R O M E
Research On Money in the Economy

No. 15-05 – September 2015

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ROME Discussion Paper Series

ISSN 1865-7052

Research On Money in the Economy

Discussion Paper Series
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Abstract

In this paper a non-linear model is applied, 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 Greek exports is estimated based on the period from 1995Q1 to 2014Q4. Looking at some of the main export partners of Greece, the euro area, Turkey and the US, and some of its most important tradeable sectors we identify significant hysteretic effects for a part of the Greek exports. We find that Greek export activity is characterized by "bands of inaction" with respect to changes in the real exchange rate and calculate the further real depreciation needed to trigger a spurt in Greek exports. To check for robustness we (a) estimate Greek export equations for a limited sample excluding the recent financial crisis, (b) use export weight instead of deflated nominal exports as the dependent variable, (c) employ a political uncertainty variable as a determinant of the width of the area of weak reaction. Overall, we find that those specifications which take uncertainty into account display the best goodness of fit. In other words: the option value of waiting dominates the real exchange rate effect on Greek exports.

JEL-Classification: F14, C51

Keywords: real depreciation; Greece; play-hysteresis; modelling techniques; switching/spline regression; export demand

Acknowledgments: We are grateful for valuable comments from Daniel Gros, Thomas Moutos and participants in the NoeG 2015 Annual Conference, Klagenfurt, where parts of this paper were presented in a keynote lecture.

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1. Introduction

In periods of Euro appreciation, European politicians and business persons have frequently been concerned with the external value of the European currency. In fact, concerns have been expressed nearly every time when the euro appreciated. For example by BusinessEurope President Ernest-Antoine Seilliere who in 2007 said to Jean-Claude Juncker, the chairman of Eurogroup, that he also agreed that the euro exchange rate had reached a “pain threshold“ for European companies (*Dow Jones International News* 2007). This statement implies that beyond some boundaries (“pain threshold”) stronger export reactions in case of an exchange rate change are expected.

In this context, it is important to assess the extent to which the euro is too strong for a specific euro area member country. For this purpose, for instance Belke and Volz (2014) report estimates of the USD/EUR exchange rate pain thresholds and rank the euro area member countries accordingly. The USD/EUR threshold is estimated to be 1.54 for Germany, 1.29 for Spain, 1.28 for Finland, 1.23 for France, 1.19 for Italy, and a very low 1.04 for Greece. The point estimate for Germany turns out to be rather close to the pain threshold of USD/EUR 1.55 which has been calculated by Belke, Göcke and Guenther (2013). What is more, the European Commission (2014) assesses Euro Area member states’ different degrees of vulnerability to changes in the exchange rate.

In this paper, however, we are – on the contrary - interested in calculating the lower real exchange rate (“competitiveness”) triggers which would lead to a spurt in Greek exports. A closer look into the more recent episode, in which the Greek real exchange rate vis-à-vis the Euro Area is getting lower and lower, might give a first indication in this regard. According to Figure 1, from 2011 until today a monotonously ongoing external devaluation is accompanied with flat Greek exports to the Euro Area. Figure 1 deals with Greek exports of chemical and related products (SITC 4) because one seventh of Greek exports are in chemical and related products (SITC 4) and also Machinery and transport equipment (SITC 7). It just covers a significant part of Greek exports. The reversal of this exchange rate movement in 2011 does not seem to have any positive effects on exports up to now. However, an ongoing one-directional further real depreciation should lead to a more significant positive effect on Greek exports. In this paper we try to quantify this trigger and how far the Greek real exchange rate is still away from it, in spite of all the wage and price reductions already conducted under the Programme.

- Figure 1 about here -

What are potential reasons of a *weak reaction* of Greek exports to small exchange rate movements with a varying direction? Let us first address the usual candidates generally applied to industrialised countries: hedging of exchange rate uncertainty, low price elasticity of exports, *pricing-to-market*, and significant (sunk) market entry or/and exit costs.[1]

Hedging of exchange rate uncertainty: in the short run, i.e. in the case of an only transitory real appreciation of the home currency, the choice of the invoice currency and the extent of cross-currency hedging play a role. Even if a larger extent of all foreign currency receivables from the Greek export business are hedged against exchange rate related losses for some time, hedging cushions the appreciation pressure only for a limited period (for German exports see Deutsche Bundesbank, 2008).

Greek export product line and price elasticity of exports: the share of relatively price-inelastic goods in the range of Greek exports is quite low (Athanasoglou, Backinezos and Georgiou, 2010, p. 44). In this respect, the Greek case is much different from, for instance, the German one for which exports to non-euro area countries, in particular, respond weakly to price competitiveness (Belke, Göcke and Guenther, 2013, and Deutsche Bundesbank 2008). Even more important, equipment and vehicles do not dominate Greece's industrial production. German firms, in contrast, are often highly specialized in these areas and maintained their position as the world market leader in terms of technology. As a consequence, importers are not able to or even do not want to switch to other suppliers even if Germany appreciates in real terms, because switching costs would be too high for them.

Pricing-to-market by Greek exporting firms: Greek export prices may show a weak cost pass-through due to a *pricing-to-market* strategy. This implies that a Greek real appreciation is mainly absorbed through a reduction in the profit margin (Stahn, 2007). Accordingly, (Athanasoglou, Backinezos, and Georgiou, 2010, p. 44) claim for the pre-crisis period that "Greek export prices elasticity is twice as much as competitors' prices. This indicates that the price competitiveness of Greek exports is determined mainly by the pricing policies and the cost of Greek exporting firms and less by the behavior of their competitors".

Sunk market entry or/and exit costs: Recent research in international economics, employing theoretical analysis and assessment of firm level data clearly confirms that "sunk costs mat-

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[1] For further reasons of a weak reaction of Greek exports see Pelagidis (2014).

ter" (Godart, Goerg and Goerlich 2009). Setting up of global export networks coincides with substantial set up costs which cannot be recouped to a large extent once a firm leaves the export market or terminates its international customer-supplier relationships. Examples of sunk costs of entering export markets are those of information gathering on the new market (costs for market research), setting up distribution and service networks, bearing the costs of establishing a brand name through advertising, and bringing the foreign product into conformity with domestic health regulations, etc. These costs are firm-specific and cannot be resold on exiting the market, at least in terms of their total value, being therefore regarded as (partially) irreversible investments (Belke, Göcke and Werner, 2014, Kannebley 2008, Roberts and Tybout 1997). The literature on, for instance, German firm export decisions has found considerable persistence in export status over time (Bernard and Wagner, 2001).[2]

Financial constraints of exporting firms: a possible explanation of a weak reaction of firms to changes in international competitiveness may especially in the Greek case rest on the lack (and increased cost) of credit for the survival or expansion of existing firms, and the creation of new ones. This constraint would naturally be more binding for firms requiring a larger amount of start-up financing in order to be created; such firms are more likely to reside in the manufacturing sector than in retail trade. Now, we continue with considerations relevant after the start of the crisis.

Credit frictions may have also been instrumental in preventing a reorientation of domestic production to exports as domestic demand collapsed. It is well known (e.g. Melitz and Trefler, 2012) that only a small subset of firms within a particular industry export, that non-exporters are less productive than exporters and pay lower wages, and that exporting firms are larger in every dimension (e.g. in terms of sales, employment, number of distinct goods produced) than non-exporting ones. A reduction in domestic demand due to fiscal consolidation will impact on exporting and non-exporting firms in different ways:

Some of the least-productive non-exporting firms will shut down; these firms were only surviving before the crisis because demand was adequate enough to generate operating profits that covered their fixed (sunk) costs.

