

$$\omega_{it}^{FX_i,\ \varphi} = \frac{(\varphi_{it}^{FX*} - \overline{\varphi}_t^{FX*})}{\sigma_t(\varphi_t^{FX*})}, \tag{32}$$

with

$$\overline{\varphi}_t^{FX*} = \frac{1}{N}\sum_{i=1}^{N}\varphi_{it}^{FX*}, \quad \sigma_t(\varphi_t^{FX*}) = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\varphi_{it}^{FX*} - \overline{\varphi}_t^{FX*})^2}.$$

Values over zero for $\omega_{it}^{FX_i,\ \varphi}$ indicate that the exchange rate flexibility is high, relative to the overall exchange rate flexibility of country i. For $\omega_{it}^{FX_i,\ \varphi}$ it indicates that the exchange rate for country i is high, relative to the overall contemporary flexibility of the other countries in the data sample.

The same procedure is applied on the capital openness variable φ^{cap}, though it does not get additionally logarithmized and only a standardization with respect to the own experienced capital openness is considered. The variable is defined as:

$$\omega_{it}^{cap_i,\ \varphi} = \frac{(\varphi_{it}^{cap} - \overline{\varphi}_i^{cap})}{\sigma_i(\varphi_i^{cap})}, \tag{33}$$

with

$$\overline{\varphi}_i^{cap} = \frac{1}{T}\sum_{t=1}^{T}\varphi_{it}^{cap}, \quad \sigma_i(\varphi_i^{cap}) = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(\varphi_{it}^{cap} - \overline{\varphi}_i^{cap})^2}.$$

The factor variables on the basis of the two index variables are defined as $\omega_{it}^{cap,\ \iota} = \iota_{it}^{cap}$ and $\omega_{it}^{FX,\ \iota} = \iota_{it}^{FX}$ henceforth.

As for the dynamic panel models with dummy variables, the different measures for the trilemma components will be applied and compared for the estimation of the functional reaction parameter in (28). The design of the estimator implies that various combinations of values for the trilemma variables will by generated, to estimate what kind of relation between the explanatory and dependent variables can be found for observations that match the corresponding combination. Therefore, it is important to analyze for which value combinations there is a sufficient number of observations, because trying to estimate a functional link in regions with no observations can lead to numerical problems. Figure 4 presents scatter plots of all relevant factor variable combinations. It provides an overview for the appropriate data regions and for outliers which should be dropped from the data set before the regression analysis.

⟨*Figure 4 here*⟩[38]

According to this overview, the following ranges of values are considered for the factor variable combinations:

- $\omega^{FX_i,\,\varphi}$ vs. $\omega^{FX_t,\,\varphi}$: -2 – 2; -2.5 – 1.7,
- $\omega^{FX_t,\,\varphi}$ vs. $\omega^{cap_i,\,\varphi}$: -2.5 – 1.7; -2 – 2,
- $\omega^{FX_i,\,\varphi}$ vs. $\omega^{cap_i,\,\varphi}$: -2.5 – 2; -2.5 – 2,
- $\omega^{FX,\,\iota}$ vs. $\omega^{cap_i,\,\varphi}$: 0.14 – 1; -2.5 – 1.8,
- $\omega^{FX,\,\iota}$ vs. $\omega^{cap,\,\iota}$: 0.14 – 1; 0 – 1,
- $\omega^{FX_i,\,\varphi}$ vs. $\omega^{cap,\,\iota}$: 0.14 – 1; -2.5 – 1.8.

6.3 Estimation results

Figure 5 till 10 present the results for the functional coefficient models. The corresponding trilemma variables used in each particular model are displayed in the headlines. For analytical convenience the parameter estimates are already transformed into their structural form. The results for the three interest rate lags are added op into one *interest rate smoothing* statement. The estimates for the output gap and the inflation rate are transformed into their structural parameter form, where the reaction of the central bank can be read directly (analogous to γ_π and γ_x in (8)).[39]

⟨*Figure 5 to 10 here*⟩[40]

[38] Axis label: $\omega^{FX_i,\,\varphi}$ = fx flex intrasec std, $\omega^{FX_t,\,\varphi}$ = fx flex crosssec std, $\omega^{cap_i,\,\varphi}$ = fx cap crosssec std (although it is labeled *crossec* it refers to the country specific capital openness, as described above) , $\omega^{FX,\,\iota}$ = fx stability index, $\omega^{cap,\,\iota}$ = cap open index.

[39] Let Γ be the sum of the matrices of the estimated parameters for the three interest rate lags (the overall *interest rate smoothing* parameter) and Ψ a matrix of the estimated parameters for the output gap or the inflation rate from (28). The structural parameters are then estimated via: $\Psi./(ONES - \Gamma)$, where "./" indicates element-wise division and "ONES" is a matrix of ones of the same dimension as Ψ and Γ.

[40] Axis label: $\omega^{FX_i,\,\varphi}$ = fx flex intrasec std, $\omega^{FX_t,\,\varphi}$ = fx flex crosssec std, $\omega^{cap_i,\,\varphi}$ = fx cap crosssec std (although it is labeled *crossec* it refers to the country specific capital openness, as described above) , $\omega^{FX,\,\iota}$ = fx stability index, $\omega^{cap,\,\iota}$ = cap open index.

The surface of the graphs represent the state dependent reaction of central banks with respect to the corresponding variable. X- and the y-axis represent the different states of the trilemma variables, while the vertical z-axis displays the parameter value. The trilemma states are measured via the factor variables defined in section 6.2. For the variables on the basis of Herwartz & Roestel (2010) negative values indicate a high realization of the two measured trilemma goals, i. e. relative high capital mobility resp. stable exchange rates. Zero indicates an average state and positive values indicate states of lower capital mobility resp. more flexible exchange rates. For the factor variables on the basis of the indices by Aizenman et al. (2008) zero indicates a low realization of the trilemma goals and one indicates a high realization.

As in the previous section it can be expected from a theoretical point of view, that in the case of lower capital mobility and exchange rate stability, central banks have more freedom to address domestic monetary policy goals. With regard to inflation and output gap this means that the reaction toward undesired developments may be stronger, i. e. the estimated coefficients are higher. If a country decides to focus on the two trilemma goals: open capital market and stable exchange rate, it would be expected that domestic policy goals are pursued to a lower extent instead. The results from the dynamic panel models gave some evidence in this direction, but suffered from the restrictive distinction of the trilemma states. Now, the graphical presentation of the functional coefficients offer the additional possibility to analyze the transition regions between these extremes. Countries can also try to maintain a reasonable degree of independence by only giving up one other trilemma target or pursue a "middle strategy" of all goals.

However, the results for the conducted interest rate smoothing must be considered as well. There are no compelling expectations regarding the impact of different trilemma states. It is most possible that a central bank does smooth the interest rate development by a lower extent, when it allows a floating exchange rate and faces restricted capital mobility, because it has to fear less consequences. Furthermore, this can also be a constellation in which central banks try to maintain credibility by carrying out a steady monetary policy. The degree of interest rate smoothing must also be taken in to account for the interpretation of the parameter values for inflation and output gap. A lower reaction on inflation combined with a low degree of interest rate smoothing can still indicate a higher degree of active monetary policy.

6.3.1 Interest rate smoothing

Figure 5, 6 and 7 show the results of the models with the three factor variables for the exchange rate stability, each combined with the variable for capital openness $\omega^{cap_i,\ \varphi}$. With regard to interest rate smoothing all three models show a similar parameter range between 0.95 and 0.85. Model 6 shows a pattern for the parameter values as described above. Smoothing is most pronounced for a combination of high capital mobility and a stable exchange rate, both relative to the country specific horizon. It drops off nearly linearly for a more flexible exchange rate and a declining capital openness. For low capital mobility and high exchange rate flexibility interest rate smoothing reaches its estimated minimum. However, smoothing stays high even for a declining capital mobility, if the country specific exchange rate stability stays high. Model 5 also shows the highest interest rate smoothing for a combination of high capital mobility and a stable exchange rate. But there is no notable decline for lower capital openness. Smoothing declines however with more exchange rate stability, where the development of the decline is again nearly linear. Then, for a highly flexible exchange rate there is a drop off of the parameter values for high capital mobility. Since this is observed at the outer border area, it might be due to outliers at the value boundary. Model 7 yields contrary results with regard to the exchange rate stability. Here smoothing declines with greater stability instead of greater flexibility. It stays relatively stable for different states of capital openness. Only for highly stable exchange rates, interest rate smoothing follows a similar pattern like model 6 and declines with lower capital openness.

Model 8 and 9 include $\omega^{cap,\ \iota}$ as measure for capital mobility. As seen in the scatter plots in figure 4, it is not a continuous measure and the results should be treated with caution. However, the results from model 8 are comparable with the ones from model 6. Interest rate smoothing is high for stable exchange rates combined with high capital mobility. The falloff is then dominated by the influence of the exchange rate stability variable. Model 9 does not match with the pattern of the other results at all. The results are exactly contrary to model

6.

Finally, in model 10 no measure for capital openness is included. It can be seen as a Taylor rule estimation under the assumption, that capital mobility is relatively high and more or less uniform across countries. The trilemma then reduces to a dilemma between monetary policy independence and exchange rate stability. The model includes the variables for country specific and contemporary cross sectional exchange rate stability. It shows a stable rate of interest rate smoothing and a decline when the exchange rate becomes country specifically stable and cross sectionally flexible.

Across the models there are substantial differences in the pattern of interest rate smoothing with regard to exchange rate flexibility and capital mobility. However, there is some evidence for the theoretical consideration above, which implies that a strict agenda toward the realization of the other two trilemma targets is associated with higher interest rate smoothing. If this agenda is relaxed, central banks seem to gain the freedom to pass through a higher degree of the interest rate target to actual interest rate, implying a higher realized policy activity. It is hard to identify a structure behind the deviations from this pattern, but since the parameter range differs by only 0.1 for the most part, it is possible that peculiar data constellations can be dominant in some of the results. This is especially true for model 8. Both variables in it have a limited variation in the data and most observations are concentrated at one. This might lead to the results for the effect of inflation and output gap, which show an unintuitive design.

6.3.2 Output gap

For the reaction toward the output gap, there is a clear theoretical expectation; less emphasize on the other two trilemma targets should give central banks the independence to address the domestic economical development. Model 10 confirms this for the stability of exchange rates. The parameter values are highest, when both of its measures indicate high flexibility. The reaction is double as high as on the average. However, for the rest of the exchange rate states the parameter values stay quite similar.

When exchange rate stability and capital openness are considered, the results show that mostly the reaction toward the output gap is higher, when only one of the trilemma targets is dropped. This is especially observed in model 9, where the parameter values are high for flexible exchange rates with high capital openness, but also for lower capital openness with stable exchange rates. The latter is true as well for model 5 and 6. Model 7 shows a general high estimated reaction for flexible exchange rates. However it is highest with low capital mobility. The parameters reach a value of over four and then decline with higher exchange rate stability to almost zero for the combination of highly stable exchange rates and high capital mobility. In contrast, the change with respect to the capital mobility is low in most regions. This lower influence can be observed for other models as well, especially in the middle regions. Model 8 presents quite contrary results with a very counterintuitive pattern.

The results suggest mainly two insights for monetary policy in the macroeconomic trilemma. First, countries do not seem to be willing or do not find it necessary to restrict themselves with respect to two trilemma targets to be able to address the domestic output gap to a higher degree. However the results suggest that more freedom for this matter can be gained by the abandonment of another trilemma target. Second it seems like the influence of the exchange rate stability plays a major role in the overall extent to which the output gap can be addressed.

6.3.3 Inflation rate

For the parameter values for the inflation rate the same structure as for the output gap can be expected. As inflation targeting is generally seen as the primary objective of central banks, the former pattern can even be more distinct. However, in model 10 this is not confirmed. Here high parameter values are mostly associated with a high exchange rate stability relative to other countries, even though there is also an increase for exchange rate flexibility for both variables.

Even though the parameter distribution differs between the models, the general results of the models point in the same direction. Model 5, 7 and 9 all show the highest parameter values for a combination of flexible exchange rates and low capital mobility. In model 9 it can also be observed, how the parameters can be maintained on a relatively high level when either the exchange rate is held highly flexible or capital mobility stays low and the respective other trilemma goal gets realized. Model 8 presents peculiar estimates again, even though the results match with those from above to some extent. Model 6 on the other hand show results contrary to the others.

In contrast to the distribution of the parameter values for the output gap, there are many state combinations for inflation where there is barely some change in the size of the estimates. This could be evidence for less change in the trilemma strategies with respect to inflation. In contrast to the panel estimations with dummy variables, the structural inflation parameter values are smaller than one for the most part, but always exceed the value one in the higher regions. Even though, the previous results suggest not to conclude that countries, which try to maintain a stable exchange rate and an open capital market, are not able to properly address inflation. The direction of the results however can be seen as valid.

