ROME
Research On Money in the Economy

No. 17-05 – April 2017

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ROME Discussion Paper Series

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ISSN 1865-7052

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Abstract

This paper estimates the role of policy and exchange rate uncertainty shocks for EU countries' exports to the world economy. We examine the performance of the four biggest economies, namely Germany, France, Italy and the UK, under policy and exchange rate uncertainty in exports to some of the most important global export destinations (United States, Japan, Brazil, Russia, and China).

For this purpose, we apply a non-linear model, where suddenly strong spurts of exports occur when changes of the exchange rate go beyond a zone of inaction, which we call "play" area – analogous to mechanical play. We implement an algorithm describing path-dependent play-hysteresis into a regression framework. The hysteretic impact of real exchange rates on exports is estimated based on the period from 1995M1 to 2015M12. Looking at some of the main export destinations of our selected EU member countries, the United States, Japan and some of the BRICs (Brazil, Russia and China), we identify significant hysteretic effects for a large part of the EU member countries' exports. We find that their export activity is characterized by "bands of inaction" with respect to changes in the real exchange.

To check for robustness we estimate export equations for limited samples (a) excluding the recent financial crisis and (b) excluding the period up to the burst of the dotcom bubble and September 11th. In addition, we employ an economic policy uncertainty variable and an exchange rate uncertainty variable as determinants of the width of the area of weak reaction of exports. Overall, we find that those specifications which take uncertainty into account display the best goodness of fit, with economic policy uncertainty dominating exchange rate uncertainty. In other words: the option value of waiting dominates the real exchange rate effect on the EU member countries' exports.

JEL-Classification: F14, C51

Keywords: export demand, global economy, hysteresis, policy uncertainty, BRICs, play-hysteresis, real exchange rate, switching/spline regression

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by
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Acknowledgments: We are grateful for valuable comments to Menzie Chinn, Laurent Ferrara; Matthias Goecke, Reinhard Neck, Barbara Rossi and participants at the 2[nd] Workshop on Uncertainty "Impact of Uncertainty Shocks on the Global Economy", May 12-13, 2016, London, and the 2015 Annual Conference auf the Austrian Economic Association (NoeG), Alpen-Adria University of Klagenfurt, where parts of this paper were presented as a keynote lecture.

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1. Introduction

This paper investigates and estimates the role of economic policy and exchange rate *uncertainty* shocks for some important EU member countries' exports to the world economy. It does so in a micro-founded macroeconomic *hysteresis* context. Hysteresis becomes valid if relations between economic variables are characterized by a situation where initial conditions and the past realizations of economic variables matter. Expressed differently, past (transient) exogenous disturbances and past states of the economic system do have an influence on the current economic relations (Belke, Goecke and Werner, 2014). A typical example is the *dynamics of the nexus of exchange rate and exports* which is assessed here for four EU member countries later on. In this context, the economic policy uncertainty index is applied to the estimation of export equations for the first time.

While appearing a rather technical issue at first glance, this is a highly relevant topic in several dimensions. In periods of euro appreciation, for instance, European politicians and business representatives of the exporting industries have frequently been concerned with the external value of the European currency. Indeed, concerns have been raised nearly every time when the euro appreciated (Dow Jones International News 2007). This statement implies that beyond some boundaries ("*pain threshold*"), stronger export reactions to an exchange rate change are expected.

In this regard, it is important to analyze in how far the euro might be *too strong* for specific euro area member countries. This was also an issue for EU member states that were not part of the European Monetary Union (EMU) such as the UK for which the benefits of the Sterling depreciation in terms of export promotion in the wake of the Brexit have been discussed intensively (Giugliano, 2015).

The reverse question of whether the external value of the domestic currency is low enough to stimulate exports is also of interest. In this case, lower real exchange rate triggers expressing "competiveness" could be derived which result in spurts for our selected EU countries' exports ("*export triggers*", Belke and Kronen, 2016).

In this paper we focus on the export performance of the four biggest economies in the European Union, namely Germany, France, Italy and the UK. We examine their respective export performance under policy and exchange rate uncertainty and, for this purpose, look at some of the most important global export destinations (United States, Japan, and the BRICs Brazil, Russia, and China). We do so by differentiating between intervals of weak and strong reaction of their exports to real exchange rate changes.

Our final selection of destination countries is predominantly made according to the trade exposure criterion. While the United States and Japan, with their relatively large shares at total exports of Germany, France, Italy and the UK, are natural and standard candidates (Belke, Goecke and Guenther, 2013) we also explicitly focus on the BRICs whose importance for economic growth in industrialized countries such as Germany has become particularly obvious after the financial crisis (Belke, Dreger and Dubova, 2016).

The remainder of this contribution proceeds as follows. Section 2 illustrates the importance of uncertainty in EU exports highlighting some stylized facts for the countries analyzed in this paper. In section 3, we present a simple model which serves to capture the non-linear hysteresis-type dynamics inherent in the relation between exchange rate and exports. Taking this model as a starting point, we develop an algorithm describing (macroeconomic) play-hysteresis and implement it into a regression framework in section 4. In section 5, we estimate the exchange rate impacts on German, French, Italian and UK exports to some export destinations such as the United States, Japan and some of the BRICs (Brazil, Russia and China[1]), differentiating between intervals of weak and strong reaction. Section 6 presents some robustness checks. We (a) estimate the German, French, Italian and UK export equations for a limited sample excluding the recent financial crisis, and (b) employ an economic policy uncertainty and an exchange rate uncertainty variable as determinants of the width of the area of weak reaction. The latter yields a more variable play area for our algorithm, a more sophisticated procedure to consider uncertainty in the international trade context. We argue that the policy uncertainty variable may also serve as a proxy of financial constraints of exporting firms, at least in countries of the Southern part of the euro area. Section 7 finally concludes and comes up with some tasks for further research.

2. EU exports, hysteresis and uncertainty: stylized facts

In this section we present stylized facts about EU member countries' exports, hysteresis and uncertainty to better justify the specifications of our export equations and interpret the country-specific estimation results later on.

2.1 The BRICs as an important export destination and uncertainty

Due to their fast catching-up in income, the BRIC countries account for 30 percent of world GDP at the current edge, as expressed in PPPs. The BRICs have been the primary source for global GDP growth before the financial crisis until the first years thereafter. The rebound from the crisis started earlier in many emerging markets, evolved much faster than in advanced economies (Belke, Dreger and Dubova, 2016, Fedoseeva and Zeidan, 2016). In other words, there

[1] India and South Africa are anyway less important export destination countries for EU member countries than the other BRICS countries and have been left out due to a lack of sound data.

is some reason to believe that BRICs have become an important export destination for EU countries and we may thus feel highly legitimized to include them in our analysis.

However, despite the fact that a modest recovery in the industrial countries seems to be on its way, GDP growth in the BRICs started to decline in the most recent years. Although differences across countries are striking, the slowdown is synchronized to some extent. While the acceleration of output is still high in India (a country not included in our study due to data non-availability), the Chinese economy experienced lower growth and countries like Brazil and Russia even entered a recession. In terms of the BRIC aggregate, growth not only fell below the post-crisis peak of 2010/11, but even below the rates in the pre-crisis decade. Due to the increasing role of emerging markets in the global economy, a stronger slowdown could imply *high uncertainty* in the years ahead for global growth in general and more specifically for the exports of EU countries under investigation here (Belke, Dreger and Dubova, 2016, Wright, 2015).

This high uncertainty relates to the future economic development of the BRICs. The longevity of their economic catch-up process also is a function of the social and institutional framework of an economy and its infrastructure. These factors may imply uncertainty with respect to the future dynamics of BRIC growth. All indicators evaluating the overall framework conditions still reveal a significant gap between the BRICs and industrialized economies. These data also show a clear development gap between the individual BRIC countries (Erber and Schrooten, 2012, Wright, 2015). Therefore, EU member countries' exports will face some BRIC-related uncertainty (combined with geopolitical risks) in the future.

A closer look into a *practical example* seems useful in this regard at this stage. Figure 1 deals with UK exports to the United States (exports in million EUR, exchange rate in Pound Sterling/US-dollar). According to this Figure, from the huge depreciation of the Pound Sterling around 2007/08, where the exchange rate fell from 2.87 in July 2008 to 1.85 in November 2008 which more or less persists until today, a rather flat development of the external value of the

Pound Sterling vis-à-vis the US Dollar is accompanied by more or less flat UK exports to the US. What is more, the strong reversal of the exchange rate movement after the pound depreciation starting at the turn-of-the-century does not seem to have overly strong negative effects on exports in the next eight years or so which show a rather smooth course in the two thousands. However, an ongoing one-directional further real appreciation should have led to a more significant negative effect on UK exports to the US.

- Figure 1 about here -

This pattern of a *delayed reaction of exports* to a change in exchange rates is *not a singular case*. In the post-crisis period, several countries have undergone large episodes of depreciation- combined with decreasing export volumes, leading to a *disconnection in the traditional relationship* between the real effective exchange rate (REER) and export performance.[2] D*ilutions of the REER-export relationship* are even more common than REER-export disconnects. (IMF, 2015): "Dilutions in the REER-export relationship occur when the relationship is still in line with theoretical expectations (i.e., rising exports when the REER depreciates), but exports are far less responsive than expected based on historical estimates". More generally, a weak and sometimes asymmetric impact of the exchange rate on exports is fully in line with recent developments of empirical trade literature (see, e.g., Fedoseeva and Zeidan, 2016, and Verheyen, 2013). This is exactly where our export hysteresis under uncertainty approach kicks in.

2.2 Weak reaction of EU countries' exports to exchange rate changes: the drivers

What are the reasons behind a *weak reaction* of EU countries' exports to small exchange rate movements (with a varying direction)? To answer this question, let us first address the usual

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2 This puzzle is most notably present in Japan. From 2011 to 2014, the Japanese REER depreciated by almost 30 percent; over the same period its export volumes fell by 0.6 percent. See IMF (2015).

candidates generally applied to industrialized countries' exports: hedging of exchange rate uncertainty, low price elasticity of exports, pricing-to-market, significant (sunk) market entry or/and exit costs and, since the financial crisis, also exporters' refinancing constraints, i.e. financial uncertainty which appears highly correlated with policy uncertainty.

Countries' export product line and price elasticity of exports: Exports to non-euro area countries respond particularly weakly to price competitiveness, especially when looking at the German economy (Belke, Goecke and Guenther, 2013, and Deutsche Bundesbank 2008). Equipment and vehicles are the dominating products of Germany's industrial production. Being highly specialized in these groups of production Germany is still a technological world market leader. This results in importers not being able or willing to switch to an alternative of supply even if the currency in Germany (the euro) appreciates in real terms, as the occurring switching costs prevent them from doing so. Specialized sectors may also be dominant for French (aircraft) and British trade (motor vehicles), but on the whole German specialization is more profound. The main export branch of Italy is the export of medicaments which is also a strong sector for both France and the UK. Considering the exports of all four exporting countries indicates a stronger evidence of hysteresis for the highly specialized German exports compared to the exports of the three other countries analyzed in this paper.

Hedging of exchange rate uncertainty: When looking at the short run, the extent of cross currency hedging and the selection of the currency of computation play a major role in the case of a merely transitory real appreciation of the home currency. These hedging activities dampen the pressure to appreciate only for a limited time period, even if a bigger amount of foreign receivables in the export business are hedged against exchange rate losses for some time (Belke and Kronen, 2016, for German exports see Deutsche Bundesbank, 2008).

Pricing-to-market by exporting firms: Due to a pricing to market strategy, EU countries' export prices may show a weak cost pass-through. A real appreciation is then mainly absorbed by a reduction in the profit margin (Gagnon and Knetter, 1995, Stahn, 2007). According to Fedoseeva and Zeidan (2016) exchange rates are not the main driving force in determining the EU countries' exports to the BRICs. A pricing-to-market strategy is not usually used by exporters to protect the market shares in BRIC markets.

Sunk market entry or/and exit costs:

A variety of research in international economics using both theoretical analysis and the assessment of data on the firm level postulate that "sunk costs matter" (Godart, Goerg and Goerlich, 2009). Establishing a global export network results in major set-up costs which cannot be recovered completely when leaving the market and dissolving international relationships. More concrete examples of costs occurring when entering a market are the gathering of crucial information such as market research, establishing distribution and service networks, making the brand recognizable and adjusting the quality of products to local health regulations (Belke and Kronen, 2016). These costs cannot be recovered completely when exiting the market. They have to be considered as (at least partially) irreversible investments (Belke, Goecke and Werner, 2014, Kannebley, 2008, Roberts and Tybout, 1997). The export status over time is therefore quite persistent over time for German firms (Bernard and Wagner, 2001).

Following the recent crisis another important factor has to be added to the list: *(re)financing uncertainty* whose relevance is not only evident in the seminal Greek case, but also in some euro are member countries in the periphery and is closely correlated with euro are policy uncertainty (Pástor and Varonesi, 2011, Belke and Kronen, 2016, and the references cited therein).

A high level of uncertainty generally has the potential to raise the cost of capital, due to the macroeconomic character of policy uncertainty which makes it difficult to (Baker, Bloom and

Davis, 2012). Additionally, many managers do not diversify their holdings of wealth. Consequently, a higher policy and financial uncertainty may motivate managers to be cautious when taking risks and making investment decisions such as investing in export-oriented labor force and distribution networks (Panousi and Papanikolaou, 2011).

Financial constraints of exporting firms:

A weak reaction to changes in international competitiveness may be due to the increased cost (or lack) of credit to support or expand existing firms, and the establishing of new ones (Amiti and Weinstein, 2011, and for the correlation with policy/political uncertainty, Manzo, 2013, and Pástor and Varonesi, 2011). This financial barrier would be more relevant for firms which require a bigger amount of start-up financing (Bricongne et al., 2012, Goerg and Spaliara, 2013, Ito and Terada-Hagiwara, 2011). The paper continues with some arguments relevant for the time period after the start of the crisis.

Frictions in credit may have prevented a necessary reorientation of domestic production to exports when domestic demand collapsed (Mélitz and Trefler, 2012, Belke and Kronen, 2016).