The more productive among the non-exporting firms will try to substitute for the fall in domestic demand by starting to export. In principle, they will be helped in this endeavour by the

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[2] See also Papadogonas, Voulgaris and Agiomirgianakis (2007) on hysteresis in Greek exports, and Aydin and Ifantis (2004), pp. 156-157, on hysteresis in Greek-Turkish foreign trade.

reduction in wages associated with the process of internal devaluation. However, the switch to exporting is fraught with difficulties for would-be first-time exporters due to substantial costs related to acquiring information about foreign markets, customizing their products to fit local tastes and set up distribution networks (Das, Roberts and Tybout, 2007). Furthermore, because most entry costs must be paid up front, only firms with sufficient liquidity can cover them. The severe credit constraints experienced by Greek firms since 2009 have made the task of first-time entry into foreign markets particularly difficult.[3]

Existing exporters would, in principle, be able to take advantage of the reduction in wages in order to increase their exports. Nevertheless, the advantage conferred to these firms by the decline in labour costs was, to a large extent, counterbalanced by the large increases in non-labour costs due to the rise in real interest rates (which were often above 10%) and energy costs (mostly as a result of tax hikes) (Moutos, 2015).

Beyond the considerations mentioned above, for both exporting and non-exporting firms, the immediate effects of the decline in demand arising from domestic agents may – ceteris paribus – involve a move up along a (given) decreasing average cost curve. The rise in average costs involved would then be larger *the larger is the drop in domestic demand, thus making it harder to increase exports* (Belke, Oeking and Setzer, 2014). The difficulty of accessing new markets will be exacerbated by the worsening financial situation of the firm, since the search for new export markets requires financial resources which become scarcer as credit ratings drop.

We also note that breaking into new markets does not happen instantaneously. If, as a result of front-loaded fiscal consolidation, the decline in domestic demand for traded goods is large enough so that it destroys firms' credit rating and worsens their ability to raise finance to expand their operations abroad, the hoped-for increase in exports may be far smaller than if consolidation proceeded at a slower pace initially, thus giving time to firms to expand and consolidate their presence in new markets (Moutos, 2015).

In a nutshell, we can describe the process described above as the confluence of factors shifting both the (downward-sloping) average cost curves and the product demand curves of monopolistically competitive firms. The global financial crisis produced the initial adverse shock on product demand, which was followed by the reduction in product demand due to a strong

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[3] Dinopoulos, Kalyvitis and Katsimi (2015) and Pelagidis (2014) provide evidence, based on data from Greek exporting firms, for the role of credit constraints in accessing foreign markets.

dose of front-loaded fiscal consolidation. These shocks would –ceteris paribus – induce a leftward (upward) climb along a given average cost curve.[4] The wage declines were expected to shift the average cost curves downward, but were, to a large extent, neutralized by the increases in non-labour costs (e.g. energy, capital). The uncertain net effect of these shifts, as well the non-availability of credit to speed-up access to foreign markets as they were recovering from the global crisis, may be a relevant explanation of developments since 2009 (Moutos, 2015).

Note also that Greece entered the crisis with an institutional environment that was not favourable to building competitive businesses. In the crisis, labor costs have decreased, but at the same time some of the costs and the uncertainties of doing business have increased. For existing exporters, shortage of finance is perhaps the most important of those, but there are many others. For factor mobility, bureaucracy, corruption and an overall perception of a deteriorating environment ("institutional uncertainty") have been increasingly important barriers (Arkolakis, Doxiadis and Galenian, 2014, pp. 21ff.). In this context, findings of an overall increase of the "band of inaction" (determined by exit and entry costs multiplied with uncertainty, see Belke and Göcke, 2005) in Greek exports are realistic, because institutional uncertainty has increased while fixed and variable costs have decreased (Belke, Göcke and Hebler, 2005).

Based on the arguments above, a non-linear reaction of exports to exchange rate changes seems reasonable: Small exchange rate changes will only have weak effects, however stronger exchange rate changes with an monotonously ongoing trend into one direction, will at some point (let it be named "*pain threshold*") result in larger reactions of the export volume. The exchange rate which forces the firm to a change of the volume of its export activity (i.e. the pain threshold) will be highly product dependent and will differ widely from company to company and from sector to sector (von Wartenberg, 2004). There is *heterogeneity of the exchange rate threshold across firms*, i.e. on the micro level: On the one hand, suppliers of niche products, such as in the field of specialized mechanical engineering or certain segments of the automobile business can perhaps shrug off the increase in value of the euro with comparative ease, while firms with standard products have a huge problem with a strong euro. Moreover, dependent on *past* exchange rate movements, the firms have earlier decided on their export activity status and e.g. spent sunk costs on market entry investments at a time

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[4] The effects described here bear some resemblance to Krugman's (1984) "import protection as export promotion".

when the exchange rate was favorable – or, vice versa, may have left the export markets if the exchange rate was unfavorable. Thus 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. 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 demanded micro data may not be available. However, aggregation of non-linear path-dependent microeconomic activity to a sectoral or macroeconomic analysis is not straightforward as well, since the path-dependent dynamic pattern may differ between the micro perspective of a firm and the aggregated macro perspective of an entire sector/economy consisting of *heterogeneous* firms (see discussion in Göcke, 2002).

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

The paper proceeds as follows. In section 2, 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 3. In section 4, we estimate the exchange rate impacts on Greek exports to some export destinations such as the euro area, Turkey and the US, differentiating between intervals of weak and strong reaction. Section 5 presents some robustness checks. We (a) estimate Greek export equations for a limited sample excluding the recent financial crisis, (b) use export weight instead of deflated nominal exports as the dependent variable, (c) employ a political uncertainty variable as a determinant of the width of the area of weak reaction. This variable may also serve as a proxy of financial constraints of Greek exporting firms. Section 6 concludes.

2. Hysteresis in exports: A ‘band of inaction’ in a microeconomic point of view

Hysteresis is an effect that occurs when a market is subjected to sunk market-entry costs (Baldwin 1989, 1990). This means that firms willing to export have to make an investment to enter the market, e.g. setting up a distribution and service network or introductory sales promotion. These expenses differ from firm to firm and cannot be retrieved if the firm decides to leave the export market again; i.e. the costs to enter the market are sunk. If the exchange rate changes while prices on the export market do not change proportionally an exporting firm has to sustain revenue changes in their home currency when the exchange rate varies. In a situation where the foreign currency appreciates (corresponding to a depreciation of the home currency), entering the market may become profitable, under consideration of the sunk entry costs

After a firm has entered the export market, due to a sufficient appreciation of the foreign currency, a depreciation may occur. However, once the firm has entered the market, it is still profitable to sell as long as variable costs are still covered. The previous entry is not fully compensated due to entry costs which have to be viewed as sunk ex post. The effect is analogous when considering sunk exit costs. The corresponding reaction pattern to changes of the exchange rate for a single firm is illustrated in Figure 2. The foreign exchange rate x is defined as the price of foreign exchange expressed in the home currency. The exchange rate x_c precisely compensates the variable unit costs of production of the firm. If the home currency depreciates (or alternatively the foreign currency appreciates) the unit revenues which are changed back to the exporters home currency increase. As the sunk exit costs must be covered before entering the export market an entry exchange rate x_{in} which exceeds the variable costs (x_c) is required. If the losses triggered by a foreign devaluation are larger than the sunk exit costs an active firm will exit the export market. The exit trigger x_{out} must therefore be located below x_c. Hence, there is a difference between the entry and exit triggers in a situation with sunk entry and exit costs. The path-dependence on the micro level occurs discontinuously when an entry or exit trigger rate is passed.[5] Both triggers combined result in a ‘band of inac-

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[5] According to Krasnosel’skii and Pokrovskii (1989), p. 263, this pattern corresponds to a so-called “non-ideal relay”.

tion'. If the exchange rate is located inside this band the current state of the firm's activity cannot be stated with certainty.