6.4 Summary of the results of the functional coefficient model

In summary the results of the functional coefficient estimations provide some evidence for the theoretical considerations on the relation between the macroeconomic trilemma and monetary policy. For the most part, the impact of inflation and the output gap on the interest rate are the highest, for a lower capital mobility and a more flexible exchange rate resp. if one of the two a true. Especially for the output gap strong effects are more associated with the abandonment of only one of the two trilemma variables.

The influence of exchange rate stability seems to be more pronounced than the influence of monetary policy. In many of the figures it can be observed that the parameter values stay almost equal for different states capital mobility if the exchange rate stability does not change. This dominance of the exchange rate regime was also found by Herwartz & Roestel (2010, p. 16). It can be a result of the development that most developed countries have already reached a high common level of capital openness in the 1980s (cf. Rodrik 2010, p. 173ff). This idea is supported by the fact that the discussed pattern can be found for both capital openness variables, even though their method of measurement is quite different.

The development of the impact of the variables across different states of the trilemma could not be clarified throughout. Partly, the models show quite different patterns. However, for lots of models and variables it can be observed, that there is a relative quick decline from higher values. Thereafter the decline weakens. High parameter values are additionally associated with the border regions of the trilemma variables. This must be taken into account when policy makers ponder whether they should abandon other trilemma goals to be able to act more intense toward domestic economic problems. Furthermore, there are relative few steady intermediate levels of parameter value for different states of the trilemma variables (as discussed only to some extent with respect to capital openness). This means that there is neither a *free lunch* for monetary independence. Countries seem to experience a direct effect of their trilemma strategy for their monetary policy at most. How this trade-off is shaped can not be fully explored. Though, especially for the effect of the exchange rate stability on the parameter values of the output gap, the decline from high to low values often follows a nearly linear path (see model 6 and 7). That there are much differences among the patterns of the model results indicates however, that the connection between the variables is not very tight. Countries seem to be able to follow strategies that allow them to overcome some of the trilemma constraints. For example by holding a large amount of reserves, to intervene on the capital market.

Finally, the results on interest rate smoothing are unclear. The models give contradictory results for its development. However, as the estimates vary only over a range of 0.1, the effect of the trilemma seem to be not very pronounced.

The overall reliability of the results could be further approved by applying statistical significance tests on the result. One possibility would be inference on the state dependency of the estimates via the bootstrap confidence interval approach by Herwartz & Xu (2010, p. 14f). However, in combination with the single country results and the benchmark results from the dynamic panel models with interaction dummies, the structure of the estimates seem plausible at provide a fruitful extension to the debate on the macroeconomic trilemma.

7 Summary and conclusion

The aim of this study was to shed light on the restrictions for monetary policy with regard to the macroeconomic trilemma. Most studies so far have neglected the actual design of monetary policy and only paid attention to the general structure of the trilemma, which was generally approved. However, a more detailed modeling of the interest rate determination, as the measure for independent monetary policy, is needed, to understand the intentions of policy makers. In this study multiple regression techniques were applied to analyze how the trilemma effects interest rate policy by central banks. This section summarizes and discusses the results and suggests further possible research in the field of the macroeconomic trilemma.

7.1 Concluding discussion of results

To investigate interest rate policy, Taylor like monetary policy rules were estimated and analyzed. In a first approach backward and forward looking Taylor rules were estimated separately for different countries to test the similarity of the results across countries as well as across different specifications. For both aspects a general similarity could be confirmed. All countries seemed to target inflation and showed a similar degree of interest rate smoothing. This result also holds for a specification with more explanatory variables as well as for back- and forward looking estimation. Further, the coefficient of determination $\mathbf{R}^2$ suggested an overall high degree of explanation for the model. The results were additionally compared to the country specific means of measures for the other trilemma components, i. e. exchange rate stability and monetary openness. Although this did not yield clear patterns, the results of the single country regressions were important. First, the similarity of the estimates implied, that the selected countries are suitable to be pooled into a panel dataset. Second, the approach in the last section, where a backward looking model without the additional variables was applied, is justifiable against the background of the similar results for the backward and forward looking models, even though the literature suggest a better econometric fit of forward looking variants.

At the beginning of this study it was argued, that the structure of the influence of the macroeconomic trilemma on monetary policy should be analyzed preferably differentiated. As there were discovered diverse patterns of trilemma strategies in the literature, it is likely that the effect of these patterns differs as well. Nevertheless, dummy variables were used in the fifth section as a raw method to distinguish different states of the trilemma. In a forward looking Taylor rule, estimated as a dynamic panel model, it was analyzed, whether the dedication to one or both of the other trilemma goals leads to different interest rate policy. The results for different measures of exchange rate stability and capital openness provide some evidence for the theoretical considerations on the influence of the trilemma. Countries which pursue an exchange rate stability or monetary openness tend to have lower coefficients for inflation and output gap in the Taylor rule, meaning that they conduct a less active monetary policy. However, these results do not hold throughout and are not significant over all trilemma measures. The output gap differences in particular are mostly insignificant, except for the dummy combination of high capital openness and stable exchange rates (cf. table 12). The indistinct and varying results can be caused by more sophisticated patterns in the trilemma, which are not appropriately captured by the restrictive distinguishing via dummy variables. Therefore, these results should be seen as a benchmark for the more differentiated analysis in section six.

In the final section a functional coefficient regression was used to model the behavior of central banks under different states of the macroeconomic trilemma. This kind of modeling is very suitable for this research, because it allows a more differentiated analysis of the problem. Even though the results are not uniform once again, they support the main theoretical considerations on the relation between monetary policy and the macroeconomic trilemma and provide further insight into the former black box of the degree of monetary independence. The estimations suggest that the interest rate reaction on inflation and the output gap by central banks is strongest for low capital openness and flexible exchange rates. However, most countries does not seem to sacrifice both trilemma goals to address the output gap. They only reject one while maintaining the other. The results do not provide clear picture of the development of the impact of the trilemma states on monetary policy. There is however some evidence, that the degree of exchange rate stability has a stronger impact than the capital openness. Further, strong changes are mostly observed in border regions of trilemma states.

This is accurate for high as for low values. Although the results are not stable throughout, policy makers should keep this finding in mind when considering giving up some exchange rate stability or capital openness for more monetary independence or pursuing maximal exchange rate stability, as shown in the example of Switzerland. For the former the necessary steps might be drastic and the latter might lead to a massive decline of sovereignty over domestic monetary policy. In this regard a "middle solution" as found in many studies might be a more appropriate choice.

For an explicit and comprehensive conclusion on the pattern of monetary policy under the influence of the macroeconomic trilemma the results for the different measures vary too much. For example, the proposed statement by Clarida (2009) in section three, claims that countries which experience a high exchange rate flexibility and open capital markets lay more emphasize on inflation targeting, would be confirmed by model 7 and 9 but neglected by model 5, 6 and 8.

Concluding it can be said, that the results contribute a valuable extension to research on the macroeconomic trilemma so far. The differentiated analysis of the design of monetary policy gives further insight in the phenomenon and should be considered in further research.

7.2 Suggestions for future research

One of the main problems in this study remains the measurement of the trilemma components, as mentioned in the introduction. In this study different measures were compared and it is likely that the varying results can be ascribed to this. Hence, further effort should be directed on this issue. Regarding the used variables it is considerable that the indices by Aizenman et al. (2008) do not show enough variation, while the variables by Herwartz & Roestel (2010) are too volatile. A "middle solution", which incorporates more stability with respect to its state, with a distinctive variation would be desirable. For specifications of monetary policy rules, with respect to the influence of the exchange rates and foreign interest rate impact, different measures should be considered as well, as the current variables do not seem to be best possible. As additional variables the amount of reserves held by a country has been used in previous studies and can contribute to further research.

An interesting continuative research topic would be a more detailed investigation of the degree of interest rate targeting. The results from the dynamic panel model and the functional coefficient model provided some evidence that the parameter value for inflation varies between smaller than one and greater than one; the critical value for an adequate interest rate reaction. It would be interesting to see whether the trilemma constellations can really interfere with this target of monetary policy.

Finally, it would be desirable to extent the research on other countries. The blessing of similar countries for a panel estimation can also turn out as a curse, when the similarity prevents necessary variation in the data. As pointed out in previous studies, less developed countries are more exposed to the trilemma and would might contribute a more distinct pattern for the impact of the trilemma on their monetary policy.

Appendix

A Tables

Table 4: List of variables

Variable	Symbol	Database	Definition	Description
Interest rate	i	IFS		Overnight money market rate or, if not available, the three month treasury bill rate. Proxy for the short-term nominal interest rate, the policy instrument of the central bank.
Inflation	π_t	IFS	$ln(CPI_t) - ln(CPI_{t-4})$	
Output gap	x		$gdp^r - gdp^r_{HP}$	Difference between real and potential real GDP. If real GDP is above its potential, it indicates an expansionary state, if it is below its potential, it indicates recessive state of the economy.
Real GDP	gdp^r	IFS DS		Real GDP index or, if not available, real industry production.
Potential real GDP	gdp^r_{HP}			The potential output is calculated using the HP trend of gdp^r with 1600 for the smoothing parameter. To avoid inaccurate trend determination at the beginning and the end of the timeseries pre- and post-sample observations are used for its etimation.
Exchange rate	e_{ij}	DS		Units of domestic currency of country i per one unit of the base country's (j) currency.
Exchange rate trend	e_{ij}^{HP}			HP trend of exchange rate (e_{ij}) with 1600 for the smoothing parameter. If countries try to stabilize or peg their exchange rate, it approximates the desired exchange rate level.
Exchange rate gap	ϱ_t		$e_{ij} - e_{ij}^{HP}$	Difference between the exchange rate (e_{ij}) and its trend. If the exchange rate is above (below) its trend, it indicates that the domestic currency's value is lower (higher) than desired.

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Continue of table 4

Variable	Symbol	Database	Definition	Description
Real interest rate	r		$(i_{it} - \pi^e_{it})$	
Real interest rate differential	τ_t		$(r_{it}) - (r_{jt})$	Difference between domestic and base country's real interest rate in logs.
Inflation expectations	π^e_t	IFS	$ln(CPI_t) - ln(CPI_{t-4})$	Inflation expectations in t, implying static expectation formation.
Exchange rate flexibility	φ^{fx}_t		$\sum\limits_{m \in t-1} (\Delta \ln e_{ij,m})^2$	Sum of squares of the differential of the log of the exchange rate between country i and the associated base country j for all month m in the quarter t.
Capital openness	φ^{cap}_t		$(r_{it-1} - r_{jt-1})^2$	Squared differential of the real interest rate in country i and the real interest rate in the associated base country j. Ceteris paribus countries with high financial integration should expirience a smaller real interest rate difference to other countries.
Exchange rate flexibility index	$\iota^{FX}_i t$		$\frac{0.01}{0.01+\sigma(\Delta(log\ e_{ij}))}$	
Capital openness index	ι^{cap}			Capital openness index by Chinn & Ito (2006, 2008), which is based on the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions.
Monetary independence index	ι^{MI}_{it}		$1 - \frac{corr[i_{iy}, i_{jy}] - (-1)}{1-(-1)}$	

Table 5: Descriptive statistics

	Interest rate	Inflation	Output gap	Exchange rate gap	Real interest rate dif.
Mean	7.09	3.89	0.11	-0.004	0.49
σ	4.45	3.59	1.23	0.07	2.56
Min	0.0006	-1.40	-6.53	-0.38	-13.35
Max	21.73	23.20	6.78	0.32	9.83
N	2161	2233	2196	1959	2089

Table 6: Stationarity tests

	Australia	Austria	Belgium	Canada	Denmark
Interest rate	-2.114	-2.826*	-1.566	-2.007	-1.319
Inflation rate	-2.087	-2.905**	-2.149	-3.340**	-3.695***
Output gap	-3.842***	-4.489***	-4.094***	-4.552***	-4.375***

	Eurozone	Finland	France	Germany	Ireland
Interest rate	-2.515	-1.267	-1.212	-3.349**	-1.522
Inflation rate	-2.938**	-2.986**	-3.682***	-2.649*	-3.225**
Output gap	-2.998**	-4.673***	-4.031***	-5.498***	-3.723***

	Italy	Japan	Netherlands	New Zealand	Norway
Interest rate	-1.261	-1.449	-1.803	-1.686	-1.216
Inflation rate	-3.495***	-3.615***	-2.839*	-2.305	-2.855**
Output gap	-4.985***	-4.337***	-4.336***	-4.682***	-3.365**