By starting to export the more productive firms among the non-exporting ones will aim to substitute for the decline in domestic demand (Belke, Oeking and Setzer, 2014). The lower increase (or fall) in wages accompanying the process of internal devaluation will support these efforts

(Belke and Kronen, 2016). This switch comes along with difficulties for potential exporters as costs arise from assessing foreign markets and customizing products to local preferences as well as setting up foreign distribution networks (Das, Roberts and Tybout, 2007). Since most entry costs must be paid beforehand, these costs can only be covered by firms with a sufficient level of liquidity. The *credit constraints* not only Greek but also Italian and other firms have been confronted with since 2009 have made the task of first-time entry into foreign markets in some cases difficult (Belke and Kronen, 2016).

It is to note that not only Greece entered the crisis with an unfavorable environment for building a competitive business. Following the crisis, labor costs decreased while the costs and uncertainties of doing business has increased. Next to many others, the preeminent example is the shortage of finance. For factor mobility other obstacles such as bureaucracy, an overall perception of a deteriorating environment ("institutional uncertainty") and corruption have become increasingly relevant (Arkolakis, Doxiadis and Galenian, 2014, pp. 21ff.). This makes the explanation of a "band of inaction" (determined by exit and entry costs multiplied with uncertainty, see Belke and Goecke, 2005) in a country's exports a straightforward issue, since *institutional uncertainty has increased while fixed and variable costs have decreased* (Belke, Goecke and Hebler, 2005). Admittedly, Greece is the strongest case in this context, but the latter could be relevant for some of the EU countries in our sample (for instance, Italy for which ECB President Mario Draghi claimed a credit crunch) in a weaker form as well (Belke and Verheyen, 2014).

2.3 Non-linear reaction of exports to exchange rate changes

Based on the arguments above, a *non-linear reaction of exports to exchange rate changes* seems reasonable: small changes of the exchange rate will only cause weak effects; but stronger changes with an underlying monotonously ongoing trend into one direction, will at some point (which we called "*pain threshold*" in the introduction) lead to larger reactions of the export volume (Belke, Goecke and Werner, 2015). The exchange rate which lets the firm change the volume of its export activity (i.e. the "pain threshold") will be highly product dependent and will differ significantly among companies and sectors (von Wartenberg, 2004).

There is thus *heterogeneity of the exchange rate threshold across firms*, i.e. on the micro-economic level. Niche products suppliers, such as those in the branch of specialized mechanical engineering or in specific segments of the automobile sector may be able to compensate the increase in value of the euro relatively easily, while for firms exporting standard a strong euro poses a big problem (Belke and Kronen, 2016). What is more, dependent on *past* exchange rate changes, the firms have earlier on determined their export activity status and have spent costs (which are now sunk) on market entry investments at a point in time when the exchange rate was favorable – or, vice versa, may have left the export markets if the exchange rate was unfavorable. Hence, past decisions are determining the exporters' current reaction to exchange rate movements. This type of path-dependence (not only) in foreign trade is associated with the term "hysteresis" (Baldwin, 1989, 1990, and Dixit, 1994).

Empirically addressing the phenomenon of non-linear reactions of exports is not straightforward (Belke and Goecke, 2001, 2005). Since firms are (due to differences concerning e.g. their pricing-behavior, their sunk cost structure etc.) heterogeneous concerning their reaction on exchange rate changes, the *micro* data in need (extended financial and balance sheet information on single exporting firms) may *not be available*. Moreover, institutional mechanisms to safeguard a sound EU governance such as the Macroeconomic Imbalance Procedure (MIP) in the euro area tend to rely on *macroeconomic* export data and, thus, current account balances. Hence, we take the need of a micro foundation of macro hysteresis very serious, but take into account micro heterogeneity not by panel estimation based on heterogeneous firms but by an adequate aggregation mechanism. However, the aggregation of non-linear path-dependent microeconomic activity to a macroeconomic analysis is far from straightforward as well, because the path-dependent dynamic pattern may differ among the micro perspective of a firm and the aggregated macro perspective of an entire economy consisting of *heterogeneous* firms (see the discussion in Goecke, 2002).

In this paper we employ an approach which captures the path-dependent non-linear dynamics on the macroeconomic level. We call this approach *play-hysteresis*, since it reveals an analogy to mechanical play known from ferro-magnetism. Play is integrated into a standard regression framework. This has the advantage of a lower demand of underlying data, since macroeconomic data can be used. Furthermore, by employing a theory that is testable by using more readily available macro data, the paper brings hysteresis closer to applicability (e.g., for policy makers).

2.4 Hysteresis in exports and the BRICs

While there are a few studies around on hysteresis *in BRIC countries' exports*, studies on hysteresis in exports *toward the BRICs* (which we investigate in this contribution) are very scarce. Examples of the former are Ito and Terada-Hagiwara (2011) for Indian exports and Kannebley Jr. (2008) for Brazilian exports. Regarding the latter, De Prince and Kannebley Jr. (2013) estimate hysteresis in exports to (i.e. imports of) Brazil. They show that correcting for hysteresis makes the quantity and the price of Brazilian imports more sensitive to exchange rate variations. For this purpose, they employ an empirical measure of strong macro hysteresis, as developed by Belke and Goecke (2001, 2005), and incorporate it into import demand and pass-through panel cointegration equations. Yerger (1999), as another example, estimates the significance of hysteretic exports to (imports of) the US.

2.5 Hysteresis in exports of EU member countries – empirical evidence

The literature on hysteretic exports of the four EU member countries under investigation here is much richer. However, in contrast to this contribution, exports to the BRICs are not investigated and policy uncertainty is not considered in any of the studies. Using different empirical approaches, Belke, Oeking and Setzer (2014) and Belke, Goecke and Guenther (2013) are estimating the degree of hysteresis in *German* exports. Belke, Oeking and Setzer, 2014) and Bricongne et al. (2012) assess the significance of hysteresis in *French* exports. Belke, Oeking and Setzer (2014) and Bugamelli and Infante (2003) check for hysteretic *Italian* exports. *UK* export hysteresis is investigated by Anderton (1999) and Greenaway, Kneller and Zhang (2010). Goerg and Spaliara (2013) exploit firm-level data for the UK and the period 2000 to 2009 and focus on the extensive margin of exports (which is also our focus in the theoretical part of this paper) and check firms' exit from the export market. In particular, they assess whether such exit has become more prevalent during the crisis. They come up with the result that export-market exit has indeed become more probable during the crisis.

2.6 Significance of the BRIC export markets for the EU member countries

Whereas the importance of the US and the Japanese market for EU member countries' hysteretic exports have been described in a sufficient number of studies before (see, e.g., Verheyen, 2013, Belke, Goecke and Guenther, 2013, and the literature cited therein) the significance of the BRIC export markets for the EU member countries' under investigation has still to be put under closer scrutiny.[3] This is because there is strikingly *little written about the factors that drive European exports to the BRIC countries* – the main focus of this contribution (Fedoseeva and Zeidan, 2016).[4] In general, the BRICs are seen as the core of an emerging "global middle class" which is expected to cause a major change in the demand for goods, creating *significant opportunities for European exporters* (Desdoigts and Jaramillo, 2009). Henderson (2011) adds that around 40% of the world consumers are living in the BRIC countries. Hence, stagnation of the European demand as during the high times of the euro crisis pushes exporters to look for new destinations for their goods, among them the BRICs – and the other way round. If the BRICs' growth diminishes, EU exporters may have to return to the intra-EU markets (Koeppen, 2012).

[3] Estimating exports from EU countries to Japan surely have to take the natural disaster ("Fukushima") in Japan into account. See Belke (2013).

[4] Some notable exceptions include Havlik, Pindyuk and Stoellinger (2009) and De Castro (2012) based, however, on simple correlations and eyeball econometrics.

Let us take the example of Germany here. Years of strong economic growth in the BRICs (Brazil, Russia, China but also India which is not investigated here) can be interpreted as a blessing particularly for Germany's export industries. However, Germany is currently feeling the recent significant loss of momentum in the BRIC economies described further above, although trade is still staying remarkably high as can be expected from a trade hysteresis perspective (Fedoseeva and Zeidan, 2016, KfW, 2015).

In the global crisis year 2009, China and India were the only BRICS countries to grow, whereas the Brazilian, Russian and South African economies contracted. "2010 was once again a good year for all five. However, economic momentum in the BRICS has slowed down considerably since 2011 and Brazil and Russia in particular have slipped into a veritable crisis, albeit for different reasons" (Fedoseeva and Zeidan, 2016, KfW, 2015).

The BRICS' growth has strongly promoted Germany's export industry. German goods exports to the BRICS amounted to merely EUR 27 billion in the year 2000 but climbed to EUR 131 billion in 2014. This represents an increase from 4.5 to 11.6 % of total exports. These days, the *composition* of Germany's exports to the BRICS by sector is the following: 27 % vehicles, 26 % engineering, 13 % chemical products, 12 % electronics and 22 % others (KfW, 2015).[5]

This pattern of export development is striking with an eye on the fact that the boom in the BRICs can be mainly traced back to progress in the manufacturing sector. "This implies that the BRICS have advanced in areas in which the German economy is strong as well. Germany is therefore facing increased competition, both within the BRICS and on third-country markets. The figures document Germany's high international competitiveness" (KfW, 2015).

[5] See http://www.bricpartner.com/en/Nd/i/more/Growth+Markets%3A+German+Exports+to+the+Bric+Region+Growing/idn/2098.

However, the individual BRICS are relevant for German exports to a different extent. China and Russia clearly are the most important German export destinations among the BRICs and stand for the largest portion of export growth since 2000. German exports to Brazil, India and South Africa (the latter two countries have not been investigated by us do to a lack of sound data especially for export deflators and exchange rates) follow at a considerable distance, having also developed far less dynamically (Erber and Schrooten, 2012, Fedoseeva and Zeidan, 2016, KfW, 2015).

Even after 2010 German exports to China have continuously grown strongly. But this is not the case for German exports to Russia which declined sharply since 2012 as a result of the Russian economic crisis and the sanctions imposed on the country in 2014 (Erber and Schrooten, 2012, KfW, 2015). Itaú BBA, Latin America's largest Corporate & Investment Bank, argues for the export destination Brazil: "The political and economic uncertainty will probably continue in 2016".[6] And OECD (2016) adds: "The deep recession is set to continue in 2016 and in 2017 against the backdrop of high political uncertainty and ongoing corruption revelations that are undermining consumer and business confidence, leading to a continuous contraction in domestic demand. … Deep political divisions have reduced the chances for any noticeable momentum on policy reforms in the near term".

Therefore, the issue of *policy uncertainty* (which is amplified by other geopolitical risks such as the fight against terrorism) German and other exporters see themselves confronted with is particularly relevant for the export destinations Brazil and Russia.

In previous studies, however, policy uncertainty has been *exclusively linked with developing countries*' (such as Thailand), emerging economies' (such as South Africa) and problematic industrialized countries' (i.e. Greek) exports but not to industrialized countries' exports (Belke

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6 See https://www.itau.com.br/itaubba-en/economic-analysis/publications/brazil-scenario-review/political-uncertainty-and-continued-recession-in-2016#.

and Kronen, 2016, Hlatshwayo, and Saxegaard, 2016). Hlatshwayo, and Saxegaard (2016) find for South Africa that *increased policy uncertainty* diminishes the responsiveness of exports to the REER and *has short and long-run level effects on export performance*.[7]

2.7 Significance of a euro devaluation for Euro area member countries' exports

The euro exchange rate has seen significant fluctuations since the start of the monetary union. The main focus of recent years has been the euro devaluation following the expansionary unconventional monetary policies of the ECB. The European Commission (2014) has recently estimated the euro area member states' varying degrees of vulnerability in terms of exports to changes in the exchange rate. One variable is the difference of the real exchange rate elasticity of export volumes. Among others, it looks at possible differences in the real exchange rate elasticity of export volumes. The empirical results show that export elasticities for real exchange rate movements are significantly higher in Italy and France than in Germany, due to Germany's stronger connection to global value chains (European Commission, 2014).

To a certain extent, these differences can be traced back to the different characteristics in the product structure of exports.

These differences in the elasticity can, to a certain extent, be traced back to idiosyncrasies in the product structure of exports. Exports of sophisticated products tend to be less reactive to changes of the exchange rate than exports of more homogenous products. The shares of capital goods in total exports (which cannot be substituted that easily) is lower in Portugal, Spain and, to some extent, Italy (European Commission, 2014).

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[7] In a similar vein, Handley and Limão (2015) find that Portugal's 1986 preferential trade agreement with the European Community increased trade to a large extent because uncertainty over trade declined. In a related context different from trade issues, Belke, Goecke and Hebler (2005) show that structural change on CEEC labor markets is fostered via reducing institutional uncertainty once they have adopted the acquis communautaire.

France, a country with a relatively high percentage of capital goods and services, shows high values of export price elasticity. This suggests that there are other factors determining export elasticity differences, such as the quality of the products and services exported.

3. Hysteresis in exports: the 'band of inaction' on the micro level

Hysteresis occurs when a market exhibits sunk market-entry costs (Baldwin 1989, 1990). Firms who are eager to export have to invest to enter the market, such as introductory sales promotion setting up or distribution and service networks. These expenses are different for every firm and cannot be regained if the firm leaves the export market afterwards; i.e. the costs from entering the market are sunk. A change of the exchange rate under prices which do not change proportionally results in revenue changes for the exporting company. If the foreign currency appreciates (corresponding to a depreciation of the home currency), it may become profitable to enter the market when considering sunk costs (Belke and Goecke, 1999).