-Figure 2 here-

Adding uncertainty regarding the future exchange rate into the regression, strengthens the hysteresis characteristics by considering option value effects.[6] Since exiting the export market will destroy investments made beforehand, an exporting firm may stay when the home currency devalues despite currently losing money. In a situation where the devaluation turns out to be only temporary an immediate exit could be a mistake. The possibility to "wait-and-see" under uncertainty therefore shifts the exit trigger to the left. The entry trigger is respectively shifted to the right when waiting with an entry under uncertainty. Hence, the "band of inaction" is widened in a situation with uncertainty.

Changes in exchange rates will result in extensive changes in revenue for the home currency if the price elasticity of demand in the respective export market is high. Conversely, when the price elasticity of demand in the export market is high, changes in exchange rates do not result in big unit revenue changes. The size of the band-of-inaction will therefore increase if, the demand elasticity declines, the absolute values of the sunk entry and exit costs rise, and the uncertainty of the exporters' future situation increases.

On the micro level hysteresis appears in the form of a band of inaction, i.e. the difference between both thresholds. Belke and Göcke (2005) focus on the form and the location of a hysteresis loop on a macro level and therefore concentrate on the *issue of aggregation.* [7] Aggregating is not straight forward if heterogeneity concerning the magnitude of sunk exit/entry costs and/or the level of uncertainty of the future market situation and/or the elasticity of demand is considered, i.e. entry and exit triggers are different for varying exporting firms. This (realistic) case of heterogeneity changes the hysteresis characteristics in the transition from the micro to the macro perspective: the aggregated hysteresis loop shows no discontinuities. Although a dynamic pattern similar to a "band of inaction still occurs.

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[6] For an extensive treatment of uncertainty effects see Dixit, Pindyck (1994). 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).

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

Belke and Göcke (2005) show that macro behavior can also be described by areas of weak reactions which are – corresponding to mechanical play – called "play" areas. [8] Permanent aggregate export effects do not result from minor changes in the forcing exchange rate variables, as long as the changes take place inside a play area. If changes, however, go beyond the width of the play area, abrupt strong reactions (with persistent effects) of the output variable, in this case exports, occur.[9] The precise value of the exchange rate which arises just after the complete pass-through of the play area can be characterized as a "pain threshold", since, once this value of the exchange rate is passed the reaction of exports to a change in the exchange rate will become much stronger. Play-hysteresis does, however, differ in two aspects to the micro-loop. First, the play-loop shows no discontinuities in its function. Second, as in mechanical play (e.g. steering a car) the play area, defining the area of weak reactions, is shifted with the earlier values of the forcing variable (exchange rate): Every time the direction of the movement of the forcing variable changes it starts with traversing a play area. Then, after the whole play area is passed, a spurt reaction can be observed, if the forcing variable continues its course in the same direction (see Belke, Göcke and Werner, 2014).

The following section will present a straightforward empirical framework to test for a play-type impact of the exchange rate on exports, as depicted in this chapter. We use an algorithm which was developed in Belke and Göcke (2001) specifying play-hysteresis and apply it in a standard regression framework.

3. An empirical model of play-hysteresis

3.1 A linear approximation of exchange rate impacts on exports

To depict an impression of the linear play-dynamics – as developed by Belke and Göcke (2001, 2005) – we will first show the implications based on Figure 3. We assume a constant width of the play area p to simplify the illustration. The starting point of our explanation is point A (x_0) which is located on the (right) upward leading spurt line. If the forcing variable decreases at this point we will enter the play area. A weak "play" reaction is initiated until the play area p is passed entirely. If the forcing variable is degraded further a downward spurt

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[8] For play hysteresis, see Krasnosel'skii and Pokrovskii (1989), pp. 6 ff. See Göcke (2002) for different types of hysteresis.

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

reaction will be initiated in point G and the value x_5 (with: $p=x_0-x_5$). As long as the reaction takes place in the play area a weak reaction of the variable y results from changes in x. A continuing decrease of x induces a strong response of the dependent variable along the (downwards) spurt line.

The forcing variable may also start with an increase going from x_0 (A) up to x_1 (point B) followed by a subsequent decrease to x_2 (C). The initial reaction of y can be observed on the right spurt line. Due to the increase along the spurt line from A→B the corresponding play area is shifted vertically upward from line GA to line DB ($p=x_1-x_3$). A following reduction of x_2 (C) to x_3 (D) takes place in a play area again.[10] The play area is passed to an extent 'a' which is specifically depicted in the figure. Assume a following decrease $x_2 \rightarrow x_3 \rightarrow x_4$ (C→D→E). After the entire play width p has been passed in point D (x_3), a strong spurt reaction on the downward leading spurt line up to point E results. At this point, a further decrease (i.e. a devaluation of the foreign currency) leads to a sudden strong decrease of the exports. Thus, x_3 can be considered as a kind of "pain threshold". This "pain threshold" is, however, not defined by a constant trigger level as seen in the microeconomic portrayal of sunk costs, but path-dependent, as the position of the play lines may be shifted vertically by movements along the spurt lines. In this case the play area reacts in the opposite course as before, so that for a following increase to the earlier value of x_3 (F) the reaction is described by the new play area EF.

-Figure 3 here-

3.2 An algorithm capturing linear play

This section presents a play algorithm which was developed by Belke and Göcke (2001, 2005) to analyze employment hysteresis[11] and then adapt it to our main research question, i.e. the identification of an exchange rate "pain threshold" for Greek exports. A shift in the forcing variable x (Δx) may occur either along the play area p resulting in a weak reaction or on a spurt line inducing a strong spurt reaction of the dependent variable y (Δy). The change in position of x along the play area is defined as Δa (and cumulated as a) and the movement in

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[10] 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.

[11] Based on Portuguese firm-level data, Mota (2008), pp. 99 ff., and Mota et al. (2012) use this linear play-algorithm to estimate and compare *aggregate* employment hysteresis with micro level adjustment patterns.

the spurt area is depicted as Δs. We start with the case for Δx entering a play area. This change will be denoted as Δx_j^s. Applying this case to Figure 3 this corresponds to the trajectory B→C→E. Before all movements of x have led to j changes between the two spurt lines. The following change Δx_j^s can enter the play area to the extent of Δa_j or traverse the entire play width p and penetrate the alternate spurt line by Δs_j. Since we started from a spurt line the cumulative movement in the play area a_j corresponds to the change Δa_j. The trajectory B→C in Figure 3 illustrates the distance "a". These considerations can be summarized by the following expression:

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

Changes in the variable y (Δy) triggered by Δx_j^s are generated by the play reaction (B→C) and – if the entire is passed – additionally of a spurt reaction (D→E). Let the parameter α indicate the weaker play reaction and $(\alpha + \beta)$ the stronger spurt reaction:

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

The play lines are shifted vertically by movements along the spurt lines. The cumulative vertical motion V_{j-1} of the relevant play line resulting from all movements on both spurt lines corresponds to:

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

The dependent variable y is identified by the shift V determined by past spurts and the prevailing 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 4 depicts the interpretation of the implementations of equation (4). Therefore, the hysteresis loop is measured by a simple linear equation based on the artificial variable s_j. The "*spurt variable*" s_j encompasses all earlier and present spurt movements that lead to a shift of the actual relation between x and y.