	Spain	Sweden	Switzerland	Thailand	UK
Interest rate	-0.983	-1.570	-1.769	-2.449	-1.465
Inflation rate	-2.917**	-2.421	-2.293	-4.660***	-3.652***
Output gap	-3.845***	-5.419***	-3.821***	-3.347**	-4.320***

H_0: Variable contains a unit root
Four lagged differences of the variable are included for the ADF test
Significance level by MacKinnon approximate p-value.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Single country regressions of the backward looking Taylor rule

	AUS	AUS	AUT	AUT	BEL	BEL	CAN	CAN	DEN	DEN	EU	EU	FIN	FIN
β_π	0.0948*	0.233***	0.0996	0.281***	0.120**	0.434***	0.205***	0.303***	0.167**	0.620***	-0.117	0.399**	0.0757	0.570***
	(1.70)	(3.10)	(1.34)	(3.54)	(2.03)	(5.30)	(2.62)	(3.37)	(2.61)	(8.35)	(-1.25)	(2.38)	(1.56)	(11.03)
β_x	0.528***	0.428***	0.254*	0.0573	0.364**	0.244*	0.384***	0.339***	0.0381	0.0388	0.243***	0.0909	0.156*	0.0860
	(4.11)	(3.21)	(1.82)	(0.44)	(2.39)	(1.75)	(3.28)	(2.87)	(0.43)	(0.53)	(4.09)	(1.33)	(1.89)	(1.54)
ρ_1	0.901***	0.812***	0.887***	0.822***	0.840***	0.618***	0.805***	0.751***	0.850***	0.483***	0.699***	0.843***	0.938***	0.526***
	(22.40)	(15.77)	(16.51)	(14.83)	(15.20)	(9.28)	(14.99)	(12.72)	(20.91)	(9.00)	(9.73)	(9.75)	(24.06)	(12.40)
β_ϱ		-1.252		195.2***		-10.42**		1.971		0.0766		-1.467		-1.998
		(-0.89)		(3.55)		(-2.17)		(0.63)		(0.08)		(-1.54)		(-1.36)
β_τ		0.136**		0.261***		0.481***		0.153**		0.635***		-0.279***		0.543***
		(2.61)		(3.25)		(4.91)		(2.10)		(8.51)		(-3.64)		(11.52)
constant	0.379	0.271	0.319	0.238	0.623**	0.963***	0.504**	0.383	0.402*	0.799***	1.137***	-0.312	0.151	0.898***
	(1.65)	(1.19)	(1.47)	(1.14)	(2.13)	(3.53)	(2.09)	(1.57)	(1.82)	(4.36)	(3.33)	(-0.57)	(0.47)	(4.38)
N	114	114	74	74	75	74	114	114	114	109	44	44	75	74
R^2	0.945	0.949	0.936	0.953	0.909	0.931	0.907	0.911	0.928	0.958	0.877	0.910	0.942	0.980
adj. R^2	0.944	0.946	0.933	0.949	0.906	0.926	0.904	0.907	0.926	0.956	0.868	0.898	0.940	0.978
AIC	340.5	337.1	143.0	124.8	185.4	165.1	381.8	380.9	356.5	290.7	31.05	21.51	221.9	143.4
BIC	351.4	353.5	152.2	138.7	194.7	178.9	392.8	397.3	367.4	306.8	38.19	32.21	231.1	157.2
DW	1.68	1.44	1.62	1.48	1.88	1.24	1.87	1.68	2.14	1.05	1.17	1.69	1.77	1.22
β_π	0.95	1.24	0.88	1.58	1.88	1.13	1.05	1.22	1.11	1.19	-0.39	2.54	1.22	1.20
Mean of														
φ^{FX}	0.0018		0.0000		0.0001		0.0005		0.0001		0.0028		0.0008	
ι^{FX}	0.40		0.99		0.93		0.60		0.91		0.32		0.62	
φ^{cap}	0.61		-0.68		-0.65		0.06		-0.23		-0.23		0.31	
ι^{cap}	0.77		0.86		0.81		0.99		0.81		-		0.86	
ι^{MI}	0.47		0.41		0.43		0.41		0.45		0.49		0.45	

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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	FRA	FRA	GER	GER	IRE	IRE	ITA	ITA	JAP	JAP	NEL	NEL	NEZ	NEZ
β_π	0.163***	0.519***	0.0938	0.0947	0.117**	0.687***	0.113***	0.446***	-0.0434	-0.0410	0.0319	0.177***	0.0853***	0.129***
	(3.26)	(6.48)	(1.33)	(1.23)	(2.62)	(8.88)	(2.80)	(7.18)	(-0.87)	(-0.84)	(0.69)	(2.88)	(4.98)	(3.36)
β_x	0.519***	0.486***	0.332***	0.321***	0.263	0.195	0.467***	0.477***	0.0467	0.0188	0.538***	0.363***	0.174***	0.245***
	(2.65)	(2.90)	(3.72)	(3.55)	(1.44)	(1.44)	(3.06)	(3.77)	(1.28)	(0.52)	(5.38)	(4.65)	(3.25)	(3.72)
ρ_1	0.780***	0.495***	0.899***	0.888***	0.795***	0.368***	0.880***	0.594***	0.967***	0.961***	0.904***	0.846***	0.867***	0.831***
	(12.74)	(6.65)	(16.82)	(14.61)	(12.29)	(5.25)	(18.17)	(9.86)	(39.90)	(39.12)	(23.99)	(19.43)	(29.93)	(25.50)
β_ϱ		-16.17***		0.572		-2.373		-3.000		1.449***		83.44***		1.709
		(-3.25)		(0.76)		(-0.64)		(-1.67)		(2.99)		(6.36)		(0.91)
β_τ		0.505***		0.0226		0.668***		0.413***		0.0166		0.207***		0.0808*
		(5.37)		(0.76)		(8.10)		(6.24)		(0.82)		(2.88)		(1.95)
constant	1.145***	1.598***	0.290	0.362	1.266**	1.645***	0.533	0.945***	0.0297	0.0669	0.498**	0.408**	0.668***	0.728***
	(2.86)	(4.50)	(1.53)	(1.67)	(2.48)	(4.24)	(1.33)	(2.75)	(0.51)	(1.09)	(2.55)	(2.58)	(3.03)	(3.16)
N	75	74	73	73	75	71	75	74	114	114	74	74	112	101
R^2	0.938	0.957	0.959	0.960	0.891	0.944	0.962	0.974	0.983	0.984	0.948	0.972	0.948	0.942
adj. R^2	0.936	0.953	0.958	0.957	0.886	0.940	0.960	0.973	0.982	0.983	0.945	0.970	0.946	0.939
AIC	201.8	175.9	109.1	112.1	259.4	202.5	196.4	164.2	140.1	134.5	124.8	83.36	253.3	227.7
BIC	211.1	189.7	118.3	125.9	268.6	216.1	205.6	178.1	151.0	150.9	134.0	97.19	264.2	243.3
DW	1.70	1.14	0.96	0.93	1.70	0.79	2.00	1.49	1.19	1.21	1.55	1.29	1.56	1.65
β_π	0.74	1.03	0.93	0.84	0.57	1.09	0.94	1.10	-1.33	-1.04	0.33	1.15	0.64	0.76
Mean of														
φ^{FX}	0.0002		0.0024		0.0004		0.0007		0.0024		0.0000		0.0022	
ι^{FX}	0.86		0.33		0.82		0.71		0.37		0.98		0.46	
φ^{cap}	-0.47		0.23		0.69		0.32		0.07		-0.17		0.38	
ι^{cap}	0.73		0.99		0.72		0.71		0.97		0.99		0.89	
ι^{MI}	0.43		0.49		0.44		0.45		0.49		0.41		0.44	

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table continues on next page

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	NOR	NOR	SWE	SWE	ESP	ESP	SWI	SWI	THA	THA	UK	UK
β_π	0.0679**	0.455***	0.106**	0.606***	0.163**	0.853***	0.0228	0.429***	0.151	0.412***	0.0997*	0.169**
	(2.00)	(7.14)	(2.54)	(10.54)	(2.26)	(12.09)	(0.52)	(6.37)	(1.22)	(3.61)	(1.79)	(2.57)
β_x	0.145**	0.0994*	0.145*	0.151***	0.352	0.110	0.0724	0.0600	0.0924	0.0321	0.188*	0.177*
	(2.12)	(1.74)	(1.94)	(2.81)	(1.39)	(0.69)	(1.15)	(1.16)	(1.01)	(0.29)	(1.93)	(1.83)
ρ_1	0.935***	0.655***	0.902***	0.545***	0.797***	0.232***	0.938***	0.712***	0.857***	0.558***	0.876***	0.835***
	(31.20)	(13.30)	(23.81)	(12.34)	(10.89)	(3.67)	(26.71)	(16.71)	(12.01)	(6.67)	(18.80)	(16.52)
β_ϱ		-1.238*		-0.318		-5.703**		0.404		-4.295		-0.971
		(-1.75)		(-0.50)		(-2.17)		(0.64)		(-0.90)		(-1.01)
β_τ		0.417***		0.564***		0.785***		0.333***		0.507***		0.101**
		(6.94)		(9.86)		(12.13)		(7.21)		(6.19)		(2.07)
constant	0.193	0.285*	0.228	0.416***	1.181*	1.857***	0.0829	0.529***	0.152	0.462	0.419*	0.330
	(1.01)	(1.74)	(1.13)	(2.83)	(1.75)	(4.48)	(0.73)	(4.72)	(0.37)	(1.44)	(1.71)	(1.34)
N	114	112	114	113	75	74	114	114	58	58	114	114
R^2	0.956	0.971	0.952	0.976	0.843	0.948	0.915	0.943	0.830	0.905	0.920	0.923
adj. R^2	0.955	0.970	0.951	0.975	0.836	0.944	0.913	0.941	0.821	0.896	0.917	0.919
AIC	284.7	239.0	310.7	235.0	297.2	212.3	244.0	202.4	211.8	182.2	329.1	328.2
BIC	295.7	255.3	321.7	251.3	306.5	226.2	255.0	218.8	220.0	194.6	340.1	344.6
DW	2.31	1.78	2.06	0.65	2.06	1.84	1.61	1.20	2.24	1.40	1.99	1.81
β_π	1.05	1.32	0.80	1.11	1.08	1.33	0.36	1.49	1.06	0.93	0.81	1.02
Mean of												
φ^{FX}	0.0006		0.0007		0.0010		0.0003		0.0023		0.0012	
ι^{FX}	0.59		0.69		0.54		0.63		0.68		0.46	
φ^{cap}	0.36		0.66		0.01		0.36		0.28		0.38	
ι^{cap}	0.69		0.70		0.84		0.99		0.39		0.99	
ι^{MI}	0.48		0.47		0.46		0.45		0.42		0.46	

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Single country regressions of the forward looking Taylor rules

	AUS	AUS	AUT	AUT	BEL	BEL	CAN	CAN	DEN	DEN	EU	EU	FIN	FIN
constant	0.349***	0.274**	0.295	0.102	0.247	0.348**	0.150	0.161	-0.159	0.111	0.697***	0.903***	0.146	0.633***
	(2.76)	(2.48)	(1.31)	(0.44)	(1.47)	(2.28)	(1.04)	(1.18)	(-1.21)	(0.57)	(3.96)	(5.35)	(0.98)	(3.99)
ρ_1	0.872***	0.825***	0.858***	0.874***	0.933***	0.863***	0.924***	0.921***	0.902***	0.828***	0.760***	0.691***	0.899***	0.641***
	(32.03)	(25.20)	(18.84)	(17.69)	(26.70)	(14.10)	(22.73)	(25.40)	(24.28)	(12.58)	(21.92)	(19.07)	(24.16)	(15.21)
γ_π	1.255***	1.324***	1.285***	1.829***	0.391	0.939***	0.770	1.051	2.652***	1.527***	0.00424	-0.0216	1.677***	1.281***
	(5.32)	(9.36)	(3.71)	(3.51)	(0.63)	(2.92)	(0.73)	(1.43)	(4.83)	(3.44)	(0.02)	(-0.13)	(6.62)	(22.21)
γ_x	3.546**	1.784***	2.700***	2.010	6.001	2.945	4.313	4.088	0.220	0.245	0.853***	0.730***	2.146	0.0861
	(2.56)	(2.84)	(3.75)	(1.51)	(1.55)	(1.57)	(1.50)	(1.64)	(0.31)	(0.78)	(9.98)	(10.76)	(1.41)	(0.38)
γ_ϱ		-14.40**		2547.4**		-23.54		-24.77		0.779		3.622***		-7.754**
		(-2.38)		(1.97)		(-0.70)		(-1.00)		(0.21)		(4.38)		(-2.56)
γ_τ		0.315*		-0.149		0.918*		-0.572		1.029**		0.0947		1.013***
		(1.70)		(-0.17)		(1.75)		(-0.70)		(2.29)		(1.08)		(12.21)
N	109	109	70	70	70	70	109	109	109	100	40	39	70	70
Q-stat	39.61	40.99	62.89***	80.87***	23.00	21.47	51.97*	50.13	49.39	42.35	19.92	21.47	34.50	25.51
J	7.680	18.87	18.02**	22.89*	7.537	16.53	17.09*	18.57	7.141	12.01	14.15	14.82	5.042	16.29
Mean of														
φ^{FX}	0.0018		0.0000		0.0001		0.0005		0.0001		0.0028		0.0008	
ι^{FX}	0.40		0.99		0.93		0.60		0.91		0.32		0.62	
φ^{cap}	0.61		-0.68		-0.65		0.06		-0.23		-0.23		0.31	
ι^{cap}	0.77		0.86		0.81		0.99		0.81		-		0.86	
ι^{MI}	0.47		0.41		0.43		0.41		0.45		0.49		0.45	