However after a firm has entered the exporting market due to a sufficiently high appreciation of the currency in the exporting market a depreciation may follow. The pattern of reaction for a single firm is shown in Figure 2. The exchange rate is expressed as the ratio of the home currency to the foreign currency. The value x_c illustrates the exchange rate that compensates the variable unit costs for the exporting firm. A depreciation of the home currency (or an appreciation of the foreign currency) increases the unit revenue resulting from changing back to the exporters' home currency. The exchange rate barrier x_{in} is higher than the variable unit costs due to the existence of sunk costs. If an active firm observes losses higher then sunk exit costs induced by a foreign devaluation it will exit the market. The exchange rate trigger x_{out} resulting in an exit therefore has to be below x_c. There is a band between the exit and entry costs. On the micro level the path-dependence appears discontinuously if an entry or exit trigger rate is passed.[8] The two triggers result in a "band of inaction". The state of activity between the two barriers, i.e. the "band of inaction", depends on whether the firm was active or inactive beforehand and cannot be stated with certainty (Belke and Goecke, 1999).

-Figure 2 here-

While Figure 2 depicts the case without uncertainty, we now illustrate a case including uncertainty. Adding *uncertainty* concerning the future exchange rate (or other types of uncertainty such as policy uncertainty, Belke and Kronen, 2016) into the regression, enhances the hysteresis characteristics by allowing for option value effects.[9] As an exit from the export market destroys the investment made prior to entering the market, an exporting firm might stay if the home currency devalues even though it is currently losing money. If the currency only devalues for a short amount of time and starts to appreciate again a premature exit could be a mistake. The option to "wait-and-see" therefore shifts the exit trigger to the left when considering uncertainty. Correspondingly the entry trigger is respectively shifted to the right resulting in a widening of the "band of inaction" in a situation with uncertainty (Belke and Goecke, 2005, Belke, Goecke and Werner, 2015).

Changes in exchange rates result in extensive changes in revenue for the home currency when the price elasticity of demand in the export market is high. Conversely, a high level of price elasticity of demand results in smaller changes in unit revenue for changes of the exchange rate. The width of the band-of-inaction will rise if the absolute values of the sunk entry and exit costs increase, the demand elasticity falls, and the uncertainty of the exporters' future situation increases (Belke and Kronen, 2016).

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8 According to Krasnosel'skii and Pokrovskii (1989), p. 263, this pattern corresponds to a so-called "non-ideal relay".

9 See Belke and Goecke (1999) in a hysteresis context. For an extensive treatment of uncertainty effects see Dixit, Pindyck (1994, Ben Bernanke (1983) which was extended more recently and quantified by Bloom (2009). For an empirical application to trade based on macro time series see Parsley and Wei (1993). For studies based on micro panel data see Roberts and Tybout (1997) and Campa (2004).

Deriving from the idea of a band of inaction, Belke and Goecke (2005) try to locate a hysteresis loop on a macro level and therefore focus on the *issue of aggregation.* [10] The aggregation process is not straightforward when considering heterogeneity of sunk exit/entry costs and/or the extent of uncertainty of the future market situation and/or the elasticity of demand is for different firms resulting in different triggers is considered (Greenaway, Kneller and Zhang, 2010). This (realistic) consideration of heterogeneity alters the hysteresis characteristics when aggregating from the micro to the macro perspective: the resulting aggregated hysteresis loop shows no discontinuities.

Belke and Goecke (2005) demonstrate that macro behavior reveals areas of weak reactions which are – corresponding to mechanical play – called "play" areas and resemble the dynamic of a band of inaction. [11] Aggregate exports show no permanent effects when minor changes in the forcing exchange rate variable occurs, as long as the change takes place inside a play area. If the change does, however, go beyond the range of the play area, an abrupt strong reaction (with a persistent effect) of the output variable, in this case exports, occurs.[12] The value of the exchange rate variable that can be observed after completely passing the play area can be specified as a "pain threshold", as the reaction of exports to changes in the exchange rate will be much stronger after passing this value. There are, however, two aspects in which play-hysteresis differs compared to the micro-loop. First, the play-loop displays no discontinuities in its function. Second, similar to mechanical play (e.g. steering a car) the play area is shifted by earlier values of the forcing variable (exchange rate): Every change in direction of the forcing variable

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[10] For an applicable aggregation procedure from micro to macro hysteresis see Amable et al. (1991), Cross (1994), and Belke and Goecke (2005).

[11] For play hysteresis, see Krasnosel'skii and Pokrovskii (1989), pp. 6 ff. See Belke, Goecke and Werner (2014) and Goecke (2002) for different types of hysteresis.

[12] For an empirical macro analysis of 'spurts' in investment based on *micro*-threshold models see Darby et al. (1999). See Pindyck (1988), pp. 980 f., and Dixit and Pindyck (1994), pp. 15 f., for a non-technical description of 'spurts' based on microeconomic sunk cost mechanisms.

results in a new traversing of the play area. Once the whole play area is passed, a spurt reaction occurs, if the forcing variable continues along the same direction (see Belke, Goecke and Werner, 2014).

The following section will present an empirical framework to test for a play-type impact of the exchange rate on total exports, with and without uncertainty. We use an algorithm developed in Belke and Goecke (2001) specifying play-hysteresis and apply it within a standard regression framework.

4. The empirical model of play-hysteresis

4.1 A linear approximation of exchange rate impacts on exports – with and without uncertainty

To illustrate the dynamics that underlie the play dynamics – as developed by Belke and Goecke (2001, 2005) – we will exhibit the implications based on Figure 3. As a start, we presume the play area p to have a constant width, i.e. the *absence of uncertainty*, while uncertainty will be implemented later on. Our explanation starts in point A (x_0) and is located on the (right) upward spurt line. A decrease of the forcing variable will result in entering the play area and a weak "play" reaction follows until p is passed entirely. A further depreciation will initiate a downward spurt reaction in point G for a value of x_5 (with: $p = x_0 - x_5$). The reaction of y depends on the grade of penetration of the play area.

An increase from x_0 (A) up to x_1 (point B) followed by a subsequent decrease to x_2 (C) may also occur. The reaction of y can be observed on the upward spurt line which results in an increase along the spurt line from $A \rightarrow B$ resulting in an upward shift from line GA to line DB ($p = x_1 - x_3$) for the corresponding play area. The following reduction of x_2 (C) to x_3 (D) results in another play reaction.[13] The play area is not passed entirely but for the extent of ‘a’ depicted in the figure. Assume a following decrease $x_2 \rightarrow x_3 \rightarrow x_4$ (C→D→E). Passing the entire play in point D (x_3) results in a strong spurt reaction along the downward leading spurt line up to point E. In this point a further decrease of x will result in another strong spurt reaction. The value x_3 can therefore be seen as a “pain threshold”. This trigger is, however, not defined by a constant value since a shift along the spurt line also shifts the play area therefore resulting in another “pain threshold” whose magnitude has to be considered path-dependent. A following increase to the earlier value of x_3 is described by the new play area penetration EF.

-Figure 3 about here-

Considering the option value-of-waiting effects, *the play area is widened when including increasing uncertainty*. Therefore changes in the play width in Figure 4 have to be illustrated. We start from point A (x_1) after an upward spurt reaction. The opposing (left) spurt line is shifted horizontally, depending on the current width of the play area, while the right spurt line is fixed after the upward spurt. When considering uncertainty, the opposite spurt line is generally shifted by different degrees due to the variable play while the spurt line that was traversed most recently acts as an anchor. A high degree of uncertainty, for example, leads to a larger play width γ_0, which results in a left spurt located at spurt $down_0$. A fall from $x_1 \rightarrow x_2$ for the γ_0-situation leads to a weak play reaction (A→B). If, however, uncertainty is reduced after reaching point B a reduction of the play width from γ_0 to γ_1 will ensue a horizontal shift of the left spurt $down_0$ to spurt $down_1$. The reduction of the play area causes the system to end up in C while simultaneously shifting the play area downwards. Concluding, movements on the spurt line following from changes in the forcing variable x as well as changes of the width of the play area result in

[13] In the case of ‘mechanical play’ there would not even be any observable reaction of y inside the play area. See Krasnosel’skii and Pokrovskii (1989), p. 8.

vertical shifts of the corresponding play line and therefore in persistent hysteresis effects (Belke, Goecke and Werner, 2015).

-Figure 4 here-

4.2 An algorithm depicting linear play

We present the play algorithm developed by Belke and Goecke (2001, 2005) to analyze employment hysteresis[14] and then apply it to our main research question. Shifts of the forcing variable x (Δx) can occur along the play area p yielding a weak reaction or on a spurt line resulting in a strong spurt of the dependent variable y (Δy). A change of x along the play area is written as Δa (and cumulated as a) and movements in the spurt area are defined as Δs. The system starts with Δx entering the play area which results in a change Δx_j^s. This corresponds to the trajectory $B \rightarrow C \rightarrow E$ in Figure 3. The change Δx_j^s may enter the play area up to the extent of Δa_j or cross the entire play and traverse the spurt line by Δs_j. As the starting point was on a spurt line the aggregated movement along the play a_j conforms to the change Δa_j. The distance "a" is described by $B \rightarrow C$ in Figure 3. This sequence can be expressed by the following expression:

$$\Delta x_j^s = a_j + \Delta s_j \qquad \text{with: } \Delta s_j = \begin{cases} \text{sign}(\Delta x_j^s) \cdot (|\Delta x_j^s| - p) & \text{if } \ (|\Delta x_j^s| - p) > 0 \\ 0 & \text{else} \end{cases} \tag{1}$$

The change in y (Δy) written as Δx_j^s can be depicted by the play reaction ($B \rightarrow C$) and – if the play is passed entirely – of the spurt reaction ($D \rightarrow E$). The parameter α indicates the weaker reaction along the play and $(\alpha + \beta)$ represents the stronger spurt reaction:

$$\Delta y_j^s = \alpha \cdot a_j + (\alpha + \beta) \cdot \Delta s_j \qquad \text{with: } |\alpha| < |\alpha + \beta| \tag{2}$$

[14] Using Portuguese firm-level data, Mota (2008), pp. 99 ff., and Mota et al. (2012) apply the linear play-algorithm estimating and comparing *aggregate* employment hysteresis with micro level adjustment patterns.

A movement along the spurt line results in a vertical shift of the play line. The vertical motion V_{j-1} of the currently relevant play line resulting from past movements on both spurt lines can be written as:

$$V_{j-1} = \beta \cdot \left[\sum_{i=0}^{j-1} \Delta s_i \right] = \beta \cdot s_{j-1} \qquad \text{with: } s_{j-1} \equiv \sum_{i=0}^{j-1} \Delta s_i \qquad (3)$$

The variable y consists of the shift V determined by previous spurts and the current reaction Δy_j^s:

$$y_j = C^* + V_{j-1} + \Delta y_j^s = C^* + \beta \cdot \sum_{i=0}^{j-1} \Delta s_i + \alpha \cdot a_j + (\alpha + \beta) \cdot \Delta s_j \qquad (4)$$

$$\Rightarrow \quad y_j = C^* + \beta \cdot \sum_{i=0}^{j} \Delta s_i + \alpha \cdot \Delta x_j^s$$

$$\Rightarrow \quad y_j = C^* - \alpha \cdot \sum_{i=0}^{j-1} \Delta x_i + \beta \cdot \sum_{i=0}^{j} \Delta s_i + \alpha \cdot \left(\sum_{i=0}^{j-1} \Delta x_i + \Delta x_j^s \right) \qquad \text{with: } C \equiv C^* - \alpha \cdot \sum_{i=0}^{j-1} \Delta x_i$$

$$\Rightarrow \quad y_j = C + \alpha \cdot x_j + \beta \cdot s_j$$

Figure 5 illustrates equation (4). The hysteresis loop is expressed by a simple linear equation for which the artificial variable s_j serves as a basis. The “spurt variable” s_j includes the sum of earlier and current spurt movements that change the actual relation between x and y.

- Figure 5 about here -

The index j can be replaced by a time index t. An inclusion of further non hysteretic variables (e.g. z_t) to achieve a generalized representation of the hysteretic process yields:

$$y_t = C^* + \beta \cdot \sum_{k=0}^{t} \Delta s_t + \alpha \cdot \Delta x_t + \lambda \cdot z_t \qquad (5)$$

$$\Rightarrow \quad y_t = C + \alpha \cdot x_t + \beta \cdot s_t + \lambda \cdot z_t.$$

For a more in-depth presentation of the play algorithm (and for a translation into an EViews batch program) for a variable play width, we refer to Belke and Göcke (2001a) and Belke, Goecke and Werner (2015). To capture the impacts of uncertainty on the play width we model p as a simple linear function of an uncertainty proxy variable u_t.

$$p_t = \gamma + \delta \cdot u_t \text{ with: } \gamma, \delta \geq 0 \text{ and } u_t \geq 0 \Rightarrow p_t \geq 0 \tag{6}$$

For a proxy variable u_t we use economic policy uncertainty and exchange rate uncertainty expressed as the standard deviation of the last twelve months.

5. Empirical analysis

5.1 Existing studies

Using macroeconomic time series data for the U.S. and employing dummy variables to represent periods of appreciating exchange rates Baldwin (1990) and Krugman and Baldwin (1987) first tested the possibility of hysteresis in foreign trade. Empirical models trying to show an asymmetric effect of changes in real exchange rate on the quantity of imports were shaped by Parsley and Wei (1993). Roberts and Tybout (1997) and Campa (2004) found sunk cost hysteresis as a crucial determinant to explain export market participation by using firm level data on the micro level therefore concentrating on discontinuous micro-hysteresis. Agur (2003) discovered empirical evidence supporting the idea of structural breaks between import volume and exchange rates due to extrema in exchange rates. Kannebley (2008) finds an asymmetric adjustment in 9 of 16 sectors using a threshold cointegration model for data on the sectoral level in Brazilian foreign trade. Belke, Goecke and Guenther (2013) apply an algorithm using path-dependent play-hysteresis to show the effect of changes in the real exchange rate for German exports in the time of 1995Q1 to 2010Q3 finding significant hysteretic effects for several German exports when analyzing some of the most important export destinations the most important trade partners outside of the euro area.

Our approach that is used in this paper is the one developed by Belke, Goecke and Guenther (2013) and refined by Belke and Kronen (2016). It considers the initial concept of a *macroeconomic "hysteresis loop*", since (i) it is not analog to the discontinuous non-ideal relay interpretation as on the microeconomic firm level and since (ii) the path-dependent structural breaks in the macroeconomic relations in the system are not considered as an exogenous information. Quite the contrary, in the approach by Belke, Goecke and Guenther (2013) the emphasis lie on the explicit structural shifts determined by the prior path of the real exchange rate. Furthermore, the path-dependent relation of the real exchange rate to exports is estimated simultaneously.