-Figure 4 here-

The agglomeration induced by the index j describing past changes between the spurt lines may be replaced by an accumulation over a concrete time index t. Further non-hysteretic regressors (e.g. z_t) can be included to achieve a generalized representation of the hysteretic process:[12] $y_t = C^* + \beta \cdot \sum_{k=0}^{t} \Delta s_t + \alpha \cdot \Delta x_t + \lambda \cdot z_t$ (5)

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

4. Empirical analysis

4.1 Existing studies

The possibility of hysteresis in foreign trade was first tested by Baldwin (1990) and Krugman and Baldwin (1987) by using macroeconomic time series data for the U.S. economy and employing dummy variables representing periods of an appreciating exchange rate. Empirical models that aim to capture an asymmetric effect of real exchange rate volatility and real exchange rate fluctuations on imported quantities were developed by Parsley and Wei (1993).

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[12] For a more detailed explanation of the algorithm calculating the artificial spurt variable s_t and for the implementation into batch programs of standard econometric software see Belke and Göcke (2001) and the appendix.

They do however doubt the validity of the hysteresis hypothesis as a way to explain the persistent U.S. trade deficits in the 1980s. Roberts and Tybout (1997) and Campa (2004) found sunk cost hysteresis to be an important determinant in explaining export market participation using micro firm level data and therefore focusing on discontinuous micro-hysteresis (but still emphasizing the heterogeneity of firms). Agur (2003) found empirical evidence to support the notion of structural breaks in the relation between exchange rates and import volume resulting from exchange rate extrema. Applying a threshold cointegration model for sectoral data in Brazilian foreign trade, Kannebley (2008) could identify an asymmetric adjustment in 9 of 16 sectors. Belke, Göcke and Guenther (2013) use an algorithm with path-dependent play-hysteresis to analyze the impact of real exchange rates changes on German exports for the period from 1995Q1 to 2010Q3. They find significant hysteretic effects for a major part of German exports when looking at some of the main export destinations outside the euro area and most important tradeable sectors of Germany.

Compared to existing studies of hysteresis in foreign trade, our approach taken in this paper is the one developed by Belke, Göcke and Guenther (2013). It is closer to the original concept of a *macroeconomic* "hysteresis *loop*", since (i) it is not related to the discontinuous non-ideal relay interpretation as in the microeconomic enterprise level case and since (ii) the path-dependent structural breaks in the macroeconomic relations are not implemented in the system as an exogenous information. On the contrary, in the by Belke, Göcke and Guenther (2013) approach the structural shifts are explicitly determined by the historical path of the real exchange rate. What is more, the path-dependent relation of exports to the real exchange rate is simultaneously estimated.

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

The model for "play regression" shows the following characteristics: It is based on linear sections, where adjoining parts are 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 current position of the linear function and the switchover from one section to the other is defined by the past realizations of the input variable x. The model is a peculiar case for a switching regression framework, as adjoining sections are linked.[13] The magnitude of the estimated play area p determines the position of the knots whose position is not known a-priori. The knots permit a differentiation for the

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

relation between x and y characterized by two differing slopes (for $\beta \neq 0$). The amount of coefficients that describe the hysteretic dynamics is small: only the play width p, the basic slope α, and the difference in slopes β have to be determined.

We expect the standard regression model assumptions to be true: the error term is independently, identically and normally distributed and has a constant finite variance for all segments, and the regressors are estimated without error and do not correlate with the error term.

The parameters of our model are non-linear, as knots are not known beforehand and since the spurt variable s is determined by an estimated play width p. The assumptions made concerning the error term and regressors ensure that the OLS-estimators are best linear unbiased estimators for a standard regression model so the OLS-estimator can be considered as a maximum likelihood estimator. For knots that are a-priori unknown, local maxima and brakes in the likelihood function result. If, however, the adjacent parts are joined in a switching regression model the OLS-/ML-estimator will lead to consistent and asymptotically normally distributed estimates.

Due to the finite sample characteristics of the play regression a straightforward estimation is still problematic: for estimations with small samples the estimates of the coefficients is not approximately normally distributed which may result in local maxima for the likelihood function.[14] Additionally, standard regression model assumptions may not be met. For the case of non-stationary variables non-finite variances may occur. In addition the application of cointegration analysis is obstructed as the play dynamics are characterized as a mixture of short- and long-term dynamics. Despite these shortcoming, we are not aware of a technique that delivers this (small sample) distribution and the critical values for the estimators while being directly applicable to our specific model. A solution to this particular problem is therefore beyond the scope of this paper.[15]

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[14] 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.

[15] The standard procedure for using non-stationary variables is to use first differences. Unfortunately, this does not work for our algorithm, since the path-dependent effects that are used as a basis are related to the *level*s of the forcing/original variable (i.e. the exchange rate). Mota et al. (2012) point out that OLS estimates are, in a time series econometrics sense, super-consistent, and can therefore 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 by re-estimating the long run relation with FM-OLS in order to avoid cointegration problems. The above mentioned problems do however remain for the first step (identification of the play) and for small sample properties

To find the ideal play width which determines the value of the spurt variable and minimizes the residual sum of squares a grid search over the width of a invariant play parameter $p_t = p = \gamma$ is conducted (for a constant width p). The spurt variable and transition knots are estimated for every value of p using the data of the forcing variable (exchange rate). The realization of γ is predetermined for every grid point. The slopes α and β representing the coefficients in the OLS-estimation can now be determined straightforward by using the corresponding spurt variable in the regression resulting from the grid search. The optimal OLS-estimate for the play variable results from 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.

To test for the existence of play hysteresis the following equations have to be considered:

$$y_t = C + \alpha \cdot x_t + \beta \cdot s_t(\gamma) + \lambda \cdot z_t \qquad \text{with: } |\alpha| < |\alpha + \beta| \tag{5}$$

$$p_t = \gamma \qquad \text{with: } \gamma \geq 0. \tag{6}$$

In order to test whether play is significant the hypothesis (H1) $\beta \neq 0$ has to be tested against the alternative $\beta = 0$.[16] When neglecting the limitations of the results due to, for example, non-finite variance and the resulting spurious regression induced by including non-stationary variables into the regression framework, the OLS-estimators of the equation can be seen as asymptotically unbiased and asymptotically normally distributed. However, since the small sample properties remain problematic we closely follow Belke, Göcke and Guenther (2013) and refrain from further conclusions concerning exact inference.

4.3 Estimating play-effects in Greek exports

4.3.1 Data and Variables

In order to check for the empirical relevance of the hysteresis model for Greek exports, we now estimate equation (5) which generalizes hysteretic behavior of exports dependent on movements in the exchange rate. In our empirical application, we use export data for some of the most important Greek export destinations - namely the

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[16] According to Belke and Göcke (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. $|\alpha| < |\alpha + \beta|$)

Euro area, Turkey and the United States[17] – as the dependent variable, disaggregated by product groups (SITC), and the respective Greek real exchange (defined below) as the hysteretic input variable. To be as parsimonious as possible, we employ foreign real GDP, a linear trend and seasonal dummies as additional non-hysteretic explanatory/controlling variables.

The exact definitions of the time series used are as follows. Nominal exports are denoted as current € and are taken from the Eurostat database (Comext, http://epp.eurostat.ec.europa.eu/newxtweb/). The export series are deflated by the GDP deflator of the export destination country (Source: OECD). Alternatively, we will proxy real exports by weight of exports (kg, see (http://epp.eurostat.ec.europa.eu/newxtweb/setupdimselection.do) in our robustness check in section 5. We calculate real exchange rates as $\frac{CPI_t^{GREECE}}{CPI_t^j} \cdot e_t^j$, i.e. real exchange rates are calculated using the Greek CPI divided by the CPI of the export destination and, if Turkey or the United States is the Greek export destination, multiplied with the nominal bilateral exchange rate (sources: OECD).[18] The real GDP time series are taken from the OECD database and, in case of the Euro Area as the Greek export destination, from Eurostat. Our estimation period ranges from 1995Q1 to 2014Q4 for Greek exports to the US, and, for reasons of data availability for Greek exports to the Euro Area, from 1996Q4 to 2014Q4 and for Turkey as the export destination of Greek exports only from 1998Q1 to 2014Q4.[19] We also implemented a mean-shift dummy variable from 2009:Q4 until the end of the sample period as a proxy of the euro area crisis impact which appeared reasonable based on a visual inspection of the residuals.