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Continue of table 8

	FRA	FRA	GER	GER	IRE	IRE	ITA	ITA	JAP	JAP	NEL	NEL	NEZ	NEZ
constant	1.365***	1.265***	0.324**	0.425***	1.304***	1.049***	0.288	0.617**	-0.0133	-0.0469*	0.118	0.377***	0.816***	0.747***
	(3.13)	(3.63)	(2.32)	(2.74)	(3.54)	(3.49)	(0.92)	(2.39)	(-0.68)	(-1.91)	(0.77)	(3.63)	(5.04)	(3.12)
ρ_1	0.735***	0.740***	0.890***	0.839***	0.756***	0.687***	0.912***	0.740***	0.959***	0.962***	0.932***	0.866***	0.853***	0.868***
	(8.35)	(8.39)	(18.78)	(20.94)	(14.07)	(9.10)	(18.55)	(13.42)	(47.62)	(50.04)	(38.50)	(28.84)	(31.77)	(35.54)
γ_π	0.761***	0.808***	0.786**	1.076***	0.808***	1.068***	1.067***	1.126***	1.911***	2.263***	1.916*	0.891***	0.637***	0.576*
	(4.79)	(4.85)	(1.98)	(5.04)	(9.64)	(6.61)	(7.65)	(21.96)	(2.99)	(3.50)	(1.94)	(4.79)	(6.93)	(1.76)
γ_x	2.997***	2.781***	3.947*	2.840***	1.144	1.569*	5.470*	1.834***	0.309	0.162	10.18**	2.783**	1.334**	0.960
	(4.55)	(3.66)	(1.79)	(3.77)	(1.42)	(1.78)	(1.67)	(3.31)	(0.40)	(0.23)	(2.03)	(2.45)	(2.37)	(1.44)
γ_ϱ		-10.48		-7.760*		-35.64*		-13.58**		1.284		449.1***		1.802
		(-0.47)		(-1.72)		(-1.86)		(-2.23)		(0.13)		(3.35)		(0.11)
γ_τ		0.141		0.0169		0.580		0.733***		-0.803		1.362***		0.132
		(0.35)		(0.12)		(1.64)		(3.58)		(-1.44)		(5.28)		(0.37)
N	70	70	68	68	70	63	70	70	109	109	70	70	102	91
Q-stat	20.57	17.30	97.29***	73.71***	37.80	27.86	41.51	35.29	62.88**	60.54**	62.73***	53.93**	74.33***	59.38
J	8.254	12.06	9.529	16.64	15.33*	18.51	7.483	12.74	13.85	20.99	12.64	19.09	7.530	24.05*
Mean of														
φ^{FX}	0.0002		0.0024		0.0004		0.0007		0.0024		0.0000		0.0022	
ι^{FX}	0.86		0.33		0.82		0.71		0.37		0.98		0.46	
φ^{cap}	-0.47		0.23		0.69		0.32		0.07		-0.17		0.38	
ι^{cap}	0.73		0.99		0.72		0.71		0.97		0.99		0.89	
ι^{MI}	0.43		0.49		0.44		0.45		0.49		0.41		0.44	

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table continues on next page

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	NOR	NOR	SWE	SWE	ESP	ESP	SWI	SWI	UK	UK
constant	-0.0118	0.0470	0.161	0.207**	1.429**	1.727***	0.140*	0.164*	0.128	0.128
	(-0.10)	(0.43)	(1.54)	(2.35)	(2.18)	(4.58)	(1.82)	(1.77)	(1.04)	(1.01)
ρ_1	0.975***	0.917***	0.916***	0.804***	0.781***	0.419***	0.898***	0.861***	0.785***	0.793***
	(31.78)	(17.03)	(25.95)	(15.49)	(9.17)	(4.57)	(23.88)	(16.12)	(28.16)	(29.06)
γ_π	1.200	1.381***	0.907**	1.282***	0.668**	1.082***	0.471	1.061***	1.619***	1.651***
	(0.91)	(4.29)	(2.28)	(11.37)	(2.56)	(16.38)	(1.13)	(2.82)	(11.22)	(11.32)
γ_x	13.48	2.299	1.949	0.738*	2.622***	0.818***	1.288**	1.072*	-0.424	-0.388
	(0.74)	(1.04)	(1.38)	(1.93)	(3.28)	(2.58)	(2.10)	(1.92)	(-1.17)	(-1.09)
γ_ϱ		-23.63		-0.378		-9.677*		-4.585		-1.023
		(-1.19)		(-0.14)		(-1.72)		(-1.43)		(-0.44)
γ_τ		0.980**		0.909***		0.858***		0.563*		-0.154
		(2.09)		(4.46)		(8.62)		(1.67)		(-0.73)
N	109	103	109	104	70	70	109	109	109	109
Q-stat	63.28**	61.82**	24.27	49.81**	52.33*	40.38	41.58	37.85	32.36	31.74
J	7.754	14.58	7.852	11.58	8.394	26.60	15.39*	19.96*	11.22	16.34

Mean of	NOR	SWE	ESP	SWI	UK
φ^{FX}	0.0006	0.0007	0.0010	0.0003	0.0012
ι^{FX}	0.59	0.69	0.54	0.63	0.46
φ^{cap}	0.36	0.66	0.01	0.36	0.38
ι^{cap}	0.69	0.70	0.84	0.99	0.99
ι^{MI}	0.48	0.47	0.46	0.45	0.46

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Panel Regression with dummy variables for stable exchange rates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Used dummy variable:	$D^{FX,\varphi\ 50q}$		$D^{FX,\varphi\ 25q}$		$D^{FX,\iota\ 50q}$		$D^{FX,\varphi\ 75q}$		$D^{FX,\ 1\%}$	
ρ_1	0.994***	0.772***	0.995***	0.767***	0.983***	0.767***	0.995***	0.771***	0.984***	0.756***
	(31.37)	(17.28)	(30.56)	(17.57)	(29.02)	(17.65)	(29.80)	(17.00)	(29.02)	(15.49)
ρ_2l	-0.181***	-0.0613	-0.180***	-0.0553	-0.179***	-0.0645	-0.175***	-0.0570	-0.175***	-0.0555
	(-3.01)	(-1.16)	(-2.98)	(-1.01)	(-3.06)	(-1.31)	(-2.91)	(-1.07)	(-2.86)	(-1.01)
ρ_3	0.0897**	0.0583*	0.0902**	0.0584	0.0938**	0.0662*	0.0863**	0.0605*	0.0890**	0.0621*
	(2.10)	(1.66)	(2.07)	(1.58)	(2.29)	(1.92)	(2.03)	(1.69)	(2.13)	(1.77)
$\beta_{\pi,1}$	0.119***	0.294***	0.125***	0.298***	0.138***	0.309***	0.117***	0.287***	0.143***	0.314***
	(9.49)	(9.68)	(9.23)	(10.75)	(11.05)	(10.06)	(11.67)	(9.75)	(8.71)	(9.76)
$\beta_{x,1}$	0.172***	0.122***	0.185***	0.121***	0.174***	0.113***	0.157***	0.118***	0.119***	0.0284
	(6.40)	(4.67)	(5.07)	(3.61)	(4.16)	(3.56)	(5.60)	(4.27)	(2.82)	(0.73)
$\beta_{\varrho,1}$		-0.405		-0.00368		-0.165		-0.204		0.471
		(-1.17)		(-0.01)		(-0.41)		(-0.56)		(0.80)
$\beta_{\tau,1}$		0.211***		0.192***		0.193***		0.209***		0.230***
		(5.82)		(5.38)		(5.90)		(5.87)		(5.34)
$D\rho_D$	0.00884	0.0216	-0.000319	0.00131	0.0127*	0.00753	-0.0106	-0.00473	0.00903	0.0203**
	(0.51)	(1.48)	(-0.04)	(0.19)	(1.94)	(1.06)	(-0.88)	(-0.45)	(0.90)	(2.24)
$D\beta_{\pi,2}$	-0.0196	-0.00945	-0.0195	-0.0149	-0.0463***	-0.0392***	-0.0161	-0.000152	-0.0377*	-0.0435***
	(-0.79)	(-0.50)	(-1.35)	(-1.15)	(-3.35)	(-4.73)	(-1.29)	(-0.02)	(-1.79)	(-3.07)
$D\beta_{x,2}$	-0.122**	-0.0684	-0.0822**	-0.0327	-0.0646	-0.0144	-0.0529	-0.0356	0.0287	0.115**
	(-2.32)	(-1.58)	(-1.97)	(-0.89)	(-1.07)	(-0.43)	(-1.34)	(-0.97)	(0.51)	(2.50)
$D\beta_{\varrho,2}$		1.494**		-0.747		-0.306		-0.205		-0.877
		(2.04)		(-1.47)		(-0.54)		(-0.41)		(-1.41)
$\beta_{\tau,2}$		0.0707*		0.0631***		0.0567***		0.0503**		-0.0232
		(1.73)		(3.08)		(3.18)		(2.50)		(-1.02)
constant	0.191***	0.356***	0.192***	0.376***	0.200***	0.372***	0.211***	0.375***	0.192***	0.363***
	(3.44)	(4.99)	(3.35)	(5.00)	(3.38)	(5.04)	(3.47)	(5.02)	(3.40)	(4.89)
γ_π^{stable}	1.029	1.228	1.106	1.230	0.898	1.164	1.075	1.270	1.032	1.137
γ_π^{flex}	1.231	1.269	1.310	1.295	1.350	1.333	1.247	1.271	1.401	1.320
N	1727	1725	1727	1725	1719	1717	1719	1717	1719	1717
sargan	1254.5	2108.7	1257.0	2105.9	1255.9	2093.8	1251.6	2094.4	1254.0	2081.4
p	0.756	5.22e-11	0.740	6.90e-11	0.740	9.40e-11	0.768	8.89e-11	0.752	3.11e-10
hansen	13.66	11.86	12.30	11.22	11.66	7.928	10.53	7.132	12.52	12.85
p	1	1	1	1	1	1	1	1	1	1
ar1	-3.657	-3.917	-3.650	-3.888	-3.693	-3.917	-3.659	-3.893	-3.644	-3.909
p	0.000255	0.0000895	0.000262	0.000101	0.000222	0.0000898	0.000254	0.0000992	0.000268	0.0000925
ar2	1.011	-1.165	0.828	-0.962	0.833	-1.028	0.737	-1.094	0.729	-1.063
p	0.312	0.244	0.407	0.336	0.405	0.304	0.461	0.274	0.466	0.288

z statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Panel Regression with dummy variables for capital openness