5.2 Characteristics of the regression model and the hypothesis for testing play effects

The model for our "play regression" can be described by the following properties: It is based on sections, with adjoining parts being linked (by so called 'knots', in Figure 3 these knots are e.g. points B, D, E for the case of the path $x_1 \rightarrow x_3 \rightarrow x_4$.). The present position of the linear function and the transition to different sections of the system are determined by the past realizations of the forcing variable x. The model is a particular case of a switching regression framework, since adjoining sections are linked.[15] The position of the knots, which is not known a-priori, is determined by the size of the estimated play area p. The knots allow for a differentiation for the relation between the variables x and y characterized by two varying slopes (for $\beta \neq 0$). The hysteretic dynamics are described by only a small number of coefficients: the play width p, the basic slope α, and the difference in slopes β have to be calculated.

We assume the assumptions of the standard regression model to be satisfied: the error term is independently, identically and normally distributed with a constant finite variance for all segments, and the regressors are estimated without error and are uncorrelated with the error term.

15 For an introduction to linear spline functions and linear switching regressions see Poirier (1976), p. 9 and p. 117.

The parameters of the estimation framework are non-linear, as knots are not known a-priori and due to the fact that the spurt variable s is specified by an estimated play width p. Due to the assumptions made about the error term and regressors, it is ensured that the OLS-estimators are best linear unbiased estimators for a standard regression model which means that the OLS-estimator can be serves as a maximum likelihood estimator. For a-priori unknown knots local maxima and breaks in the likelihood function occur. If the adjacent parts are joined in a model using switching regression, the OLS-/ML-estimator will lead to consistent and asymptotically normally distributed results.

A straightforward estimation is still problematic because of the finite sample characteristics of the play regression: when applying the model on small samples the estimates of the coefficients are not approximately normally distributed which could result in local maxima for the likelihood function.[16] Moreover, the assumptions of the standard regression model may not be fulfilled. Non-finite variances may occur for the case of non-stationary variables. In addition the usage of cointegration analysis is obstructed because the play dynamics are characterized as a mixture of short- and long-term dynamics. In spite of these shortcomings, we are not aware of a technique that yields this (small sample) distribution and the critical values for the estimators while being directly adaptable to our specific model. To solve this certain problem is therefore beyond the scope of this paper.[17]

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[16] See Hujer (1986), pp. 231 ff., Poirier (1976), pp. 108 ff., pp. 117 ff. and p. 129, Hudson (1966) and Hinkley (1969) for small sample properties in ML- (OLS-) estimations in a (spline) model with unknown but continuous switches.

[17] Using first differences is the standard procedure for using non-stationary variables. This does not work for our algorithm, since the effects that are used as a basis are path-dependent and related to the *level*s of the forcing/original variable (i.e. the exchange rate). Mota et al. (2012) show that OLS estimates are, in a time series econometrics sense, super-consistent, and can none the less be applied to estimate a spurt regression. In their hysteresis estimation, they apply (after identifying the play-width with an OLS-estimation) a third estimation step in re-estimating the relation for the long-run with FM-OLS to avoid cointegration problems. Still, the problems mentioned above remain for the first step (identification of the play) and for small sample properties.

Identifying the play width which determines the value of the spurt variable and minimizes the residual sum of squares is achieved by applying a grid search over the width of an invariant play parameter $p_t = p = \gamma$ is (for a constant width p). By using the data of the forcing variable (exchange rate) we estimate the spurt variable and transition knots for every value of p. The realization of γ is the same for every grid point. The values α and β represent the coefficients in the OLS-estimation and can now be calculated by using the matching spurt variable in the regression resulting from the applied grid search. The grid value with the highest R-squared (and therefore the minimum of the residual sum of squares), which is found in the grid search over p, yields the optimal OLS-estimate for the play variable.

Testing for play hysteresis is achieved by considering the following equations:

$$y_t = C + \alpha \cdot x_t + \beta \cdot s_t(\gamma) + \lambda \cdot z_t \quad \text{with: } |\alpha| < |\alpha + \beta| \qquad (7)$$

$$p_t = \gamma + \delta \cdot u \quad \text{with: } \gamma \geq 0. \qquad (8)$$

We want to test whether play is significant, therefore we test the hypothesis (H1) $\beta \neq 0$ against the alternative $\beta = 0$.[18] The OLS-estimators of the equation can be seen as asymptotically unbiased and asymptotically normally distributed when one neglects the limitations of the results due to, for example, non-finite variance and spurious regression resulting from including non-stationary variables into our regression framework. Seeing that the small sample properties are still problematic we closely follow Belke, Goecke and Guenther (2013) and Belke and Kronen (2016) and refrain from further conclusions concerning exact inference.

5.3 Estimating play-effects in EU member countries' exports

18 According to Belke and Goecke (2001, 2005), the hypothesis to be tested might even be more restrictive, since in terms of absolute numbers a weaker play and a stronger spurt reaction are assumed as the "typical" hysteresis pattern (i.e. $|\alpha| < |\alpha + \beta|$)

5.3.1 Data and Variables

First, we check for the relevance of the hysteresis model for the EU member country's exports by estimating equation (5) which generalizes hysteretic behavior of exports dependent on movements in the exchange rate.

We use (total) export data for some of the most important EU member countries' export destinations, in this case the United States, Japan and the BRICs (Brazil, Russia, and China) as the dependent variable. And as hysteretic input variable, we use the respective EU member country's real exchange rate (defined below).

To be as economical as possible, we use foreign industrial production together with a linear trend and seasonal dummies as further non-hysteretic explanatory/controlling variables.

The exact definitions of the time series used are as follows. We take the nominal exports (denoted as current €) from the Eurostat database (Comext, http://epp.eurostat.ec.europa.eu/newxtweb/). These series are then deflated by the export deflator of the export definition country (Source: OECD). We calculate real exchange rates as $\frac{CPI_t^{EU\ member\ country}}{CPI_t^j} \cdot e_t^j$, so real exchange rates are calculated using the EU member country's CPI divided by the CPI of the export destination, multiplied with the nominal bilateral exchange rate (sources: OECD).

We take the industrial production time series from the OECD. Our estimation period ranges from 1995M1 to 2015M12. The estimations for Italy and the United Kingdom begin in 1997M1 and estimations for France begin in 2000M1 due to the availability of the policy uncertainty index.

5.3.2 Exports to different export destinations – evidence on the country level

We begin with a standard regression of German exports to Brazil on the price adjusted bilateral exchange rate (W), the industrial production and, additionally, a linear trend plus dummy variables. First we exclude effects due to play dynamics (i.e. applying the restriction $\beta = 0$). The results are presented in Table 1. According to the t-statistics, all estimated coefficients of the regressors are significant and show the theoretically expected sign. To avoid issues of reverse causality, lagged production data is used. Furthermore, it results in the best goodness of fit.[19] So the Brazilian industrial production variable enters with a lag of one month. Simultaneously, the real bilateral exchange rate of the Euro (and the Pound Sterling for the UK) enters the regression. This way, we prevent possible J-curve-effects which might influence the dynamics in the hysteretic sub-system (and makes it too complex to estimate). We use this setting for all estimations carried out in this paper.[20]

- Table 1 about here -

The second step is the estimation of the constant play γ. Figure 6 shows the plot of the grid search for different values of γ: The R^2 sequence shows an absolute maximum at $\gamma = 0.08125$ (with $R^2 = 0.89$).

Corresponding to the linear standard model the R^2 shows a minimum at $\gamma = 0$ ($R^2 = 0.78$). In Table 2, the estimation results of the regression with an artificial spurt-variable (SPURT) based on the constant play-width $p = \gamma = 0.08125$ are stated.

- Figure 6 about here -

- Table 2 about here -

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[19] We use lagged production to avoid problems that are related to endogeneity of the dependent (Greek exports) and the regressor (Industrial Production of the destination country). This kind of effects cannot be excluded completely since export numbers could theoretically affect the exchange rates. Due to the fact that exchange rates define the play-dynamics, we are not able to overcome this problem easily (e.g. via using instrumental variables), and leave this problem for further research.

[20] Our regression is only directed at bilateral effects between two countries and their bilateral exchange rate. Of course, if exchange rate changes differ between export destinations, a EU member country’s exporter could react with substituting/redirecting exports away from the depreciating country towards a third country market. These cross-country effects are not considered here. However, from a sunk cost point of view, even redirecting export flows may cause sunk costs, and thus, may show some kind of cross-exchange rate play (with only weak reaction until the country structure of exchange rates changes significantly).

Again, the theoretically expected signs are shown by the coefficients. The hypothesis (H1) $\beta \neq 0$ can be refuted since the estimated coefficient of the spurt variable is β = -97131019 with a t-value of 16.0494. The spurt-variable is substituting the effects of the real exchange rate in the standard regression depicted in Table 1 which amounted to α = -630.6682 (t=–3.35), and now vanishes to an insignificant effect (α = 2548030 t = 0.6493) in the play-regression, which is in line with theory. Compared to the exchange rate effect calculated in the linear regression, the absolute effect of the spurt is also higher in the play-regression. The high empirical t-realization (which is far higher than the 5% critical value in case of a standard student-t-distribution) gives strong evidence for the relevance of hysteretic play, even though the small sample properties are unknown.

Figure 7 gives a graphical impression of the time sequence of the original real Euro/Real exchange rate (W, left scale) and of the respective SPURT (right scale). Over the observed period, the two paths show a similar form. If the exchange rate fluctuates inside the play area (of width γ *=0.08125)* periods of inaction emerge, which only leads to play/inaction effects and no variation of the spurt variable. However, the spurt series mirrors large/monotonous changes of the real exchange rate.

- Figure 7 about here -

5.3.4 General pattern of results of export regressions

- Table 3 about here -

The real exchange rate is defined in a way that a "normal" reaction of exports to the exchange or the spurt is represented by a negative sign of the estimated coefficient of the respective variable (i.e., an €-devaluation increases EU member countries' exports to the US). Therefore, a significantly negative effect for the spurt variable ($\beta < 0$) and a smaller, or better insignificant effect for the original exchange rate would be the theoretically expected result for the play dynamics. For the 20 “play regressions”, the spurt variable shows the “wrong sign” ($\beta > 0$) in six cases, and in none of the other cases did the coefficient of the original exchange rate effect exceed the one of the spurt ($|\alpha| > |\alpha + \beta|$). For the 20 “play regressions”, the spurt variable shows the “right sign” ($\beta < 0$) in 14 cases, and in none of these cases did the coefficient of the original exchange rate effect exceed the one of the spurt ($|\alpha| > |\alpha + \beta|$). In Table 3, highlighted in white, you can see the six regressions with a theoretically unexpected sign of the spurt variable. Additionally, the respective t-value of the spurt variable is shown as well. In all cases showing a spurt variable with a correct sign, the effect is significant. Summarizing, in 14 out of 20 cases, the export regressions are in line with “typical” play-dynamics and reveal “significant” t-statistics for the spurt variable (however, with the mentioned caveats concerning the distribution of the estimators).

Our model fits especially well in respect of exports of Germany to all destination countries. While this has been already documented by earlier studies for the export destinations United States and Japan (Belke, Goecke and Guenther, 2013, Belke, Goecke and Werner, 2015, and the references cited therein), the empirical success of the export hysteresis model (under certainty) regarding the BRICs does not come as a surprise either, at least not according to section 2 which underscored the relevance of the BRICs for German exporters. In particular, the *composition* by sector of Germany’s exports to the BRICS is dominated by vehicles, engineering, chemical products and electronics – less homogenous, differentiated capital goods which have only few close substitutes. What is more, *entry and exit costs* tend to be biggest in those sectors. Note also, that section 2.2 disentangled evidence in favor of local currency price stabilization in German machinery exports to China and Russia which supports evidence hysteresis in exports in the German case.

Italy (4 out of 5 significant entries with the expected sign of the spurt variable), the United Kingdom (3 out of 5 entries) and France (2 out of 5 entries) follow. In section 2, we emphasized that Italy has relatively low shares of capital goods (which have fewer close substitutes) in total exports: 4 out of 5 significant hysteretic specifications are, thus, remarkable. It was also stated that export price elasticities are high in France which does not support hysteretic specifications of exports which is mirrored in France's weak performance in Table 3. Moreover, Belke, Oeking and Setzer (2014) argue that the openness of the French economy is lower than its European counterparts investigated here. For the UK, the estimation results may also be determined by a different degree of exchange rate uncertainty the country is faced with because it did not have the euro. Finally, some of the apparent misspecifications simply appear because domestic demand is not included in the short-run parts of the individual export equation specifications (Belke, Oeking and Setzer, 2014).

In section 2.6, we argued that the issue of *policy uncertainty* (which is amplified by other geopolitical risks such as the fight against terrorism) German and other exporters see themselves confronted with is particularly relevant for the export destinations Brazil and Russia. This is mirrored in Table 3 by mostly significant results for Brazil and Russia.

The hysteretic export model does not fit particularly well when analyzing exports to China with our export hysteresis model when considering France, Italy and the UK. It is probable that the effect of Chinas GDP dominates the spurt effect on exports for these countries.

Some of the countries analyzed in this paper have been subjected to unique shocks as is the case for Russia and the sanctions following the annexation of the Crimea peninsula and the earthquakes of 2011 in Japan and the resulting nuclear disaster in Fukushima. We do consider these effects in our interpretations of the relevance of the uncertainty variable.

Fedoseeva and Zeidan (2016) identify some well-saturated BRIC markets in which European exporters face tough competition and need to apply strategic pricing – e.g. pricing-to-market – to smooth negative developments of exchange rates or inflation in order to protect their market shares. This group of exports might be negatively affected by a long-term deterioration of an importing country's economic health (i.e., production). Given that this group of exports includes mostly German exports to Russia and some manufactured products and machinery from France and Italy, the good fit of the hysteretic export model for Germany, France and Italy with the destinations Russia and Brazil becomes understandable.