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[17] Our final country selection is predominantly due to data availability and the specific kind of exchange rate regime: data should be rather homogeneous. In 2012 Greece's trade shares in 2012 have been, focusing on the five most important export destinations: 10.8% with Turkey, 7.7% with Italy, 6.4% with Germany, 5.6% with Bulgaria and 5% with Cyprus (a surprisingly large share!).

We leave out Cyprus because tax considerations are important regarding Greek "exports" to Cyprus - these are goods whose final destination is not Cyprus, but they go through Cyprus since the benefits arising from the lower profit tax rate in Cyprus is larger than the transportation cost (plus the other expenses of having a third entity in Cyprus which imports the goods from the Greek company). Gibraltar which we also do not consider here is possibly a similar case.

[18] Producer price time series were not available on a consistent basis on the sectoral level. In fact, for the euro area destination we employ synthetic euro exchange rates, which consist of hypothetical euro exchange rates before 2001 (the date of Greece's EMU entry, source: Eurostat).

[19] See Aydin and Ifantis (2004), pp. 156-157, on the specification of hysteretic export equations in Greek-Turkish foreign trade. They assume some "undertrading" in the Turkish-Greek trade relationship.

With respect to the product groups to be investigated here, note, in a nutshell, that about one fifth of each of Greece's exports are food and textiles. Pharmaceutical and chemical products make up for one seventh each.[20] Hence, we estimate regressions without and with play for eight (and in case of the Euro Area nine[21]) different product groups of Greek exports and for three different destination countries of Greek exports, the Euro Area, Turkey and the United States. This selection of sectors corresponds to data availability in the Eurostat Comext data base. To be more concrete we estimate regressions for the following sectors: (SITC 4) Animal and vegetable oils, fats and waxes, (SITC 5) Chemicals and related products, (SITC 6) Manufactured goods and (SITC 7) Machinery and transport equipment.[22] We do *not* preponderantly look at (SITC 0) Food and live animals, (1) Beverages and tobacco, (2) Crude materials, inedible, except fuels, (3) Mineral fuels, lubricants and related materials and (8) Miscellaneous manufactured articles, because we argue at different stages of our work on that the empirical realisations of these time series are not reliable. However, to enable an open discussion we report our estimation results for all SITC groups from 0 to 8. Product group 9 – i.e. commodities and transactions not classified elsewhere in the SITC – was skipped because of unknown real compositions of products in this group.

This is because we expect hysteresis effects to appear and play areas to be the larger for a given sector, the more *heterogeneous* the respective products/firms are (for instance, chemical products and road vehicles, sectors investigated for hysteresis effects in Belke, Göcke and Guenther, 2013, however, much less so fuels etc.) 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 established theoretical studies in the field of trade hysteresis thus emphasize 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, and Roberts and Tybout, 1997).

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[20] See Eurobank, different publications, and Frankfurter Allgemeine Zeitung, 5 May, 2015.

[21] Data for "machines and transportation" were only available for Greek exports to the Euro Area.

[22] See http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=14 for a detailed definition and explanation of the sectors. Like Belke, Oeking and Setzer (2014), we exclude tourism here, because hysteresis considerations (distribution networks, capacity utilisation etc.) apply only to goods exports. While exported services seem to play an important role for Greece in the field of travel and tourism for exported goods, capacity constraints should be even more binding.

Moreover, it has to be suspected that sweeping tax exemptions for shipping which exempt the income even at the personal level from any taxation, provide a strong incentive to shift profits to shipping from related activities (fuel, etc.).

Table 3 summarizes the overall results from this exercise. In the following section we exemplify our way of proceeding by providing further details about our estimations by alluding to two examples: Greek mineral fuel exports to the US (Tables 1a and 2a and Figures 5a and 6a) and Greek machinery exports to the EU (Tables 1b and 2b and Figures 5b and 6b).

4.3.2 Exports to different export destinations – evidence on the sectoral level

We start with a standard regression of Greek exports *of mineral fuels* (Mineral fuels, lubricants and related materials: Coal, coke and briquettes, Petroleum, petroleum products and related materials, Gas, natural and manufactured, Electric current) *to the United States* on the price adjusted bilateral exchange rate (W), the real Euro Area GDP and, additionally, a linear trend plus dummy variables for the first 3 quarters (Q1 to Q3). As a first stage we exclude play or spurt effects (i.e. applying the restriction $\beta = 0$). The corresponding results are stated in Table 1a. The estimated coefficients of regressors are (according to the t-statistics) significant throughout and display the theoretically expected sign. The US GDP variable enters with a lag of one quarter. Lagged GDP data are used because they produce the best fit in all our regressions and help us to avoid problems of reverse causation.[23] In contrast, we let the real bilateral US-Greek real exchange rate enter contemporaneously. Otherwise, J-curve-effects might occur which might severely interfere with the hysteretic dynamics sub-system. We employ this general setting in all our sectoral estimations conducted for this paper.[24] The sample period includes nearly two decades, which is for the \$/€ rate more than "one cycle", where starting from a high €, at first a €-depreciation trend and then an ongoing appreciation trend takes place. However, the Greek real exchange rate vis-à-vis the Euro Area does not follow the shape of a cycle but more or less an upward trend.

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[23] Using lagged GDP avoids problems related to endogeneity effects of the dependent variable (Greek exports) and the regressor (GDP of the Greek export destination country). However, we are not able to completely exclude this kind of effects since export numbers could theoretically contemporaneously affect the exchange rates. But since the exchange rate is the base of our play-dynamics, we are not able to overcome this problem in an easy way (e.g. via using instrumental variables), and must leave this problem for further research.

[24] 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 Greek exporter could react with substituting/redirecting exports away from the depreciating country towards a third country market. These cross-country effects are not considered. 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 severely).

-Table 1a about here-

As a second step, we estimate γ for the simple case with constant play. See Figure 5a for a plot of the grid search on different values of γ: The R^2 sequence shows an absolute maximum at $\gamma = 97.5$ (with $R^2 = 0.80$). The R^2 minimum at $\gamma = 0$ ($R^2 = 0.74$) exactly corresponds to the linear standard model stated in Table 1a. The estimation of the spurt/play regression with an artificial spurt-variable (SPURT) based on the constant play-width $p = \gamma = 97.5$ is presented in Table 2a.

-Figure 5a about here-

-Table 2a about here-

Again, all coefficients display the theoretically expected signs. With respect to the hypothesis (H1) $\beta \neq 0$ the estimated coefficient of the spurt variable is $\beta = -1491.222$ with a t-value of -3.793122. Note that, as expected, the spurt-variable substitutes the effects of the original real exchange rate in the linear standard regression in Table 1.**Fehler! Verweisquelle konnte nicht gefunden werden.**a which amounted to $\alpha = -630.6682$ (t=–3.35), and now vanishes to an insignificant effect ($\alpha = 222.5751$, $t = 0.74$) in the play-regression. Furthermore, the absolute effect of the spurt in the play-regression is stronger compared to the original exchange rate effect in the linear regression. However, since the small sample properties of our regression model are unknown, the t-values are most probably not student-t-distributed. Nevertheless, this high empirical t-realization (which is about three times as high as the 5% critical value in case of a standard student-t-distribution) represents at least a strong hint at the relevance of hysteretic play.