	(1)	(2)	(3)	(4)	(5)	(6)
Used dummy variable:	D^{cap1}_{50q}		D^{cap1}_{25q}		D^{cap2}_{50q}	
ρ_1	0.978***	0.774***	0.982***	0.780***	1.011***	0.713***
	(26.33)	(16.71)	(27.13)	(17.35)	(33.41)	(14.93)
ρ_2	-0.163***	-0.0530	-0.163***	-0.0502	-0.183***	-0.0540
	(-2.70)	(-0.99)	(-2.71)	(-0.93)	(-3.24)	(-1.01)
ρ_3	0.0985**	0.0530	0.0963**	0.0491	0.0838**	0.0697*
	(2.18)	(1.44)	(2.12)	(1.37)	(2.28)	(1.94)
β_π	0.112***	0.282***	0.108***	0.277***	0.114***	0.350***
	(10.23)	(8.43)	(10.41)	(8.88)	(11.81)	(10.25)
β_x	0.138***	0.131***	0.136***	0.123***	0.135***	0.0589
	(4.11)	(4.25)	(5.40)	(4.73)	(3.81)	(1.56)
β_ϱ		-0.232		-0.384		-0.974
		(-0.70)		(-1.15)		(-1.16)
β_τ		0.197***		0.203***		0.304***
		(5.68)		(5.79)		(7.68)
$D\rho_D$	-0.000846	0.0113	-0.0159	0.00391	-0.00197	0.0713***
	(-0.08)	(1.15)	(-1.50)	(0.50)	(-0.12)	(3.10)
$D\beta_{\pi,2}$	-0.0128	0.00441	0.00682	0.0237	0.00482	-0.0722**
	(-0.70)	(0.26)	(0.35)	(1.57)	(0.14)	(-2.04)
$D\beta_{x,2}$	-0.0286	-0.0587*	-0.0512	-0.0765**	-0.0122	0.0802
	(-0.77)	(-1.69)	(-1.64)	(-2.00)	(-0.30)	(1.51)
$D\beta_{\varrho,2}$		-0.180		0.427		0.764
		(-0.43)		(1.01)		(0.89)
$D\beta_{\tau,2}$		0.147***		0.250***		-0.188***
		(3.87)		(3.88)		(-5.97)
constant	0.138***	0.340***	0.142***	0.355***	0.126***	0.351***
	(3.94)	(4.60)	(3.99)	(4.53)	(4.34)	(4.44)
γ_π^{stable}	1.156	1.264	1.346	1.358	1.349	1.027
γ_π^{flex}	1.304	1.244	1.266	1.251	1.294	1.294
N	1955	1721	1955	1721	1965	1618
sargan	1433.3	2126.7	1436.1	2104.4	1417.3	2044.3
sarganp	0.0178	5.47e-12	0.0157	5.13e-11	0.0357	2.57e-13
hansen	13.35	12.87	11.58	6.167	13.66	5.723
hansenp	1	1	1	1	1	1
ar1	-3.658	-3.911	-3.652	-3.873	-3.564	-3.804
ar1p	0.000254	0.0000918	0.000260	0.000107	0.000366	0.000143
ar2	0.721	-1.470	0.628	-1.116	0.410	-1.025
ar2p	0.471	0.142	0.530	0.264	0.682	0.305

z statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Panel Regression with dummy variables for stable exchange rates combined with $D^{cap,\varphi\ 50q}$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Used dummy variable:	D^{FX1}_{50q}		D^{FX1}_{75q}		D^{FX2}_{50q}		D^{FX2}_{75q}		$D^{FX3}_{1\%}$	
ρ_1	0.969***	0.773***	0.966***	0.768***	0.964***	0.770***	0.967***	0.770***	0.967***	0.772***
	(27.22)	(17.75)	(26.94)	(17.40)	(26.79)	(17.08)	(27.12)	(16.85)	(26.86)	(16.58)
ρ_2	-0.161***	-0.0625	-0.161***	-0.0524	-0.162***	-0.0541	-0.157***	-0.0569	-0.162***	-0.0511
	(-2.68)	(-1.18)	(-2.69)	(-0.98)	(-2.78)	(-1.03)	(-2.62)	(-1.06)	(-2.69)	(-0.95)
ρ_3	0.0987**	0.0610	0.0997**	0.0560	0.103**	0.0596	0.0967**	0.0604	0.102**	0.0532
	(2.14)	(1.61)	(2.16)	(1.46)	(2.31)	(1.63)	(2.10)	(1.61)	(2.27)	(1.47)
β_π	0.114***	0.291***	0.119***	0.289***	0.120***	0.286***	0.115***	0.286***	0.120***	0.286***
	(10.45)	(9.40)	(10.43)	(9.30)	(11.05)	(9.26)	(11.92)	(9.20)	(9.67)	(8.83)
β_x	0.147***	0.112***	0.144***	0.113***	0.144***	0.116***	0.144***	0.115***	0.131***	0.100***
	(4.90)	(4.39)	(4.42)	(4.76)	(4.25)	(4.35)	(4.61)	(4.13)	(3.39)	(3.62)
β_ϱ		-0.385		-0.216		-0.161		-0.225		-0.161
		(-1.21)		(-0.70)		(-0.49)		(-0.67)		(-0.51)
β_τ		0.213***		0.203***		0.206***		0.213***		0.200***
		(6.06)		(5.94)		(6.06)		(6.08)		(5.93)
$D\rho_D$	-0.00455	0.0296*	0.00860	0.0141	0.00180	0.00302	-0.00545	0.000620	-0.00293	0.0111
	(-0.20)	(1.77)	(0.91)	(1.27)	(0.17)	(0.30)	(-0.40)	(0.06)	(-0.33)	(1.16)
$D\beta_{\pi,2}$	-0.00440	-0.0128	-0.0271	-0.0114	-0.0314	-0.0108	-0.0311	-0.00231	-0.0244	-0.00760
	(-0.11)	(-0.44)	(-1.38)	(-0.66)	(-1.30)	(-0.62)	(-1.22)	(-0.13)	(-1.04)	(-0.39)
$D\beta_{x,2}$	-0.0954	-0.0697	-0.0342	-0.0520	-0.0386	-0.0489	-0.0675*	-0.0812**	0.0151	0.000350
	(-1.59)	(-1.45)	(-0.88)	(-1.43)	(-1.01)	(-1.34)	(-1.80)	(-1.99)	(0.25)	(0.01)
$D\beta_{\varrho,2}$		1.786*		-0.214		-0.820		-0.242		-0.423
		(1.69)		(-0.34)		(-1.05)		(-0.50)		(-1.17)
$D\beta_{\tau,2}$		0.234***		0.218***		0.146***		0.137***		0.178***
		(2.92)		(5.16)		(4.30)		(2.66)		(5.46)
constant	0.190***	0.350***	0.189***	0.351***	0.200***	0.366***	0.207***	0.371***	0.198***	0.353***
	(3.41)	(5.03)	(3.37)	(4.83)	(3.32)	(4.92)	(3.35)	(4.94)	(3.26)	(4.72)
γ_π^{stable}	1.170	1.215	0.959	1.216	0.933	1.222	0.897	1.254	1.026	1.228
γ_π^{flex}	1.218	1.271	1.243	1.266	1.264	1.270	1.227	1.265	1.288	1.262
N	1721	1721	1721	1721	1713	1713	1713	1713	1713	1713
sargan	1270.9	2123.3	1272.9	2117.8	1262.4	2095.0	1263.4	2089.7	1262.4	2115.6
sarganp	0.635	7.72e-12	0.620	1.36e-11	0.683	5.45e-11	0.676	9.09e-11	0.683	6.83e-12
hansen	14.77	11.21	13.77	13.73	11.79	9.834	13.40	9.969	14.68	12.50
hansenp	1	1	1	1	1	1	1	1	1	1
ar1	-3.676	-3.909	-3.664	-3.880	-3.672	-3.880	-3.689	-3.892	-3.685	-3.861
ar1p	0.000237	0.0000928	0.000248	0.000105	0.000241	0.000104	0.000225	0.0000995	0.000228	0.000113
ar2	0.799	-1.342	0.830	-1.187	0.805	-1.227	0.731	-1.103	0.774	-1.305
ar2p	0.424	0.180	0.407	0.235	0.421	0.220	0.465	0.270	0.439	0.192

z statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Panel Regression with dummy variables for stable exchange rates combined with $D^{cap,\varphi\ 25q}$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Used dummy variable:	D^{FX1}_{50q}		D^{FX1}_{75q}		D^{FX2}_{50q}		D^{FX2}_{75q}		$D^{FX3}_{1\%}$	
ρ_1	0.968***	0.775***	0.969***	0.774***	0.969***	0.777***	0.969***	0.776***	0.969***	0.781***
	(27.15)	(17.15)	(27.18)	(17.08)	(27.59)	(17.26)	(27.37)	(17.05)	(27.68)	(17.23)
ρ_2	-0.160***	-0.0610	-0.162***	-0.0533	-0.162***	-0.0478	-0.159**	-0.0585	-0.162***	-0.0502
	(-2.69)	(-1.10)	(-2.69)	(-0.99)	(-2.68)	(-0.88)	(-2.57)	(-1.07)	(-2.67)	(-0.93)
ρ_3	0.0993**	0.0609	0.0997**	0.0540	0.100**	0.0478	0.0976**	0.0577	0.0999**	0.0476
	(2.14)	(1.57)	(2.16)	(1.45)	(2.17)	(1.30)	(2.06)	(1.55)	(2.18)	(1.34)
β_π	0.114***	0.284***	0.115***	0.285***	0.114***	0.280***	0.112***	0.283***	0.115***	0.278***
	(10.91)	(9.27)	(10.56)	(9.19)	(10.60)	(9.26)	(11.33)	(9.36)	(10.13)	(9.05)
β_x	0.142***	0.116***	0.146***	0.122***	0.147***	0.120***	0.148***	0.118***	0.137***	0.113***
	(5.37)	(4.99)	(5.09)	(5.10)	(5.11)	(5.05)	(5.26)	(4.59)	(4.41)	(4.29)
β_ϱ		-0.343		-0.359		-0.346		-0.255		-0.319
		(-1.09)		(-1.13)		(-1.04)		(-0.77)		(-1.00)
β_τ		0.214***		0.210***		0.207***		0.213***		0.206***
		(6.14)		(6.07)		(6.08)		(6.24)		(6.05)
$D\rho_D$	-0.0401**	0.00148	-0.0180	0.000557	-0.0310***	-0.00875	-0.0486***	-0.0217*	-0.0138	0.00627
	(-2.01)	(0.11)	(-1.42)	(0.06)	(-2.64)	(-0.86)	(-3.25)	(-1.83)	(-1.23)	(0.61)
$D\beta_{\pi,2}$	-0.0166	0.0122	-0.0185	0.00639	-0.0166	0.00742	0.0105	0.0354	-0.0149	0.0123
	(-0.68)	(0.53)	(-0.79)	(0.32)	(-0.61)	(0.36)	(0.32)	(1.42)	(-0.59)	(0.70)
$D\beta_{x,2}$	-0.0346	-0.0594	-0.0560**	-0.0841**	-0.0639*	-0.0751*	-0.135**	-0.158***	-0.00487	-0.0330
	(-0.78)	(-1.58)	(-2.16)	(-2.27)	(-1.83)	(-1.71)	(-2.48)	(-3.27)	(-0.12)	(-0.73)
$D\beta_{\varrho,2}$		1.444		1.085		1.003		0.369		0.352
		(1.14)		(1.44)		(1.19)		(0.84)		(0.85)
$D\beta_{\tau,2}$		0.273**		0.335***		0.289***		0.273***		0.296***
		(2.46)		(4.83)		(4.64)		(3.39)		(5.43)
constant	0.207***	0.366***	0.202***	0.369***	0.210***	0.380***	0.213***	0.381***	0.200***	0.360***
	(3.38)	(4.95)	(3.45)	(4.92)	(3.36)	(4.97)	(3.47)	(4.99)	(3.30)	(4.64)
γ_π^{stable}	1.045	1.319	1.035	1.291	1.060	1.289	1.322	1.415	1.078	1.309
γ_π^{flex}	1.223	1.265	1.233	1.263	1.240	1.256	1.209	1.257	1.239	1.254
N	1721	1721	1721	1721	1713	1713	1713	1713	1713	1713
sargan	1261.7	2105.5	1268.6	2104.4	1260.2	2090.4	1263.2	2089.2	1265.2	2103.7
sarganp	0.701	4.64e-11	0.652	5.14e-11	0.698	8.49e-11	0.677	9.56e-11	0.662	2.28e-11
hansen	14.63	9.430	15.18	9.221	7.886	6.094	10.70	11.13	15.39	6.061
hansenp	1	1	1	1	1	1	1	1	1	1
ar1	-3.687	-3.837	-3.674	-3.824	-3.684	-3.847	-3.680	-3.865	-3.679	-3.850
ar1p	0.000227	0.000125	0.000239	0.000131	0.000229	0.000120	0.000233	0.000111	0.000234	0.000118
ar2	0.663	-1.046	0.799	-0.935	0.801	-0.988	0.801	-1.006	0.771	-1.070
ar2p	0.508	0.296	0.424	0.350	0.423	0.323	0.423	0.314	0.441	0.284

z statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Panel Regression with dummy variables for stable exchange rates combined with $D^{cap,\iota\ max}$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Used dummy variable	D^{FX1}_{50q}		D^{FX1}_{75q}		D^{FX2}_{50q}		D^{FX2}_{75q}		$D^{FX3}_{1\%}$	
ρ_1	0.997***	0.763***	0.992***	0.759***	0.977***	0.763***	0.984***	0.766***	0.989***	0.771***
	(33.74)	(16.63)	(33.09)	(16.24)	(28.13)	(16.57)	(31.26)	(17.07)	(31.81)	(17.19)
ρ_2	-0.182***	-0.0466	-0.178***	-0.0430	-0.146**	-0.0399	-0.166***	-0.0544	-0.173***	-0.0563
	(-2.99)	(-0.81)	(-2.94)	(-0.74)	(-2.20)	(-0.66)	(-2.75)	(-1.02)	(-2.81)	(-1.04)
ρ_3	0.0861*	0.0553	0.0874**	0.0558	0.0703	0.0517	0.0834**	0.0628*	0.0870**	0.0616*
	(1.94)	(1.44)	(2.01)	(1.47)	(1.60)	(1.32)	(1.98)	(1.71)	(2.01)	(1.67)
β_π	0.119***	0.288***	0.120***	0.289***	0.117***	0.284***	0.119***	0.286***	0.117***	0.280***
	(14.73)	(9.11)	(13.70)	(9.17)	(15.53)	(8.94)	(15.18)	(9.10)	(15.19)	(8.55)
β_x	0.142***	0.109***	0.139***	0.106***	0.135***	0.103***	0.136***	0.105***	0.132***	0.102***
	(5.14)	(3.83)	(5.27)	(3.85)	(5.28)	(3.94)	(5.20)	(3.85)	(5.64)	(4.07)
β_ϱ		-0.337		-0.335		-0.346		-0.344		-0.349
		(-1.04)		(-1.04)		(-1.08)		(-1.08)		(-1.09)
β_τ		0.224***		0.223***		0.219***		0.219***		0.217***
		(5.83)		(5.80)		(5.72)		(5.78)		(5.56)
$D\rho_D$	0.0750	0.138***	-0.0153	0.0595*	-0.128**	-0.0351**	-0.177***	-0.0958***	-0.146***	-0.0563***
	(0.92)	(4.17)	(-0.18)	(1.73)	(-2.09)	(-2.34)	(-3.07)	(-11.07)	(-4.62)	(-3.37)
$D\beta_{\pi,2}$	-0.148	-0.136***	-0.0228	-0.0608	0.190***	0.164***	0.237***	0.237***	0.205***	0.184***
	(-1.58)	(-3.46)	(-0.13)	(-0.70)	(3.98)	(6.80)	(4.10)	(17.54)	(2.85)	(18.26)
$D\beta_{x,2}$	0.667	1.545***	0.429	0.452	0.110	0.169***	-0.0773	0.255***	0.0331	0.218***
	(0.50)	(3.44)	(0.56)	(0.81)	(0.40)	(3.49)	(-0.09)	(3.16)	(0.26)	(3.18)
$D\beta_{\varrho,2}$		156.2***		104.8***		111.0***		119.4***		89.66**
		(6.93)		(13.32)		(5.21)		(12.02)		(2.42)
$D\beta_{\tau,2}$		-0.330***		-0.0268		-0.0504		-0.0113		0.0617
		(-5.47)		(-0.17)		(-0.39)		(-0.54)		(0.94)
constant	0.213***	0.374***	0.215***	0.377***	0.224***	0.371***	0.222***	0.369***	0.215***	0.373***
	(3.94)	(5.16)	(3.96)	(5.19)	(3.94)	(4.95)	(3.88)	(4.88)	(3.71)	(4.95)
γ_π^{stable}	-0.287	0.667	0.985	0.997	3.118	1.991	3.603	2.317	3.321	2.079
γ_π^{flex}	1.213	1.269	1.215	1.263	1.188	1.262	1.200	1.267	1.209	1.254
N	1619	1618	1619	1618	1611	1610	1611	1610	1611	1610
sargan	1224.6	1998.0	1215.2	1993.1	1208.0	1970.8	1215.7	1986.4	1212.9	1942.4
sarganp	0.711	3.55e-11	0.773	5.83e-11	0.804	2.21e-10	0.758	4.62e-11	0.775	3.32e-09
hansen	12.01	10.57	13.58	12.69	13.22	12.83	9.179	5.929	13.79	6.686
hansenp	1	1	1	1	1	1	1	1	1	1
ar1	-3.490	-3.739	-3.532	-3.766	-3.502	-3.708	-3.509	-3.726	-3.541	-3.781
ar1p	0.000483	0.000185	0.000412	0.000166	0.000462	0.000209	0.000451	0.000195	0.000399	0.000156
ar2	0.904	-1.141	0.587	-1.146	-0.00586	-1.171	1.025	-0.957	0.726	-1.076
ar2p	0.366	0.254	0.557	0.252	0.995	0.241	0.305	0.339	0.468	0.282

z statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

B Figures

Figure 1: Development of Inflation over time for all countries

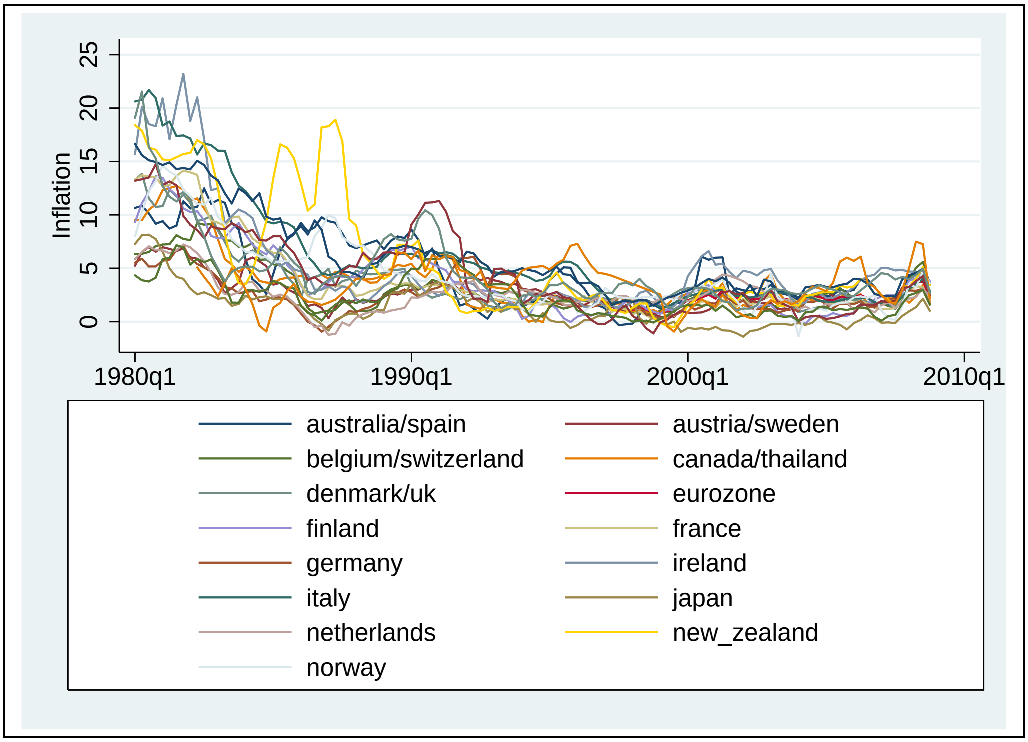


Figure 2: Histogram of Taylor rule components

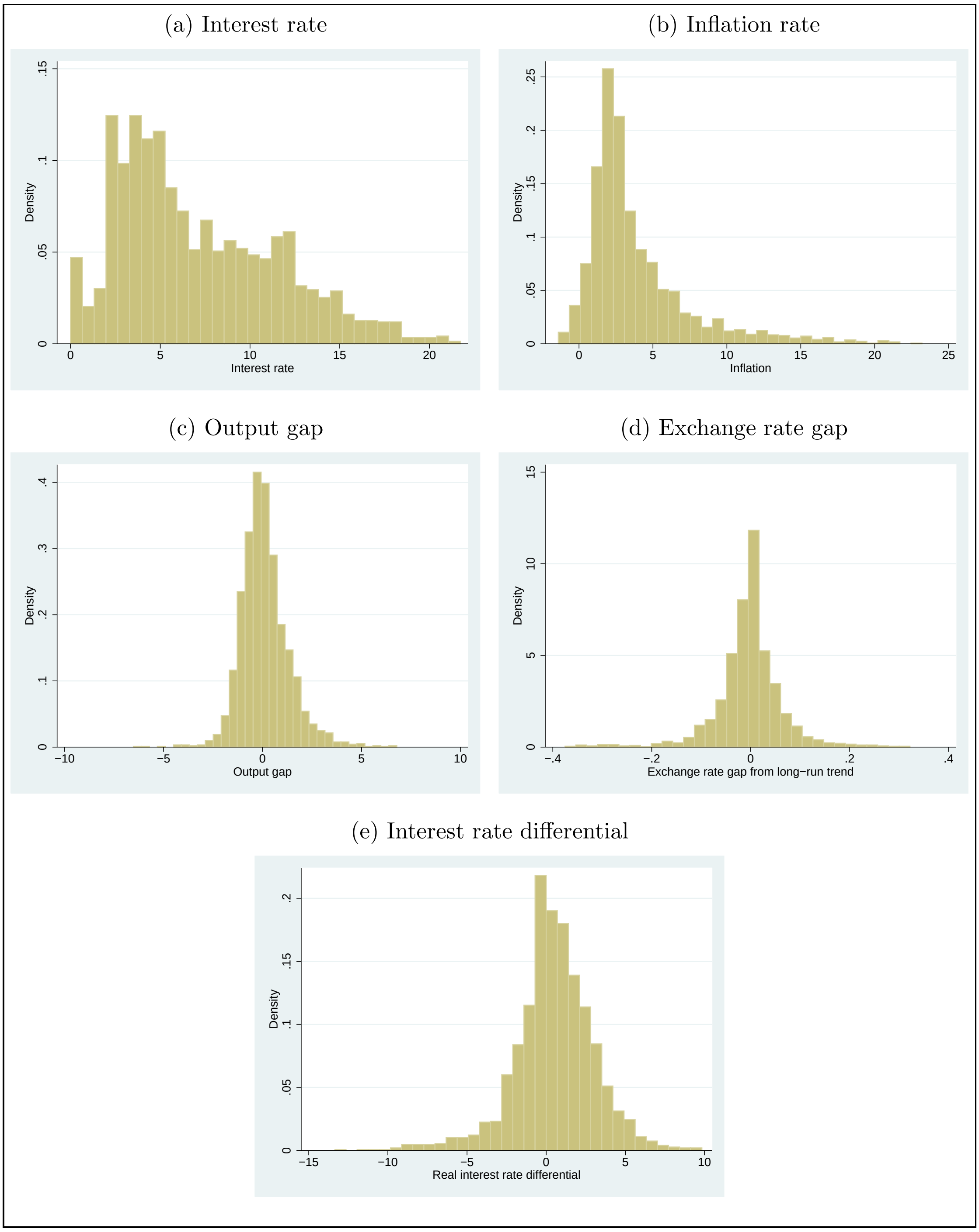
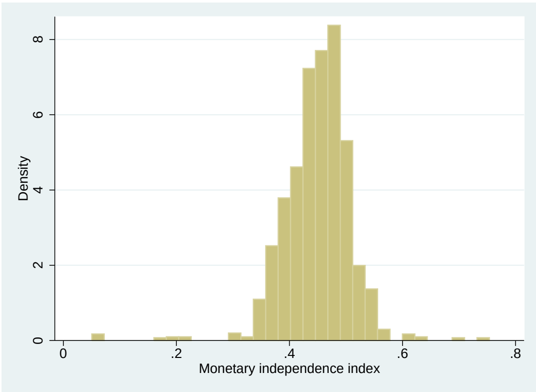
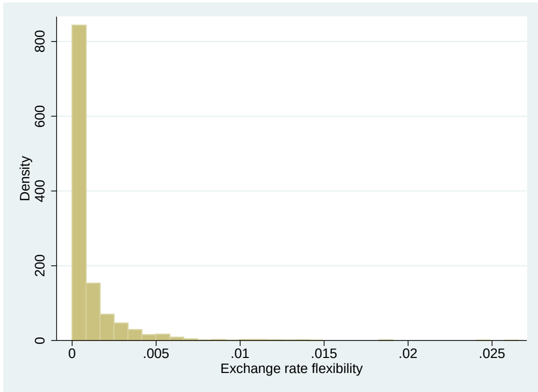