6. Robustness checks

6.1 Limited sample regressions

As a first test for robustness we shorten the sample period to exclude the effects of the global financial crisis. These estimations end in December 2007. We eliminate all effects that might result from a structural break triggered by the crisis. Table 4 shows the corresponding estimation results.

- Table 4 about here -

Out of the 20 estimations, 12 show the expected sign while 6 estimations either show an unexpected sign for the beta coefficient or yield insignificant results. Additionally, two regressions show the correct sign while the original effect of the exchange rate variable exceeds the spurt effect. While only concentrating on the pre-crisis period does lead to *better results* (i.e. a negative and significant effect of the spurt variable) for two of the regressions (French exports to Japan and British exports to Russia) it does also cause *unexpected results* for four estimations which were in line with theory in the estimations based on the initial sample period (German exports to the US and China, Italian exports to Russia and British exports to Japan). Seen on the whole, thus, our estimation results are relatively robust regarding an exclusion of the crisis period. A slightly weaker evidence in favor of export hysteresis results for Germany, implying that including times of higher uncertainty (i.e. the crisis period), the model fits better for Germany.

As a second test for robustness, we limited the sample to the period ranging from 2002 M2 to 2015 M12, thus excluding the effects of the dotcom bubble and the initially high real exchange rate for both Russia and Brazil resulting from the strongly rising prices in both countries which yield a strong fall in real exchange rates as prices are employed in the denominator. However, this specific sample period selection does not result in a better fit of our estimations, now yielding 14 estimations with an expected sign and 6 with an unexpected result (similar to our initial results but in this case British exports to China show the correct sign while those to Russia do not).[21]

6.2 Impact of policy and economic uncertainty on EU countries' export activity

To additionally test for robustness we add a degree of uncertainty to the play variable. As uncertainty variable we use the economic policy uncertainty index (http://www.policyuncertainty.com/europe_monthly.html) relevant for the EU member countries and exchange rate uncertainty. We proxy the latter by the standard deviation of the real exchange rate for the last twelve months excluding the present month[22], in accordance with Belke, Goecke and Werner, 2015, in a hysteresis context, and Belke and Gros, 2002, in general). The economic policy uncertainty variable measures policy-related economic uncertainty and is composed of three types of underlying components. One component quantifies newspaper coverage of policy-related economic uncertainty by searching for certain keywords in the media.

[21] Results for an estimation period starting after 2001 are available on request.

[22] To clarify issues: for December 2011 we therefore calculate the standard deviation from December 2010 to November 2011.

We therefore had to decide which side of the policy uncertainty variable is the correct one to be implemented in the play areas of our hysteretic export equations: policy uncertainty in the sending or in the receiving country? There are arguments in favor of both. But anyway the index is not available for the receiving country Brazil. So what are the arguments?

To measure European policy-related economic uncertainty, the producers of "Economic Policy Uncertainty", Baker, Bloom and Davis (2016), construct an index which is based on newspaper articles reporting on the uncertainty of economic policy. The two newspapers relevant per country for the four European countries considered are: Le Monde and Le Figaro for France, Handelsblatt and Frankfurter Allgemeine Zeitung for Germany, Corriere Della Sera and La Repubblica for Italy, and The Times of London and Financial Times for the United Kingdom. As with their American newspaper index, the number of newspaper articles dealing with uncertainty, economy or policy are considered.[23]

Policy uncertainty measured for an EU country may thus, beyond uncertainty in its export destination country, also be related to policy uncertainty prevailing in export destination countries such as the US, Japan and the BRICs Brazil, Russia and China. This kind of uncertainty is prominently reported in the sending countries' media as well. What is more, policy uncertainty in the receiving countries tends to quickly transform into uncertainty in the sending country and may even change governance structures there (which are like tax legislature also part of the policy uncertainty index). Hence, we feel legitimized to employ the uncertainty index for the sending country to proxy uncertainty for the exporters in the exporting countries. This is all the more so if we look at the background of our export hysteresis model.

[23] See http://www.policyuncertainty.com/europe_monthly.html. A second component reflects the number of federal tax code provisions set to expire in future years. The third component uses disagreement among economic forecasters as a proxy for uncertainty. See also Belke and Kronen (2016).

One reason for a possible connection between uncertainty and the economy is the real option approach described above. As shown, this approach suggests an option value of waiting with export decisions for the exporting country which makes us, for reasons of coherence, feel legitimized to concentrate on the implementation of policy uncertainty in the sending country in our further empirical investigations.[24]

A similar second channel looks at the consumption side and recommends implementing policy uncertainty in the receiving country. In an environment of high uncertainty, households will more likely postpone spending, especially on products such as automobiles and major appliances, goods typically exported by Germany.[25] So high political/policy uncertainty may motivate consumers to spend less and to build up a buffer stock of liquid assets (Baker, Bloom and Davis, 2012). Policy uncertainty in the receiving country may therefore impact exports of the sending country.[26] This might be also the case for unique effects in the receiving country such as the Russian trade embargo or the earthquake in Japan in 2011[27] However, this is clearly not the main thrust of our hysteresis model used in this paper.

As far as we know, the economic policy uncertainty index has not been applied in detail to export estimations before.[28] The grid search now employs the uncertainty variable as a second

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24 We implement the empirical realisations of the economic policy uncertainty index for Germany, France, Italy and the UK, provided at http://www.policyuncertainty.com/index.html.

25 Romer (1990) considers this channel as the key driver of the drop in demand during the Great Depression.

26 See Colombo (2013) in a general spill-over context.

27 Employing economic policy uncertainty relating to the receiving country yields a worse fit and theoretically not expected signs for the spurt variable. This indicates that the effect of domestic uncertainty is already included in the production variable of the destination country contained in the export equations. Results for the cases in which policy uncertainty in Russia, Japan and China are implemented in the export equations are available on request.

28 At least there is no trade-related source listed under the heading “Research on Economic Policy Uncertainty” on the “economic policy uncertainty” homepage. See http://www.policyuncertainty.com/research.html. Nor do Baker, S., Bloom, N., Davis, S.J. (2016) survey any piece on political uncertainty and exports or trade, except Handley and Limão (2015) who discuss the impact of the elimination of policy uncertainty through establishing trade agreements on the volume of trade.

variable describing the play width (Belke and Goecke 2001, 2005). The play variable is defined over time and is used to calculate the highest R^2:

$$p_t = \gamma + \delta \cdot u_t$$

The parameter c represents the constant part of the play variable δ depicts the influence of uncertainty (see eq. (6) in section 4.2).

Table 5 shows the estimation results for our prime example of German exports to Brazil (see Table 1). Including policy uncertainty results in a better fit (expressed in a higher value of R^2) than the estimations using constant play, with all coefficients keeping their expected sign and significance.

- Table 5 about here -

In the following, we display the results for four regression specifications from the previous sections, with the inclusion of the uncertainty variable:

- Table 6 about here -

Table 6 displays the results of including policy uncertainty in our estimation framework. The coefficient of the spurt variable shows the theoretically expected sign and is significant (with the exception for the areas shaded in white and exports from France to Japan which yields insignificant results). Notably, the inclusion of uncertainty results in a significant expected sign for the beta coefficient of British exports to China while the estimations with constant play resulted in theoretically wrong estimations for the spurt variable.

The results clearly show that including the economic policy uncertainty to determine the play width significantly increases quality of the export estimations for the EU, as measured, for instance, by the R^2.[29] We may deduce that policy uncertainty matters for EU member countries'

[29] Plots of the variable play are available on request.

exports and cannot be rejected empirically to be responsible for lagging export growth, when external competitiveness has significantly turned to the better.

The respective variable play pattern for our prime example of German exports to Brazil is displayed in Figure 8.

- Figure 8 about here -

We additionally integrate exchange rate uncertainty, expressed as the standard deviation of the exchange rate for the last twelve months, as the variable defining variable play. The results are illustrated in Table 7.

- Table 7 about here -

As the results show, implementing exchange rate volatility yields a *by far weaker fit* than employing constant play or using policy uncertainty as the variable defining uncertainty. Out of the 20 regressions only 9 estimations show the theoretically expected results while eight estimations result in either insignificant or positive beta coefficients. Three estimations yield the correct results for the spurt variable but with a higher significant effect of the initial exchange rate effect ($|\alpha| < |\alpha + \beta|$).

We also apply a *combination* of political and economic uncertainty by multiplying exchange rate volatility and the economic policy uncertainty index thus gaining a more volatile uncertainty variable. The results however do not differ substantially from the results shown in Table 6 and are available on request.

7. Conclusions

The paper deals with the impact of policy and exchange rate uncertainty on the relationship between EU member countries' exports and its main determinants. Our intention was to identify a band of inaction for EU member countries' exports (which is widened by economic policy and exchange rate uncertainty). For this purpose, we rely on a non-linear path-dependent model in which suddenly strong spurts of exports occur when changes of the exchange rate go beyond a so called ‘play area’ (which is similar to the phenotype of play in mechanics). We capture these non-linear dynamics in a simplified linearized way and implement an algorithm describing play hysteresis into a regression framework. For several country destinations of EU member countries’ total exports, our non-linear model including play-hysteresis shows a significant effect of the non-linear play-dynamics. Analyzing some of the largest EU member countries’ export partners, we find hysteretic play-effects in a significant part of EU member countries’ export destinations.

The existence of ‘bands of inaction’ (called ‘play’) in EU member countries’ exports should lead to a more objective discussion of peaks and troughs in those countries’ real exchange rates and, more specifically, of the relevance of internal and external devaluation and other indicators to gain international competitiveness on exports in political debates. Not every increase or decrease of the real exchange rate (as a proxy of external competitiveness) will automatically lead to reactions of the volume of exports. A large enough appreciation (depreciation) of an EU member country’s real exchange rate means passing the border of a play/inaction-area (which can be seen as a kind of “pain threshold”) and yields a strong reaction of exports. Moreover, we show that the play/inaction area is path-dependent – and changes its position with extreme real exchange rate movements. Thus, a unique “export trigger”, for instance, of the real exchange rate cannot be determined. Finally, the width of this area of weak export reaction grows with the degree of policy and, less so, of exchange rate uncertainty.

Hence, if policy and/or exchange rate uncertainty are diminished, one may expect an earlier boost in exports, if the home currency is devaluing in real terms (and an earlier fall of exports for a revaluing home currency). An elimination of policy uncertainty may result by the creation or the deepening of free trade agreements.

With an eye on the fact that analyzing the impact of uncertainty on exports is a rather new field of study, some aspects are left for further research.

Future research may look explicitly at *sectoral evidence* (Belke and Kronen, 2016) while this paper does this already implicitly by applying an aggregation mechanism over individual firms which acknowledges heterogeneity. For this purpose, one could estimate separate regressions for different product groups (see Belke, Goecke and Guenther, 2013, for the case without uncertainty). One could go even further and look at each exporting firm individually, especially if a country's exports[30] are composed of only a few exporters (for example, Portugal where Volkswagen is dominating total exports). One could then compare it to a control group of non-hysteretic firms (see Belke, Goecke and Werner (2015), pp. 28f.).[31]

In this disaggregated case, one expects hysteresis effects to occur and the play areas to be the larger, the more *heterogeneous* the products/firms are and the *bigger entry and exit costs* are. However, average productivity should play a less important role in determining the degree of hysteresis in exports (Bernard and Jensen, 2004, Greenaway and Kneller, 2003, Hiep and Ohta 2007, pp. 23f.). The seminal studies on hysteresis in trade thus underscore the importance of the *combination* of firm/goods heterogeneity and sunk costs in determining the behaviour of firms in doing business abroad (Bernard and Jensen, 2004, Roberts and Tybout, 1997).

Future research may also take into account explicitly (instead of only implicitly by including economic policy uncertainty) the *impact of financial constraints* (under the condition that an adequate and sufficiently long time series is found) *on the width of the "band of inaction"* in EU member countries' exports (Ito and Terada-Hagiwara, 2011). Regarding financial constraints the example of Greece is illuminating but not necessarily fully applicable here: "(t)he

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[30] For instance, chemical products and road vehicles, i.e. those sectors for which hysteresis effects in trade are found by Belke, Goecke and Guenther, 2013, but much less so fuels etc.

[31] We are grateful for this comment to Barbara Rossi.

reluctance of the Greek government to adhere to the agreed reform agenda raised the risk of Greece's exit from the euro area; this risk was pushed entirely on the productive sector in the form of restricted and expensive financing, putting Greek companies at an acute and persistent competitive disadvantage. The high cost of money and the need to deleverage corporate balance sheets created an uneven playing field in export markets as companies within the euro area were facing a fraction of the costs Greek companies were facing" (Pelagidis, 2014, for the Greek case and, more generally, Bems, Johnson, and Yi. 2013).

Therefore, one implicit but important factor that might be held accountable for the decrease in the number of exporters is a *worsening access to external finance*. As Amiti and Weinstein (2011) reveal, exports are highly dependent on access to finance, significantly more so than domestic operations of firms. Export promotion in this case would imply loosening export constraints. One controversial issue in this context is whether the European Central Bank's Quantitative Easing is successfully contributing to this (Belke and Verheyen, 2014).