Finally, Figure 6a conveys a graphical impression of the time sequence of the original real US-Greek exchange rate (W, left scale) and of the respective SPURT (right scale) which captures the strong impact of exchange rate changes after passing the play area (i.e. after passing a kind of “pain threshold”). The time path of the spurt variable shows of course similarities to the original real exchange rate path. However, limited variability of the original real exchange rate series inside the play area (of width $\gamma = 97.5$) is filtered away and periods of inaction emerge, exhibiting no variation of the spurt variable due to play/inaction effects. Only large/monotonous changes in the real exchange rate are reflected by the artificial spurt series.

- Figure 6a about here -

Since we do rely not so much on data for Greek exports of mineral fuels (SITC 3), we also display our estimation results for Greek exports of machinery and transport equipment (SITC 7). The interpretation of Figures 5b and 6b and Tables 1b and 2b is analogous to Figures 5a and 6a and Tables 1a and 2a.

4.3.3 Searching for Greek export triggers

If the spurt variable changes, due to a passing of the play area, this simultaneously shifts the current position and the borders of the play area. The up to now most recent shift of the play position/borders for machinery exports to the Euro Area corresponds to the exchange rate extremum of the last quarter in 2014 thus the end of our estimation sample. The corresponding lower bound, which would result in a strong spurt reaction for Greek machinery exports into the Euro Area, therefore results by subtracting the identified play γ from the last extremum. The lower threshold therefore results as a real exchange rate of 273.6771, which means that the *real exchange rate has to depreciate by a further 8% in order to cause a spurt in Greek machinery exports to the euro area* (see Tab. 10 below in the robustness check section, which includes triggers based on other regression specifications). Once this value is passed a farther depreciation of the real exchange rate for Greece/Euro Area would result in a strong spurt reaction. Of course, the percentage value of 8% should not necessarily be taken literally, but as and *equivalent of adjustment needs in other areas* such as the reduction of uncertainty (see section 5.3).

4.3.4 General pattern of results of sectoral export regressions for Greece

-Table 3 about here-

For the regressions, the real exchange rates were defined in a way that a “normal” reaction of the exports to the spurt of the exchange rates is represented b< a negative sign of the estimated coefficient of the real exchange rate (i.e. an €-appreciation reduces Greek exports to the US). A “typical” result of hysteretic play dynamics – as theoretically expected – would be a significantly negative effect of the spurt variable (i.e. $\beta < 0$) and a weaker (or even insignificant) effect of the original exchange rate. For the (8+9+8=) 25 “play regressions”, the spurt variable showed the “wrong sign” ($\beta > 0$) in seven cases, and in only a few cases the original exchange rate effect was stronger than the estimated spurt effect ($\alpha+\beta > 0$). In Table 3, regressions with a theoretically unexpected sign of the spurt variable are marked by grey shading. The respective t-value of the spurt variable is depicted in Table 3 as well. Nine times the spurt variable shows the expected sign but at the same time is not significant due to low t-statistics. Summarizing, in 9 of the 25 cases, the export regressions are in line with "typical" play-dynamics and stating "significant" t-statistics for the spurt variable (however, with the mentioned caveats concerning the distribution of the estimators). With respect to the branches, no general pattern emerges. However, our model fits especially well in respect of exports of chemicals and related products (SITC 5) i.e. one seventh of Greek total exports.

5. Robustness checks

5.1 Estimations limited to the pre-crisis period

It may make sense to focus our estimations only on the pre-crisis period until 2008Q4 (which corresponds closer with task 3.1.B than just inserting a crisis dummy as in section 4). For a complete survey of the results see Table 4.

Note again that a "typical" result of hysteretic play dynamics – as theoretically expected – would be a significantly negative effect of the spurt variable (i.e. $\beta < 0$) and a weaker (or even insignificant) effect of the original exchange rate. For the (4+4+3=) 11 "play regressions", the spurt variable showed the "wrong sign" ($\beta > 0$) in five cases, and in only a few cases the original exchange rate effect was stronger than the estimated spurt effect ($\alpha+\beta>0$). In Table 4, regressions with a theoretically unexpected sign of the spurt variable are marked by grey shading. The respective t-value of the spurt variable is stated in Table 4 as well. In two cases the spurt variable shows the expected sign but at the same time is not significant due to low t-statistics. Summarizing, in 4 of the 11 cases, the export regressions are in line with "typical" play-dynamics and stating "significant" t-statistics for the spurt variable (however, with the mentioned caveats concerning the distribution of the estimators). With respect to the branches no general pattern emerges. However our model again fits especially well in respect of exports of chemicals and related products (SITC 5) i.e. one seventh of Greek total exports.

- Tables 4 to 6 about here -

As an example of individual branch-specific estimation results, we display the results for Greek exports of chemicals and related products (SITC 5) to the EU in Tables 5 and 6. Figure 7 shows the R^2 resulting from a one-dimensional grid search over constant play γ (Greek exports of chemicals and related products to the EU - limited sample). Figure 8 displays the real exchange rate and the resulting spurt variable ($\gamma = 5.5$) for the same case.

- Figures 7 and 8 about here –

5.2 Defining real exports in weights

A further robustness check is to define exports in weights (kg) instead of deflating nominal exports explicitly. For a complete survey of the results see Table 7.

For the (4+4+4=) 12 “play regressions”, the spurt variable showed the “wrong sign” ($\beta > 0$) in three cases, and in only a few cases the original exchange rate effect was stronger than the estimated spurt effect ($\alpha+\beta > 0$). In Table 7, regressions with a theoretically unexpected sign of the spurt variable are marked by grey shading. The respective t-value of the spurt variable is stated in Table 7 as well. Five times the spurt variable shows the expected sign but at the same time is not significant due to low t-statistics. Summarizing, in 4 of the 12 cases, the export regressions are in line with “typical” play-dynamics and stating “significant” t-statistics for the spurt variable (however, with the mentioned caveats concerning the distribution of the estimators). With respect to the branches no general pattern emerges.

- Tables 7 to 9 about here –

As an example of individual branch-specific estimation results, we display the results for Greek exports of machinery and related products (SITC 7) to Turkey in Tables 8 and 9. Figure 9 shows the R^2 resulting from a one-dimensional grid search over constant play γ for Greek exports of machinery and related products to Turkey (exports as weights). Figure 10 displays the real exchange rate and the resulting spurt variable ($\gamma = 5.5$) for the same case.

We additionally calculate the lower triggers for two specifications; exports in chemical products and exports in machinery to Turkey (both expressed in weights). As a result we find a lower trigger of 0,00346 for exports in chemical products (corresponding to a further depreciation of 43% of the current real exchange rate) and a lower trigger of 0,005011 for exports in machinery (corresponding to a further depreciation of 17,3% of the current real exchange rate) (see Tab. 10). Of course, both percentage values should not be taken literally, but as *equivalents of adjustment needs in other areas* such as the reduction of uncertainty (see next sub-section).

- Figures 9 and 10 about here –

- Table 10 about here -

5.3 Impact of political uncertainty

As an additional robustness check we make the play area of weak export reaction dependent on the degree of uncertainty. For estimation purposes, we again use a grid search procedure. As uncertainty variable we implement *economic policy uncertainty* (http://www.policyuncertainty.com/europe_monthly.html) in the Euro Area. This 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. 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.[25]

The grid search now employs a second dimension in addition to constant play which is dependent of the uncertainty variable (Belke and Göcke 2001, 2005). Therefore the algorithm does not determine the highest R^2 by only inserting constant play into the regression framework, but instead by employing a linear function defining the play variable over time which is defined as:

$$\gamma = c + \delta * U \ , \tag{8}$$

where parameter c represents the constant part of the play variable and the coefficient δ marks the influence of the uncertainty variable for the variable play.