Figure 3: Histogram of trilemma variables

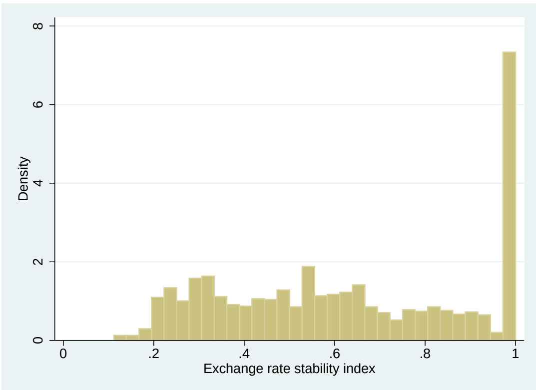
(a) Monetary independence index



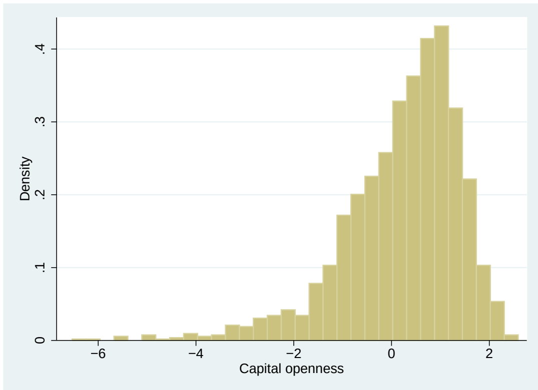
(b) Exchange rate flexibility



(c) Exchange rate stability index



(d) Capital openness



(e) Capital openness index

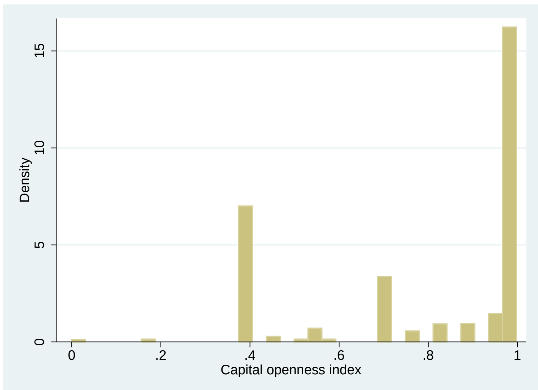


Figure 4: Scatter plots of the trilemma variables for the functional coefficient model

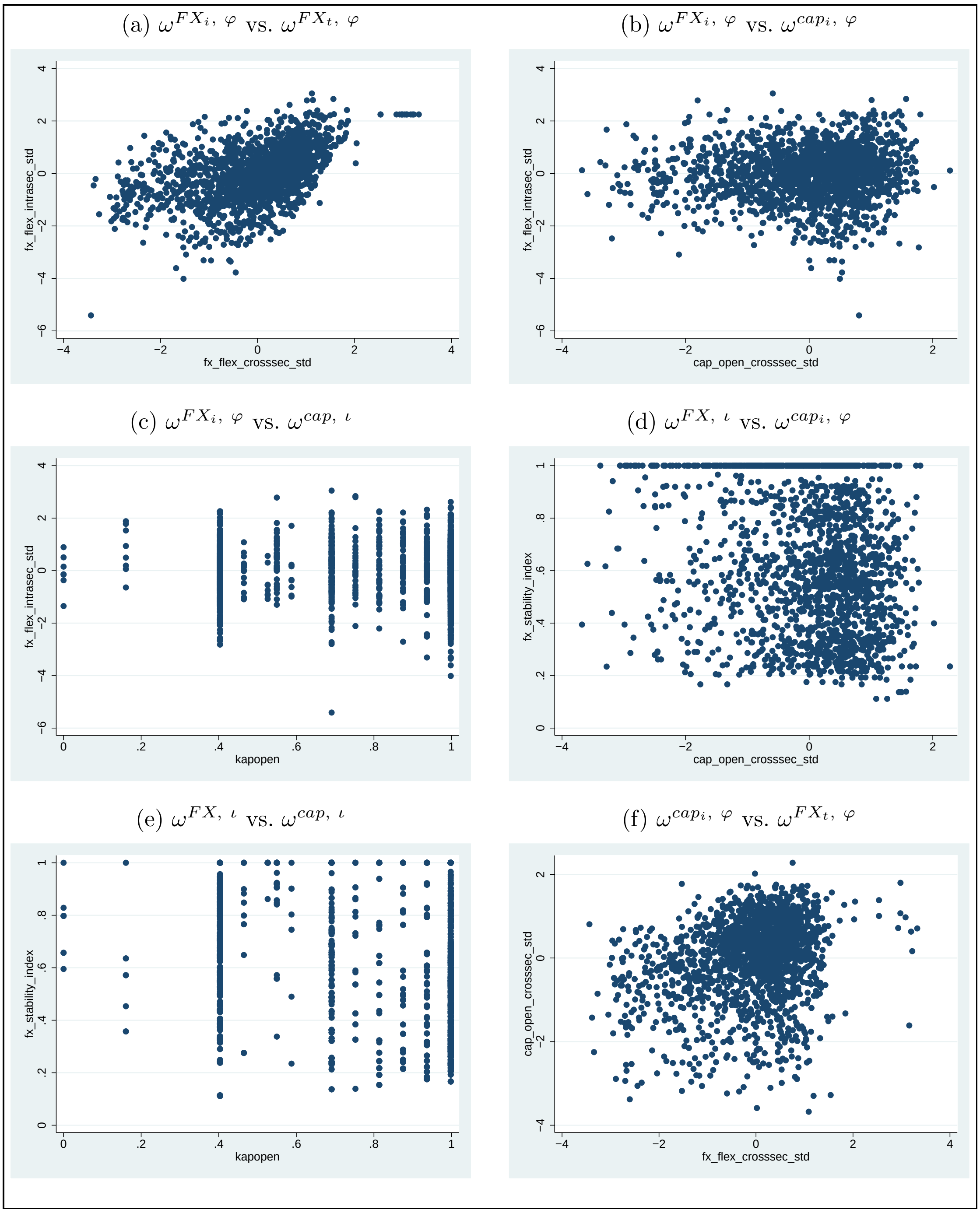
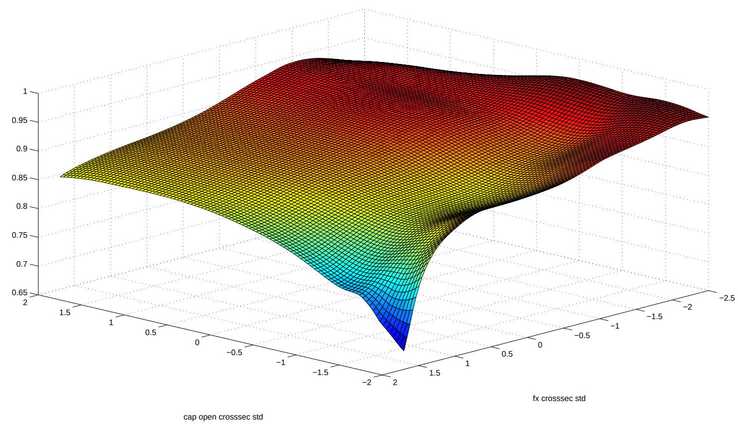
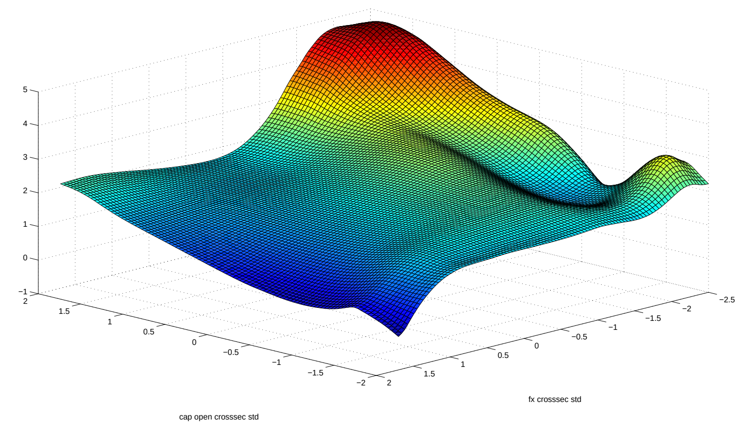


Figure 5: Functional coefficient model results for $\omega^{FX,\, t\varphi}$ vs. $\omega^{cap_t,\, \varphi}$

(a) Interest rate smoothing



(b) Output gap



(c) Inflation rate

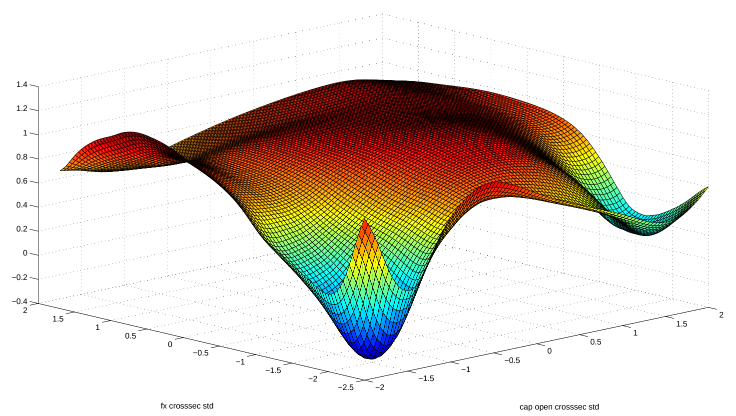
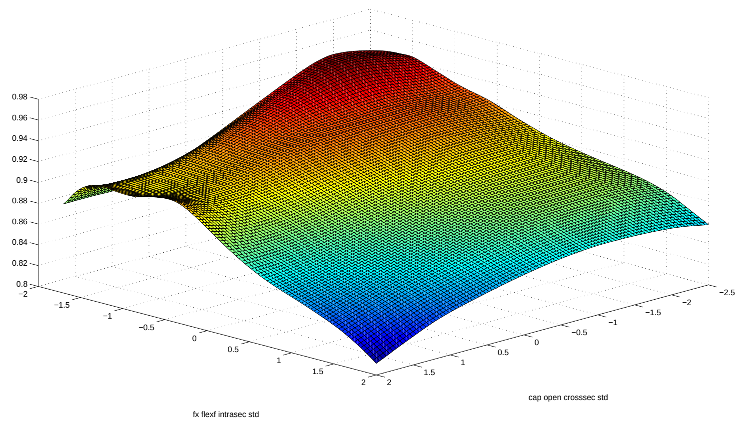
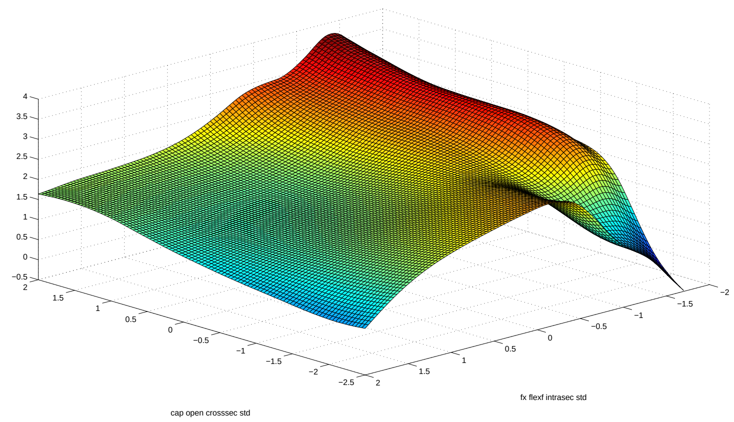