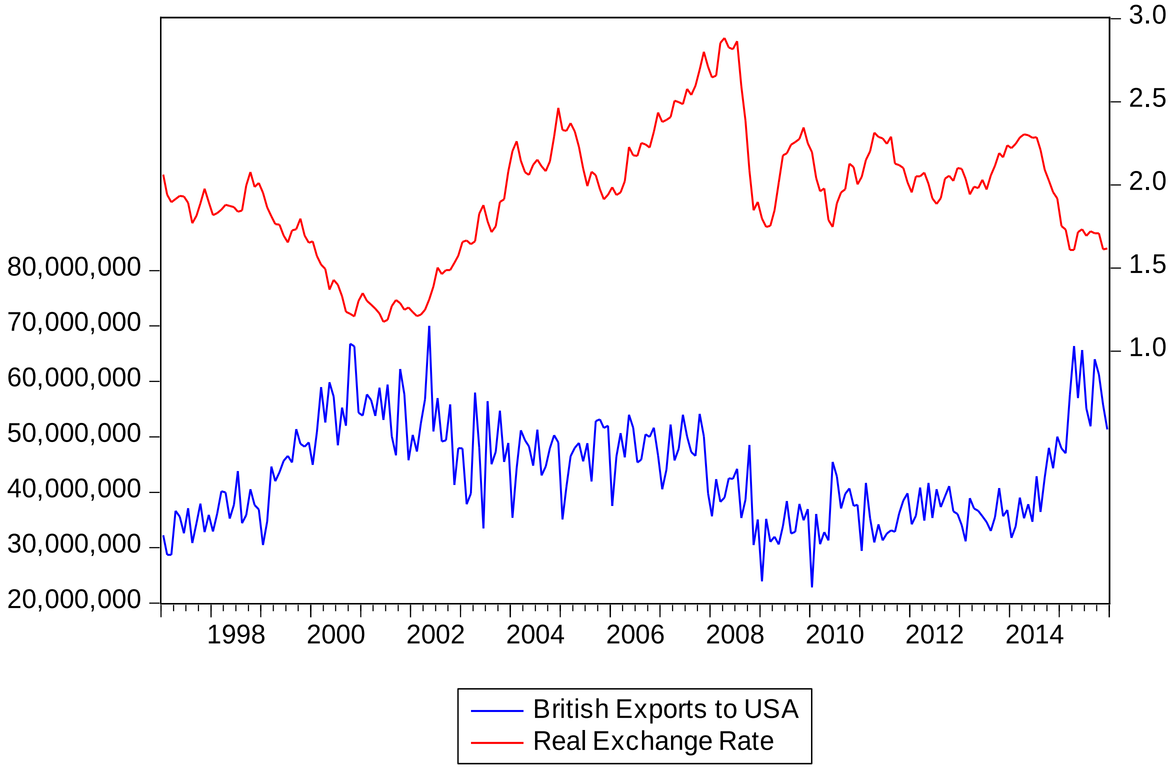
If hysteresis in exports is important for a sample of EU member countries, as our study suggest that it is, then the exit of firms triggered by the crisis may lead to a *persistent reduction of the number of exporters* in a country even after the crisis, unless the home currency will be depreciating a lot further and/or policy uncertainty and/or exchange rate uncertainty will be significantly diminished. As a result, the extensive margin matters and export activity may *become more concentrated among a smaller number of firms* (Goerg and Spaliara, 2013).

This has potentially important policy implications for countries engaged in promoting export performance. The British Government agency UK Trade & Investment, for example, appears to have a strong focus on assisting firms to start exporting, i.e., *increase the number of firms* exporting (extensive margin) rather than just the overall quantity of exports (intensive margin) (Goerg and Spaliara, 2013).

A growing number of firms having dropped out of export markets during the crisis should indeed be a reason for concern to policymakers (Goerg and Spaliara, 2013). These firms are unlikely to simply re-enter their export markets after the crisis, since partly irreversible entry costs and a still high (and very high in the UK case due to the uncertainties surrounding Brexit) policy uncertainty clearly matter for export decisions. Instead, they have to be treated like "first time exporters, relying on the same export promotion policies as firms that have never exported before" (Goerg and Spaliara, 2013).

Figures

Figure 1 – *Real exchange rate and UK exports to the United States*



Source: Monthly data, own calculation based on Eurostat and OECD data. Exports in million EUR, exchange rate in Pound Sterling/US-dollar.

Figure 2 – *Discontinuous micro hysteresis loop: export activity of a single firm*

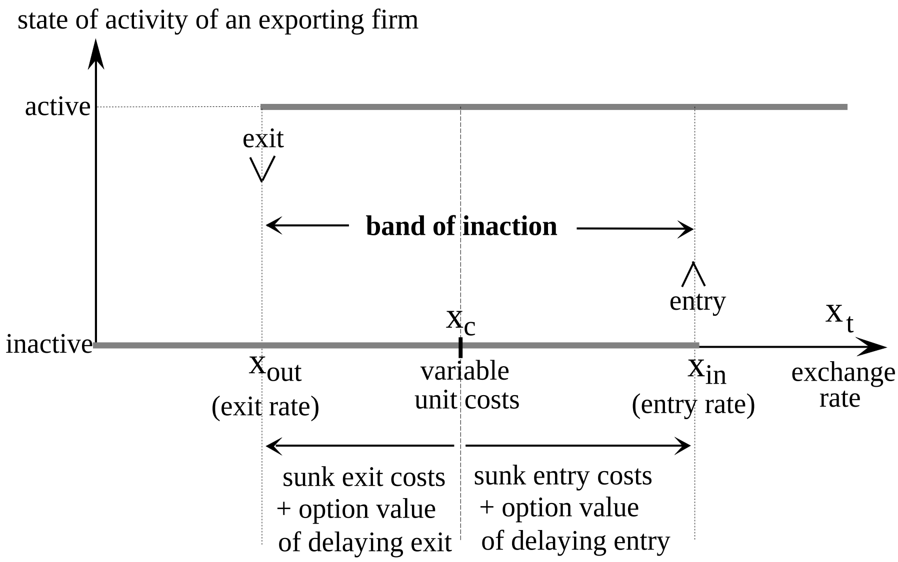


Figure 3 – *Linear play-hysteresis and spurt areas*

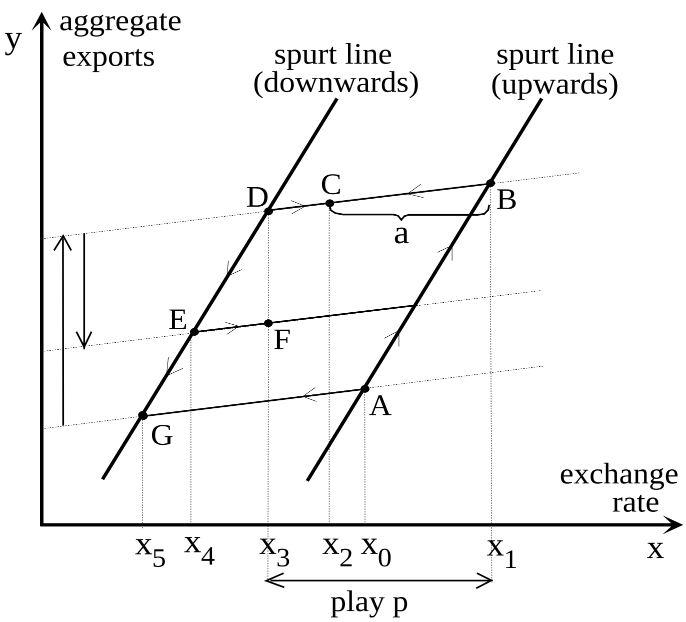


Figure 4 - *Linear Spurt Areas and Variable Play*

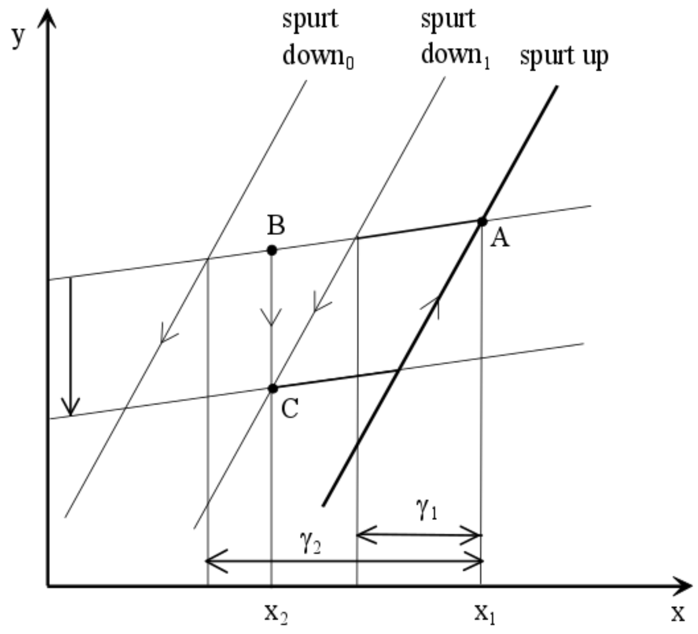


Figure 5 – *Shift of the play-lines by past spurts and the current reaction* Δy_j^s

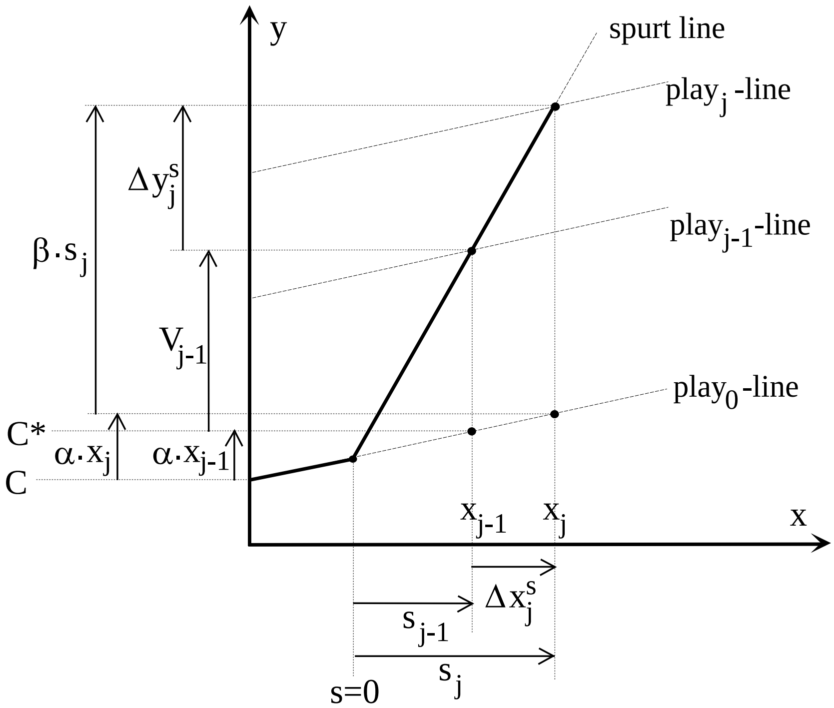


Figure 6 – *R^2 resulting from a one-dimensional grid search over constant play γ = 0.08125*