In the following, we display the results for 4 regression specifications well-known from the previous sections, now modified by including the uncertainty variable:

(1) Our standard example from section 4.3.2.: Greek machinery exports to the Euro Area, full sample period)

(2) Greek machinery exports to Turkey in kg

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[25] A potential caveat is that at the end of the sample European uncertainty is going down whereas it may be argued that “Greek” uncertainty is still high. However, there is no “Greek” uncertainty variable available for the time span needed for our estimations.

(3) Greek vegetable exports to the United States in kg

(4) Greek chemical exports to the Euro Area – period limited to 2008Q4.

Let us start with the regression results for *Greek machinery exports to the Euro Area* with variable play and political uncertainty, with play specified as: Play $\gamma = 0{,}5 + 0{,}1*U$ (with U = political uncertainty). As a comparison with the basic regression, the R-squared increases significantly from 0.743 to 0.771 (Table 12). For experimental reasons, we also display estimation results for a specification which includes the uncertainty variable simply as an additional regressor which proves to be highly significant and displays the expected sign (Table 11).

- Tables 11 and 12 about here -

We now turn to the results of the remaining three regressions with variable play, incorporating political uncertainty.

(1) Greek machinery exports to Turkey in kg (Table 13)

(2) Greek vegetable exports to the United States in kg (Table 14)

(3) Greek chemical exports to the Euro Area – period limited to 2008Q4 (Table 15).

The optimal specifications of the variable play areas are:

ad (1) play = 0 + 6.25E-06*U

ad (2) play = 0 + 2*U

ad (3) play = 0.0975 + 0.0333*U

- Tables 13 to 15 about here -

The empirical results clearly show that the inclusion of the political uncertainty variable as a determinant of the play width (i.e., the area of weak export reaction) significantly increases the goodness of fit of the Greek export equation, as measured, for instance, by the R-Squared.[26] Put more simply, *political uncertainty matters for Greek exports and cannot be rejected empirically to be responsible for nearly flat export growth, although the external competitiveness has significantly turned to the better.* We have just identified what the economic equivalent of the very low entry real exchange rate triggers is (see section 4.3.3).

The respective variable play pattern is displayed in Figures 11 to 13.

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

- Figures 11 to 13 about here –

6. Conclusions

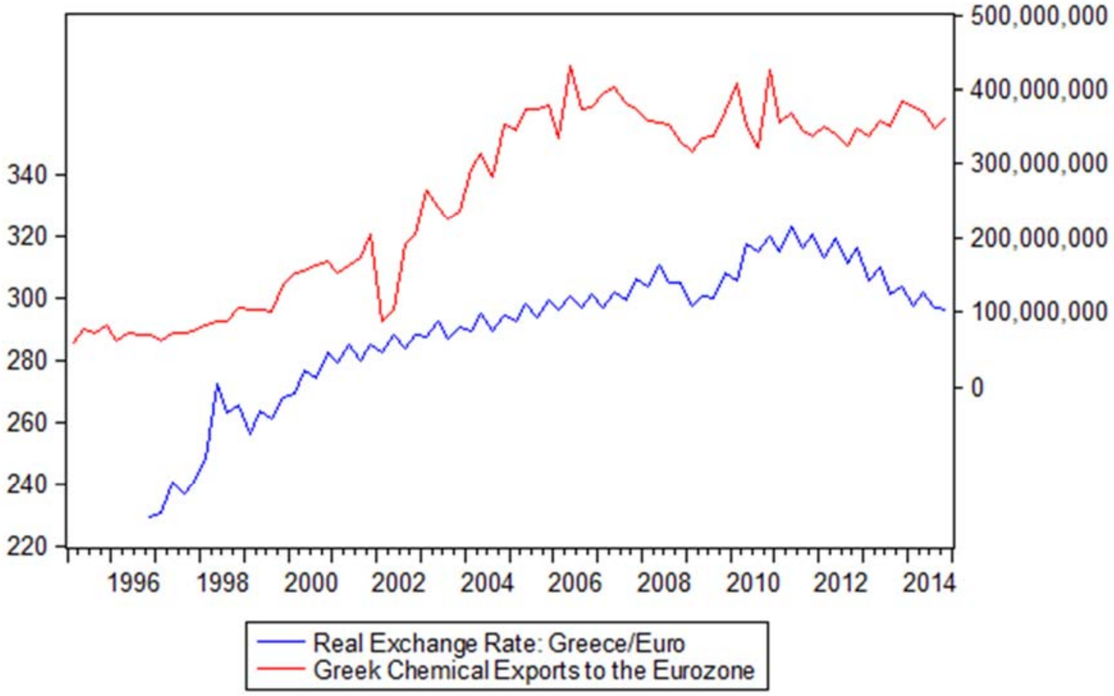
The paper deals with the impact of the exchange rate on the relationship between Greek exports and its main determinants. Our aim was to identify a band of inaction for Greek exports. We rely on a non-linear path-dependent model in which suddenly strong spurts of exports occur when changes of the exchange 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 sub-groups of Greek total exports our non-linear model including play-hysteresis shows a significant effect of the non-linear play-dynamics. Analyzing some of the largest Greek export partners, we find hysteretic play-effects in a significant part of total Greek exports.

To conclude, the existence of ‘bands of inaction’ (called ‘play’) in Greek exports should lead to a more objective discussion of peaks and troughs in the Greek real exchange rates and, more specifically, of the impact of internal devaluation and other measures to gain international competitiveness on exports in political debates and in benchmarking the efficiency of the Troika’s measures to stimulate Greek exports. Not every increase or decrease of the real exchange rate (as a proxy of external competitiveness) will automatically lead to positive or negative reactions of the volume of exports. However, a large appreciation of Greece’s real exchange rate means passing the border of a play/inaction-area (which can be seen as a kind of “pain-threshold”) and results in 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 does not exist.

Future research may also include the impact of financial constraints (provided an adequate and long enough time series for this exercise is found) on the width of the “band of inaction” in Greek exports and also an investigation of tourism exports (Bardakas, 2014, and Dinopoulos, Kalyvitis and Katsimi, 2015). With respect to financial constraints “(t)he 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).

Figures

Figure 1 – *Real exchange rate and Greek chemical goods exports to the Euro Area*



Source: Quarterly data, own calculation based on Eurostat (SITC 4) and OECD data.