Figure 6: Functional coefficient model results for ω^{FX_i},φ vs. ω^{cap_t},φ

(a) Interest rate smoothing



(b) Output gap



(c) Inflation rate

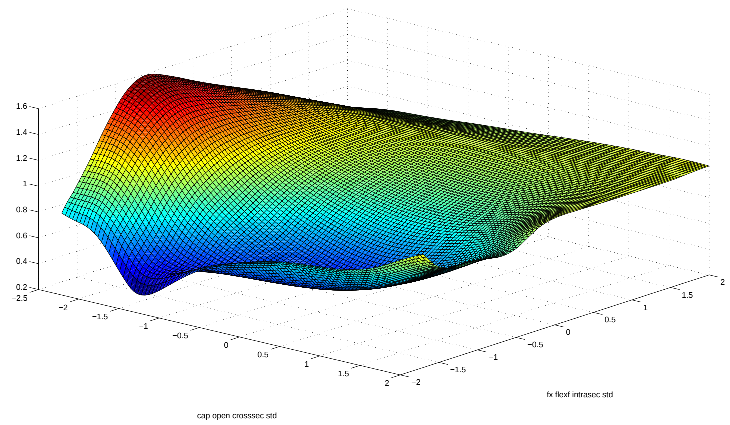
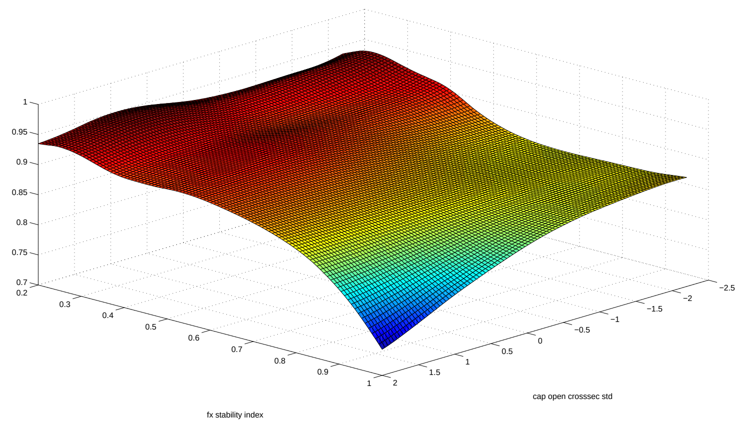
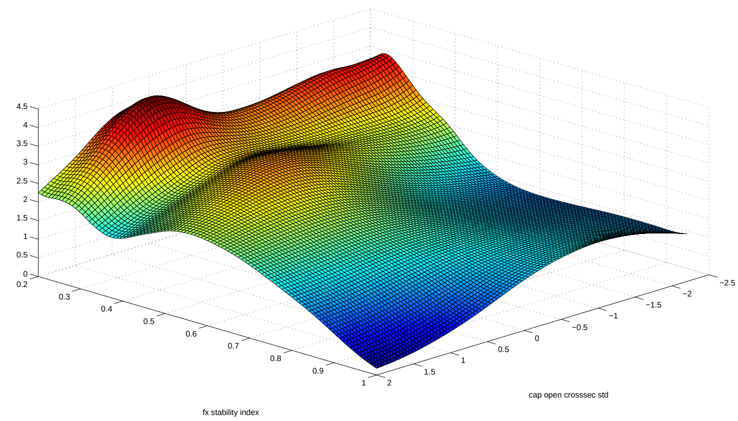


Figure 7: Functional coefficient model results for $\omega^{FX,\ \iota}$ vs. $\omega^{cap_t,\ \varphi}$

(a) Interest rate smoothing



(b) Output gap



(c) Inflation rate

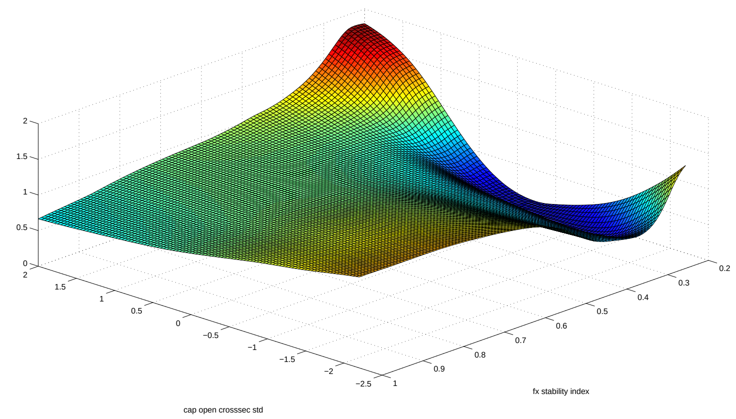
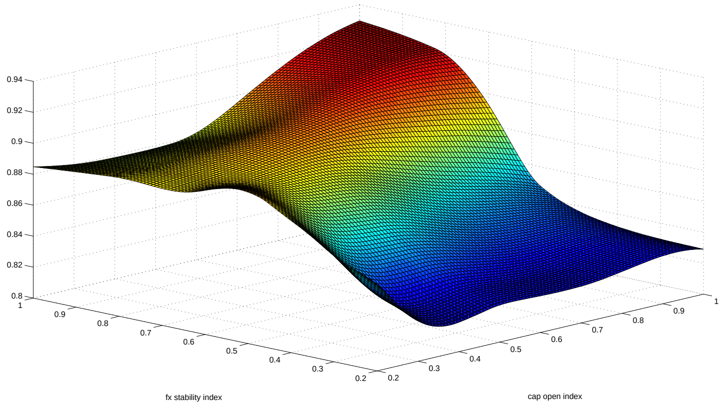
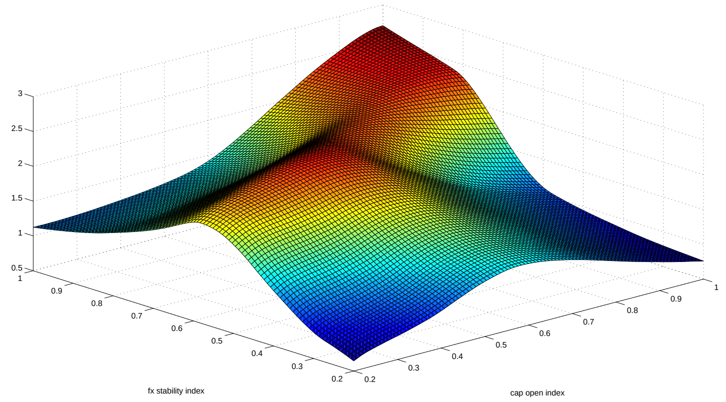


Figure 8: Functional coefficient model results for $\omega^{FX,\,\iota}$ vs. $\omega^{cap,\,\iota}$

(a) Interest rate smoothing



(b) Output gap



(c) Inflation rate

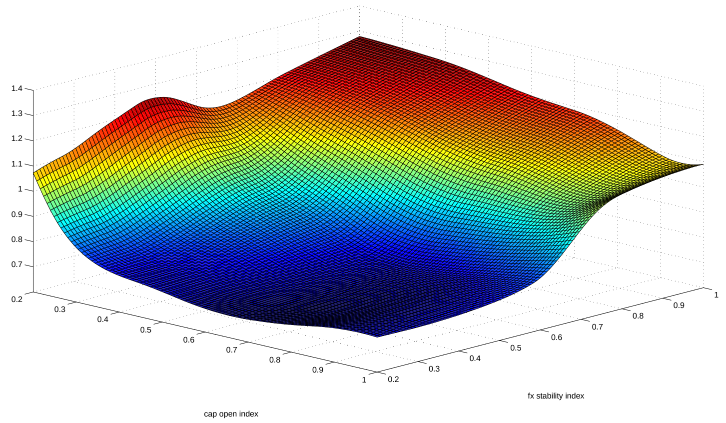
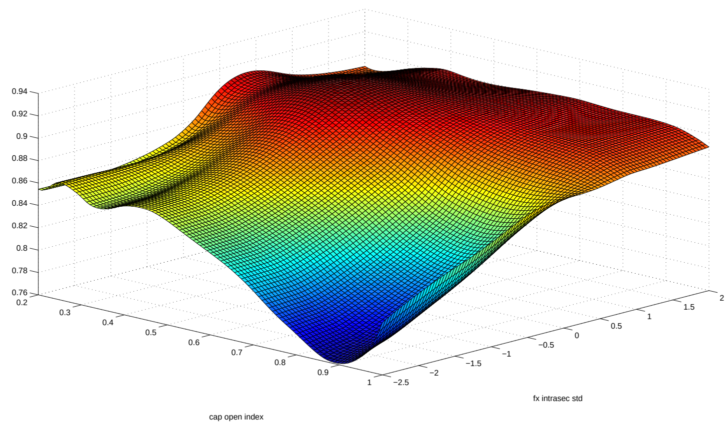
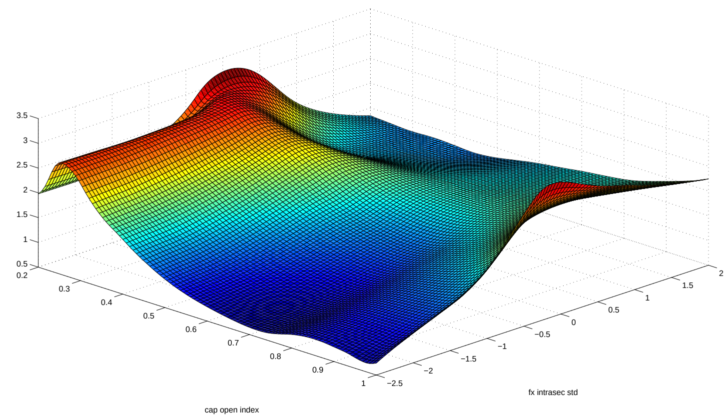


Figure 9: Functional coefficient model results for $\omega^{FX_i,\, \varphi}$ vs. $\omega^{cap,\, \iota}$

(a) Interest rate smoothing



(b) Output gap



(c) Inflation rate

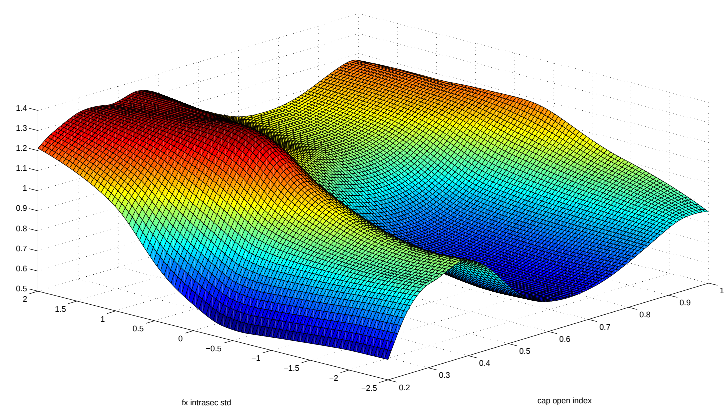
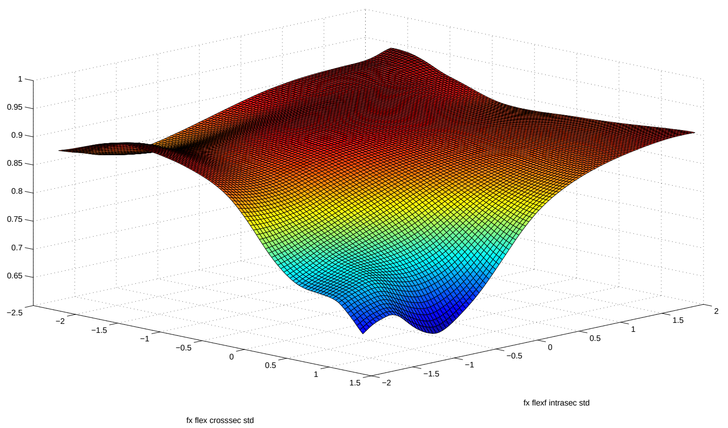
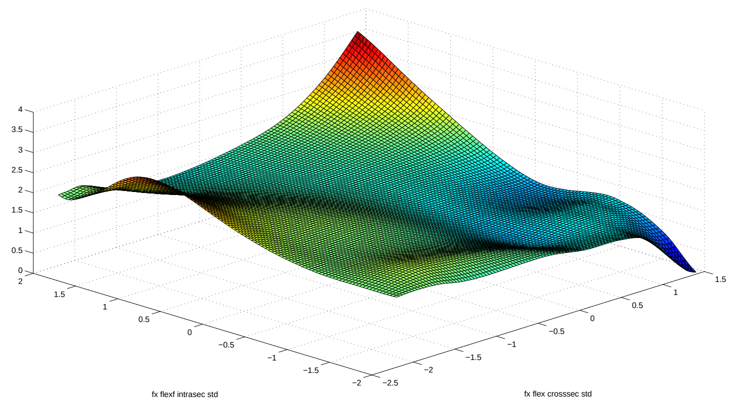


Figure 10: Functional coefficient model results for $\omega^{FX_i},\, \varphi$ vs. $\omega^{FX_t},\, \varphi$

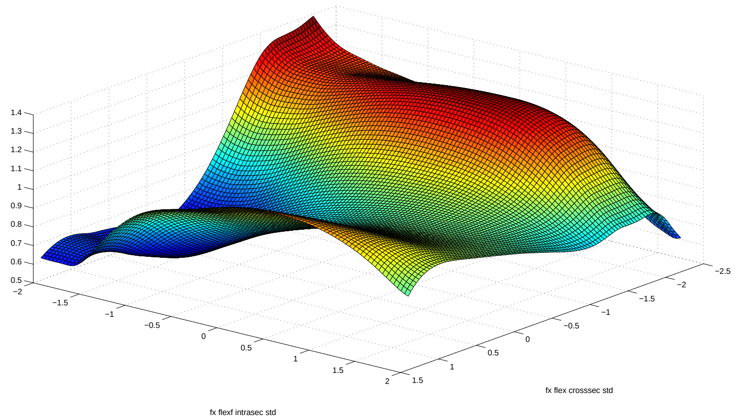
(a) Interest rate smoothing



(b) Output gap



(c) Inflation rate



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