German Exports to Brazil

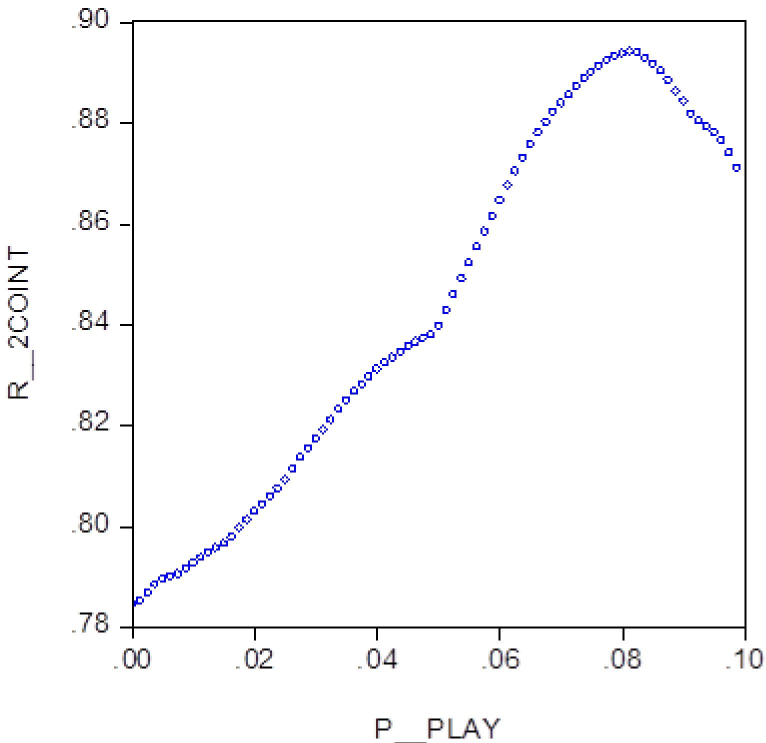


Figure 7 – *Real exchange rate and the resulting spurt variable (γ =0.08125)*

German Exports to Brazil

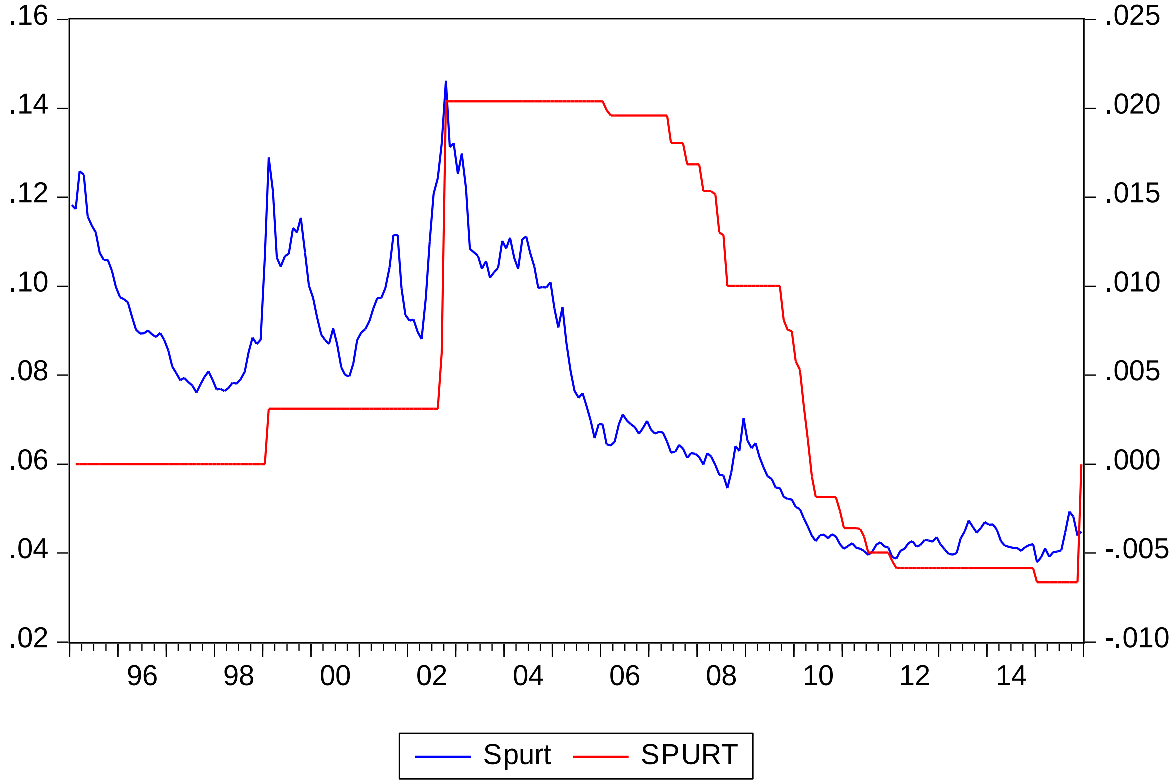
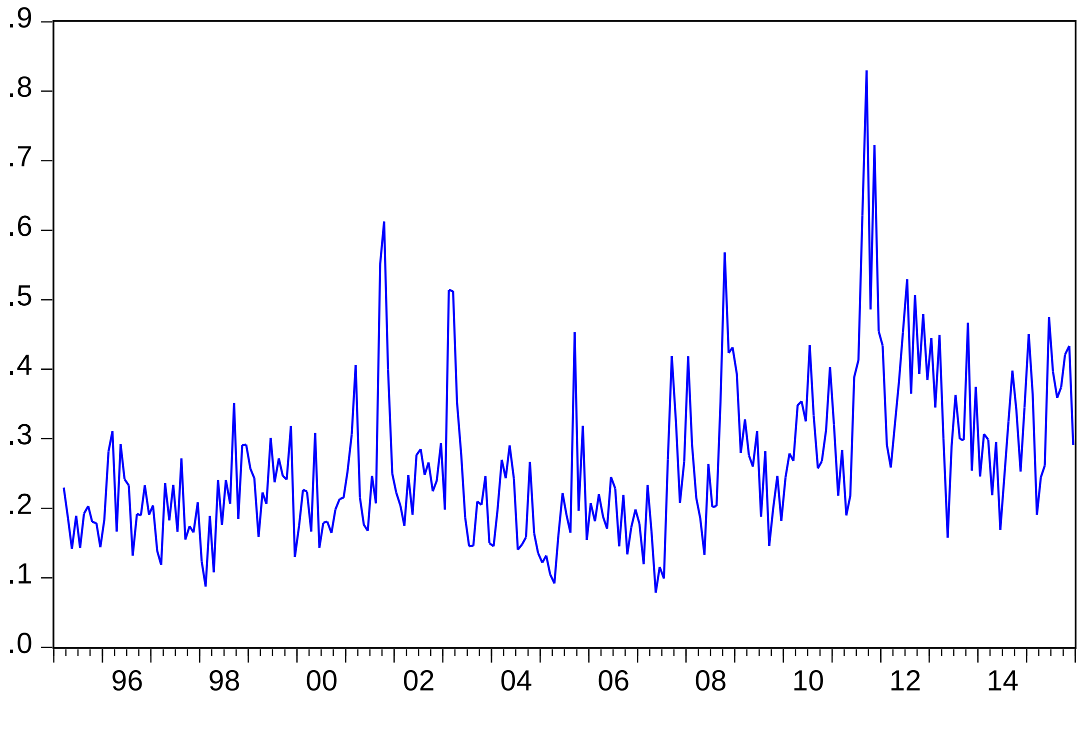


Figure 8 - *Variable Play Germany to Brazil*

PLAY



Tables

Table 1 – *Standard LS regression without play (restriction $\beta = 0$)*

German Exports to Brazil

Dependent Variable: D_BR
Method: Least Squares
Sample: 1995M01 2015M12
Included observations: 252

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3435864.	1103587.	3.113361	0.0021
W	-33160193	4159630.	-7.971910	0.0000
@TREND	7398.690	2141.765	3.454482	0.0006
IP_BR (-1)	46241.86	12765.21	3.622491	0.0004
DUMMY	-367251.7	226789.8	-1.619349	0.1066

R-squared	0.784608	Mean dependent var	5849975.
Adjusted R-squared	0.781120	S.D. dependent var	2119099.
S.E. of regression	991412.9	Akaike info criterion	30.47129
Sum squared resid	2.43E+14	Schwarz criterion	30.54132
Log likelihood	-3834.383	Hannan-Quinn criter.	30.49947
F-statistic	224.9364	Durbin-Watson stat	0.642310
Prob(F-statistic)	0.000000		

Table 2 – *LS regression with constant play $p = \gamma = 0.08125$*

German Exports to Brazil

Dependent Variable: D_BR
Method: Least Squares
Sample (adjusted): 1995M02 2015M12
Included observations: 251 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SPURT	-97131019	6051987.	-16.04944	0.0000
C	-5466448.	953507.7	-5.732988	0.0000
W	2548030.	3669929.	0.694300	0.4882
@TREND	3212.244	1530.482	2.098845	0.0369
IP_BR (-1)	129937.8	10385.28	12.51173	0.0000
DUMMY	-225154.4	159243.0	-1.413904	0.1587

R-squared	0.894182	Mean dependent var	5861722.
Adjusted R-squared	0.892023	S.D. dependent var	2115095.
S.E. of regression	695017.7	Akaike info criterion	29.76488
Sum squared resid	1.18E+14	Schwarz criterion	29.84915
Log likelihood	-3729.492	Hannan-Quinn criter.	29.79879
F-statistic	414.0608	Durbin-Watson stat	1.318650
Prob(F-statistic)	0.000000		

Table 3 – *Overview of the regression results with constant play*

	USA	Japan	Brazil	Russia	China
Germany	α = -31930662*** β = -1.73E+08 γ = 0.6 t = -3.7399***	α = 1.594894 β = -76.21796 γ = 56 t = -5.6876***	α = 2548030 β = -97131019 γ = 0.08125 t = -16.0494***	α = 36366.74* β = --68971.54 γ = 9.375 t = -4.5985***	α = 1138603 β = -2911975 γ = 1.425 t = -3.0301***
France	α =-18524578*** β = 7284324 γ = 0.30625 t = 2.1816**	α = -27193.5*** β = 11774.2 γ = 0.0625 t =1.403	α = 407223.5 β = -2301469 γ = 1.025 t = -5.9130***	α = -253447.9*** β = -138530.4 γ = 1.9125 t = -2.2430**	α = -901890.6*** β = 726135.6 γ = 1.4375 t = 2.6141***
Italy	α = -36860426*** β = -11613995 γ = 0.13 t = -1.9042*	α = -8647.419*** β = -16536.34 γ = 57.5 t = -5.6794***	α = -16837812*** β = -63471529 γ = 0.07625 t = -10.6501***	α = -98695.86*** β = -400509.9 γ = 33.75 t = -7.8010***	α = -195901.1** β = 238336.1 γ = 2.7 t = 2.0856**
United Kingdom	α = -11693001*** β = -11693001 γ = 1.125 t = -5.1811***	α = -520.2616 β = -16832.65 γ = 126 t = -7.5280***	α = -118296*** β = -715740.9 γ = 2.64 -4.4420***	α = -58425.13*** β = 37299.54 γ = 11.2125 t = 1.9911**	α = -295103.3*** β = 898175.7 γ = 14.26250 t = 4.3718***

α = estimated coefficient for the original real exchange rate (RER)

β = estimated coefficient for the spurt exchange rate variable (SPURT)

γ = estimated play width

Note: Areas shaded in grey show the expected negative sign for the β-coefficient. Areas highlighted in white either show an unexpected sign or an insignificant effect. Level of significance (student- t statistic): ***for 1%, ** for 5%, *for 10%

Table 4 – *Robustness check: Overview of the regression results excluding the crisis period*

	USA	Japan	Brazil	Russia	China
Germany	α =-13312247 β = -13312247 γ = 0.0825 t = -1.5096	α = 17.74834 β = -145.3120 γ = 80 t = -2.4429**	α = -5189146 β = -59421012 γ = 0.08 t = -6.3661***	α = -20366.16* β = -2573682 γ = 165 t = -58391***	α = 1682463*** β = -1016349 γ = 0.9 t = -3.2656***
France	α =-22645849*** β = 15575777 γ = 0.23125 t = 2.8109***	α = 40226.73 β = -60421.6 γ = 6.5 t = -2.2131**	α = -10809.93 β = -5446867 γ = 1.3875 t = -6.0544***	α = -92483.62** β = -108599 γ = 2.625 t = -2.8822***	α = -1599905*** β = 1123461 γ = 0.625 t = 2.1797**
Italy	α = -29719133 β = -30435826 γ = 0.225 t = -2.0737**	α = 12893.67* β = -42821.76 γ = 23.5 t = -4.6936***	α = 12518111 β = -26101984 γ = 0.013 t = -3.1266***	α = -5427248.7 β = 586983.3 γ = 0.125 t = 1.7070*	α = 684002.4 β = -768122.8 γ = 0.425 t = -1.9693*
United Kingdom	α = -11398477*** β = -10275345 γ = 1.625 t = -2.0668**	α = -19644.07*** β = 8597.144 γ = 0.25 t = 1.4534	α = 53539.86 β = -184271 γ = 0.75 t = -1.8334*	α = -69741.22** β = -98948.55 γ = 3.45 t = -3.1312***	α = -130688.4*** β = 230771.2 γ = 7.5 t = 4.5970***

α = estimated coefficient for the original real exchange rate (RER)

β = estimated coefficient for the spurt exchange rate variable (SPURT)

γ1 = estimated play width

Note: Areas shaded in grey show the expected negative sign for the β-coefficient. Areas highlighted in white either show an unexpected sign or an insignificant effect. Beige highlights estimations with |α| < |α + β|. Level of significance (student- t statistic): ***for 1%, ** for 5%, *for 10%

Table 5 - *LS regression with variable play p = γ = 0.0175 + 0.007875*U*

German Exports to Brazil

Dependent Variable: D_BR
Method: Least Squares
Sample (adjusted): 1995M02 2015M12
Included observations: 251 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SPURT	-92765911	5724920.	-16.20388	0.0000
C	-5084025.	933850.9	-5.444150	0.0000
W	2706823.	3651599.	0.741271	0.4592
@TREND	2784.981	1527.433	1.823308	0.0695
IP_BR (-1)	124644.8	10162.76	12.26486	0.0000
DUMMY	-221732.0	158469.3	-1.399212	0.1630

R-squared	0.895221	Mean dependent var	5861722.
Adjusted R-squared	0.893082	S.D. dependent var	2115095.
S.E. of regression	691599.0	Akaike info criterion	29.75501
Sum squared resid	1.17E+14	Schwarz criterion	29.83929
Log likelihood	-3728.254	Hannan-Quinn criter.	29.78893
F-statistic	418.6502	Durbin-Watson stat	1.330971
Prob(F-statistic)	0.000000		

Table 6 – *Overview of the regression results with variable play using economic policy uncertainty*

	USA	Japan	Brazil	Russia	China
Germany	γ = 0 δ = 0.00975	γ = 38 δ = 0.11	γ = 0.0175 δ = 0.00215	γ = 0 δ = 0.007875	γ = 0 δ = 0.00075
France	γ = 0.0075 δ = 0.0025	γ = 0 δ = 0.025	γ = 0.025 δ = 0.005	γ = 0.15 δ = 0.00875	γ = 0.65 δ = 0.0105
Italy	γ = 0.07 δ = 0.0006	γ = 22.5 δ = 0.11875	γ = 0 δ = 0.000775	γ = 25.25 δ = 0.115	γ = 1.3 δ = 0.0096
United Kingdom	γ = 0.025 δ = 0.00225	γ = 63.75 δ = 0.524	γ = 2.55 δ = 0.00058	γ = 0.5 δ = 0.052750	γ = 0.3 δ = 0.025

γ = estimated constant play width
δ = estimated variable play width
Note: Areas shaded in grey show the expected negative sign for the β-coefficient. Areas highlighted in white either show an unexpected sign or an insignificant effect.

Table 7– *Overview of the regression results with variable play using exchange rate uncertainty*

	USA	Japan	Brazil	Russia	China
Germany	γ = 0.3 δ = 7.5	γ = 30 δ = 3.5	γ = 0 δ = 0.05	γ = 0 δ = 4	γ = 1.25 δ = 0.095
France	γ = 0.2 δ = 3	γ = 76 δ = 3.25	γ = 0.95 δ = 0.095	γ = 0 δ = 2.55	γ = 1.25 δ = 0.45
Italy	γ = 0.1 δ = 0.6	γ = 22.5 δ = 4.25	γ = 0 δ = 0.95	γ = 19 δ = 0.9	γ = 1.75 δ = 1.4
United Kingdom	γ = 0 δ = 0.15	γ = 97.5 δ = 1.9	γ = 0.1 δ = 0.75	γ = 9 δ = 0.95	γ = 12.75 δ = 2.4

γ = estimated constant play width
δ = estimated variable play width
Note: Areas shaded in grey show the expected negative sign for the β-coefficient. Areas highlighted in white either show an unexpected sign or an insignificant effect. Beige highlights estimations with $|\alpha| < |\alpha + \beta|$

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Annex: An algorithm for calculating the spurt variable

In the following we present a detailed algorithm based on Belke and Goecke (2001) to calculate the extent of the current penetration into the play area a_t and the cumulated spurts s_t. We define four dummy variables describing the current state of the system. For reasons of simplification, some special cases which become relevant if the change in x *exactly* meets the border between play and spurt (e.g. in point D) are not explicitly included below. However, these cases are taken into account in the Eviews version of the algorithm.

A dummy $M_t^{\downarrow}$ indicates a movement starting in a left (downward leading) spurt line. Analogously, $M_t^{\uparrow}$ indicates a start on a right (upward leading) spurt line. Corresponding to Figure 3 e.g. for point E, $M_t^{\downarrow} = 1$ holds, and for point B $M_t^{\uparrow} = 1$ is valid.

$$M_t^{\downarrow} = \begin{cases} 1 & \text{if } \Delta s_{t-1} < 0 \\ 1 & \text{if } (\Delta s_{t-1} = 0) \wedge (\Delta x_{t-1} = 0) \wedge (\Delta a_{t-1} = 0) \\ 0 & \text{else} \end{cases} \qquad (9)$$

$$M_t^{\uparrow} = \begin{cases} 1 & \text{if } \Delta s_{t-1} > 0 \\ 1 & \text{if } (\Delta s_{t-1} = 0) \wedge (\Delta x_{t-1} = 0) \wedge (\Delta a_{t-1} = 0) \\ 0 & \text{else} \end{cases}$$

Due to the path dependence, information on the current reference spurt line has to transmitted to subsequent periods: The dummies $B_t^{\downarrow}$ and $B_t^{\uparrow}$ indicate the last (and maybe the current) spurt line. In Figure 3 e.g. for point F, $B_t^{\downarrow} = 1$ is valid, and $B_t^{\uparrow} = 1$ holds for point C.

$$B_t^{\downarrow} = \begin{cases} 1 & \text{if } \Delta s_{t-1} < 0 \\ 1 & \text{if } (\Delta s_{t-1} = 0) \wedge (B_{t-1}^{\downarrow} = 1) \\ 0 & \text{else} \end{cases} \qquad (10)$$

$$B_t^{\uparrow} = \begin{cases} 1 & \text{if } \Delta s_{t-1} > 0 \\ 1 & \text{if } (\Delta s_{t-1} = 0) \wedge (B_{t-1}^{\uparrow} = 1) \\ 0 & \text{else} \end{cases}$$

with: $B_t^{\uparrow} = 1 - B_t^{\downarrow}$

Now, we calculate the extent a_t to which the play area p_t is penetrated. We first define an auxiliary variable b_t. Play penetration a_t is calculated based on a comparison of b_t and the play width p_t.

$$b_t = B_t^{\downarrow} \cdot (1 - M_t^{\downarrow}) \cdot (a_{t-1} + \Delta x_t) + B_t^{\uparrow} \cdot (1 - M_t^{\uparrow}) \cdot (a_{t-1} - \Delta x_t) \quad (11)$$

$a_t =$

Fehler! (12)

Finally, we define changes in the spurt variable (Δs_t) induced by changes in the input variable (Δx_t):

$$\Delta s_t = \begin{cases} b_t \cdot [B_t^{\downarrow} \cdot (1 - M_t^{\downarrow}) - B_t^{\uparrow} \cdot (1 - M_t^{\uparrow})] & \text{if } b_t < 0 \\ (b_t - p_t) \cdot [B_t^{\downarrow} \cdot (1 - M_t^{\downarrow}) - B_t^{\uparrow} \cdot (1 - M_t^{\uparrow})] & \text{if } b_t > p_t \\ \Delta x_t & \text{if } [(M_t^{\downarrow} = 1) \wedge (\Delta x_t < 0)] \vee [(M_t^{\uparrow} = 1) \wedge (\Delta x_t > 0)] \\ \Delta x_t - p_t & \text{if } (M_t^{\downarrow} = 1) \wedge (\Delta x_t > p_t) \\ \Delta x_t + p_t & \text{if } (M_t^{\uparrow} = 1) \wedge ((-\Delta x_t) > p_t) \end{cases} \quad (13)$$

The width of the play p_t was not addressed up to now but is at the heart of our paper. In a simple case p_t is defined as a constant parameter p_t=p=γ witch has to be estimated. However, it is central for our paper that it is easy to generalize the model in a way where the play width p_t is determined by other variables. The higher the empirical realization of the economic policy uncertainty or the exchange rate uncertainty variable u_t is, the more important are option value effects of waiting, and thus the play area is expected to widen. In technical term this can be expressed in a simple linear way as a function of, e.g., an uncertainty proxy variable u_t:

$$p_t = \gamma + \delta \cdot u_t \qquad \text{with: } \gamma, \delta \geq 0 \text{ and } u_t \geq 0 \Rightarrow p_t \geq 0 \quad (14)$$

Table A.1: Implementation of the algorithm into an EVIEWS-batch program

```
  SMPL 97.1 15.12
  'INPUT AREA
GENR s_up=1       'set 1 for a maximum as an initial extremum (else 0)
```

```
!an = 97.2        'first estimation quarter (time of the first extremum in a
  spurt area)
!en = 15.12       'last estimation quarter
!n = 214    'number of sample point (calculated from !an to !en)
!g = 20     'precision of the grid search for the constant play component
!m = 0      'minimum of the grid search for the constant play component
!b = 20     'maximum of the grid search for the constant play component
!h = 20     'precision of the grid search for the variable play component
!y = 0      'minimum of the grid search for the variable play component
!v = 1      'maximum of the grid search for the variable play
GENR w = wk_ru    'hysteretic input variable
GENR u = U_d

'END OF INPUT AREA

  'INITIALISATION
  SMPL 97.1 15.12
  GENR dw=na
  GENR d_spurt=na
  GENR play=na
  GENR spurt=na
  GENR bs_do=na
  GENR s_do=na
  GENR bs_up=na
  GENR pb=na
  GENR pc=na
  GENR pa=na
  GENR punkt_do=na
  GENR punkt_up=na
  GENR dw=w-w(-1)
  C=0
  matrix(!g,!h) R_2m =0
  matrix(!g,!h)  C_11m = 0
  matrix(!g,!h)  C_12m = 0
  matrix(!g,1) P_CONSTA =0
  matrix(1,!h) P_VARIA =0
  SMPL !an !an
  GENR bs_up=s_up
  GENR s_do=1-s_up
  GENR bs_do=1-s_up
  SMPL !an-1 !an
  GENR pa=0
  GENR pb=0
  GENR pc=0
  GENR d_spurt=0
  GENR spurt=0
  'END OF INITIALISATION

  'START OF GRID SEARCH
  FOR !0=1 TO !g    'LOOP FOR P_CONSTA
  FOR !1=1 TO !h    'LOOP FOR P_VARIA
  SMPL !an !en
  GENR spurt=0
  GENR play = !m+((!0-1)/(!g))*(!b-!m) + (!y+((!1-1)/(!h))*(!v-!y))*u
  P_CONSTA(!0,1) = !m+((!0-1)/(!g))*(!b-!m)
  P_VARIA(1,!1) = !y+((!1-1)/(!h))*(!v-!y)

  IF @MIN(play)>0 THEN

   FOR !2=1 TO !n  'LOOP FOR THE DETERMINATION OF THE SPURT VARIABLE

    SMPL !an+!2 !an+!2

    GENR punkt_do=(pa(-1)=play(-1))*(pa(-1)<>0)*s_up(-1)+(pb(-1)=play(-
  1))*(pb(-1)<>0)*bs_up(-1)
    GENR punkt_up=(pa(-1)=play(-1))*(pa(-1)<>0)*s_do(-1)+(pb(-1)=play(-
  1))*(pb(-1)<>0)*bs_do(-1)
```

```
    GENR s_do=(pa(-1)<>play(-1))*(pb(-1)<>play(-1))*((d_spurt(-
  1)<0)+(s_do(-1)=1)*(d_spurt(-1)=0)*((dw(-1)=0)*(pa(-1)=0))) + punkt_do
    GENR s_up=(pa(-1)<>play(-1))*(pb(-1)<>play(-1))*((d_spurt(-
  1)>0)+(s_up(-1)=1)*(d_spurt(-1)=0)*((dw(-1)=0)*(pa(-1)=0))) + punkt_up
    GENR bs_do=(pa(-1)<>play(-1))*(pb(-1)<>play(-1))*((d_spurt(-
  1)<0)+(d_spurt(-1)=0)*(bs_do(-1))) + punkt_do
    GENR bs_up=(pa(-1)<>play(-1))*(pb(-1)<>play(-1))*((d_spurt(-
  1)>0)+(d_spurt(-1)=0)*(bs_up(-1))) + punkt_up
    GENR pb=bs_do*(1-s_do)*(pa(-1)+dw) + bs_up*(1-s_up)*(pa(-1)-dw)
    GENR pc=s_do*(dw>0)*dw + s_up*(dw<0)*(-dw)
    GENR pa=pc*(pc<=play) + bs_do*(1-s_do)*(pb>0)*(pb<=play)*pb + bs_up*(1-
  s_up)*(pb>0)*(pb<=play)*pb
    GENR d_spurt=s_do*((dw<0)*dw+(dw>play)*(dw-play)) + s_up*((dw>0)*dw+((-
  dw)>play)*(dw+play)) + bs_do*(1-s_do)*((pb<0)*pb+(pb>play)*(pb-play)) +
  bs_up*(1-s_up)*((pb<0)*(-pb)+(pb>play)*(play-pb))
    GENR spurt=spurt(-1)+d_spurt

   NEXT

  ENDIF

   c=0
   SMPL !an !en
   IF @MEAN(spurt)=0 THEN
   EQUATION eq1 LS            'insert base estimation
   ELSE
   EQUATION eq1.LS ST12        'insert estimation with spurt
   ENDIF

   GENR EC = RESID
   R_2m(!0,!1) = @R2
   C_11m(!0,!1) = c(1)
   C_12m(!0,!1) = c(2)

   c=0
   GENR RESID=na
   GENR EC=na

  NEXT
  NEXT   'END OF GRID SEARCH


  'SEARCH FOR HIGHEST R²

   coef(2) c_und_d
   scalar r2_max=0

   FOR !i=1 TO !g
    FOR !j=1 TO !h
      IF  ( R_2m(!i,!j) > r2_max ) THEN
      r2_max=R_2m(!i,!j)
      c_und_d(1)=p_consta(!i,1)
      c_und_d(2)=p_varia(1,!j)
     ENDIF
    NEXT
   NEXT

' Using highest R²

SMPL !an !en
GENR play = c_und_d(1) + c_und_d(2)*u

 FOR !2=1 TO !n

  SMPL !an+!2 !an+!2

GENR  punkt_do=(pa(-1)=play(-1))*(pa(-1)<>0)*s_up(-1)+(pb(-1)=play(-
  1))*(pb(-1)<>0)*bs_up(-1)
```

```
GENR  punkt_up=(pa(-1)=play(-1))*(pa(-1)<>0)*s_do(-1)+(pb(-1)=play(-
   1))*(pb(-1)<>0)*bs_do(-1)
GENR  s_do=(pa(-1)<>play(-1))*(pb(-1)<>play(-1))*((d_spurt(-1)<0)+(s_do(-
   1)=1)*(d_spurt(-1)=0)*((dw(-1)=0)*(pa(-1)=0))) + punkt_do
GENR  s_up=(pa(-1)<>play(-1))*(pb(-1)<>play(-1))*((d_spurt(-1)>0)+(s_up(-
   1)=1)*(d_spurt(-1)=0)*((dw(-1)=0)*(pa(-1)=0))) + punkt_up
GENR  bs_do=(pa(-1)<>play(-1))*(pb(-1)<>play(-1))*((d_spurt(-
   1)<0)+(d_spurt(-1)=0)*(bs_do(-1))) + punkt_do
GENR  bs_up=(pa(-1)<>play(-1))*(pb(-1)<>play(-1))*((d_spurt(-
   1)>0)+(d_spurt(-1)=0)*(bs_up(-1))) + punkt_up
GENR pb=bs_do*(1-s_do)*(pa(-1)+dw) + bs_up*(1-s_up)*(pa(-1)-dw)
GENR pc=s_do*(dw>0)*dw + s_up*(dw<0)*(-dw)
GENR  pa=pc*(pc<=play)  +  bs_do*(1-s_do)*(pb>0)*(pb<=play)*pb  +  bs_up*(1-
   s_up)*(pb>0)*(pb<=play)*pb
GENR  d_spurt=s_do*((dw<0)*dw+(dw>play)*(dw-play))  +  s_up*((dw>0)*dw+((-
   dw)>play)*(dw+play))     +     bs_do*(1-s_do)*((pb<0)*pb+(pb>play)*(pb-
   play))+bs_up*(1-s_up)*((pb<0)*(-pb)+(pb>play)*(play-pb))
GENR spurt=spurt(-1)+d_spurt

NEXT


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 c=0
 EQUATION eqcoint.LS    'insert spurt estimation
 GENR EC = RESID


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 'Converting into data series
IF !h=1 THEN
  delete graphEC graphCoint
  genr  p__play=na
  genr  r__2coint=na
  genr  r__2ec=na
  vector(!g) R_2coint=0
  R_2coint=@COLUMNEXTRACT(R_2m,1)
  vector(!g) R_2ec=0
  R_2ec=@COLUMNEXTRACT(R_2ec,1)
  MTOS(R_2coint,r__2coint)
  MTOS(R_2ec,R__2ec)
  MTOS(p_consta,p__play)
  graph graphEC.scat  r__2ec p__play
  graph graphCoint.scat  p__play r__2coint
  delete R_2coint 'R_2ec
ENDIF

' Cleaning
delete s_up s_do bs_up bs_do  pb pc pa punkt_do punkt_up
```

Transcriptions:

a_t = pa ; $B_t^{\downarrow}$ = bs_do ; $B_t^{\uparrow}$ = bs_up ; b_t = pb ; $M_t^{\downarrow}$ = s_do ; $M_t^{\uparrow}$ = s_up ; p_t = play ; s_t = spurt ; Δs_t = d_spurt ;

u_t = u ; x_t = w ; Δx_t = dw ; y_t = BAI ; γ = c_und_d(1) ; δ = c_und_d(2) .

Comments:

In order to apply the batch program, some information has to be delivered in the `'INPUT AREA`, since the starting point has to be characterized, due to the path dependence of the system. It is necessary to start in a spurt area (with either $M_t^{\uparrow}$ = s_up = 1 or $M_t^{\downarrow}$ = s_do = 1).

Therefore, the sample has to be truncated on occasion and in the **'INPUT AREA** the variable s_up has to be set to 0 or 1.