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

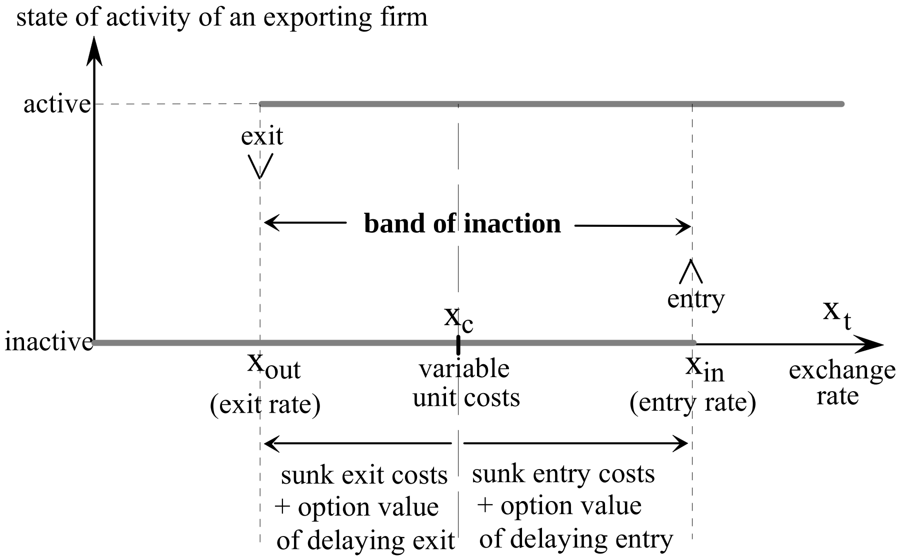


Figure 3 – *Linear play-hysteresis and spurt areas*

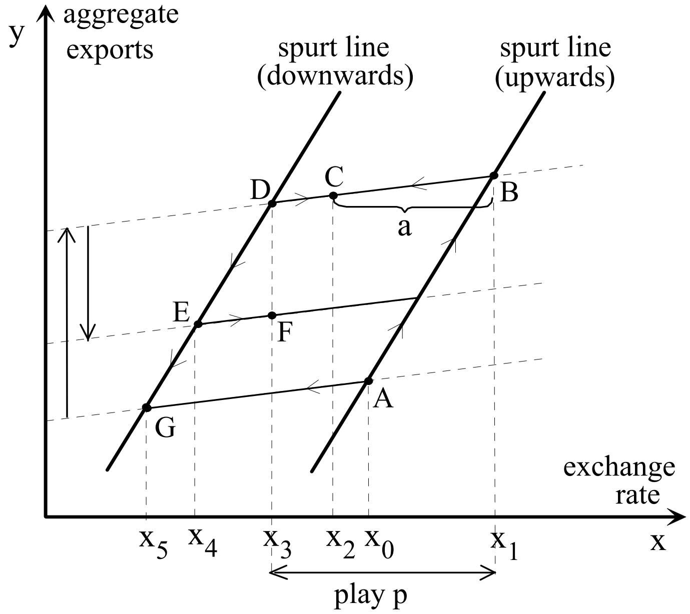


Figure 4 – *Shift of the play-lines by past spurts and the current reaction* Δy_j^s

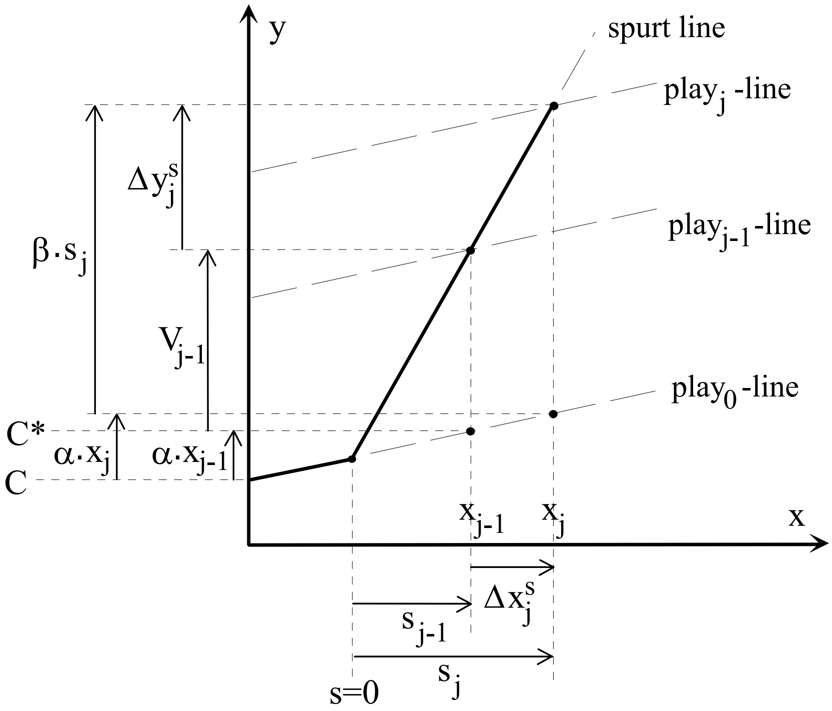


Figure 5a – *R^2 resulting from a one-dimensional grid search over constant play γ*

Greek mineral fuel exports to the US

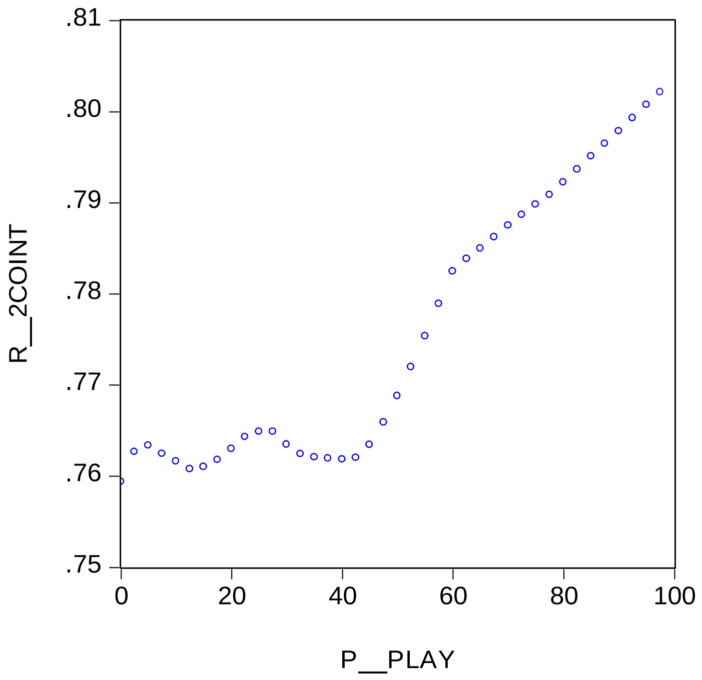


Figure 5b – *R^2 resulting from a one-dimensional grid search over constant play γ*

Greek machinery exports to the EA

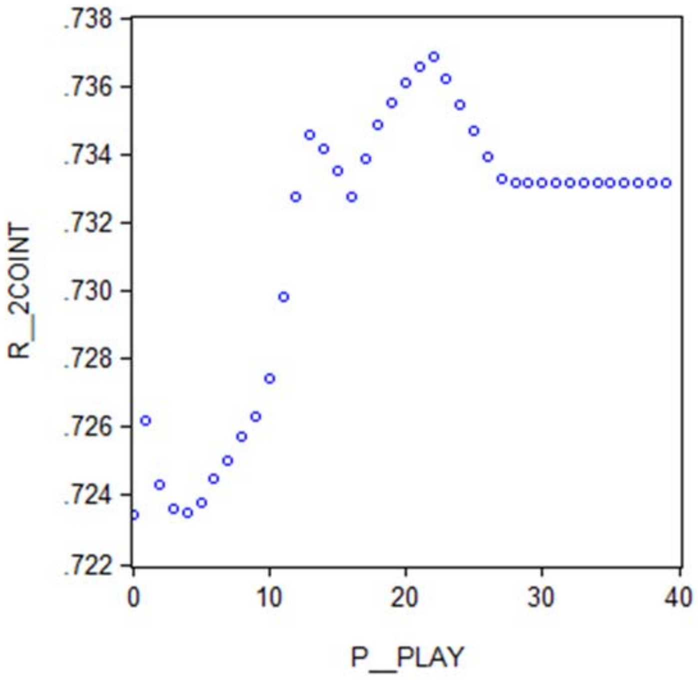


Figure 6a – *Real exchange rate and the resulting spurt variable (γ =97.5)*

Greek mineral fuel exports to the US

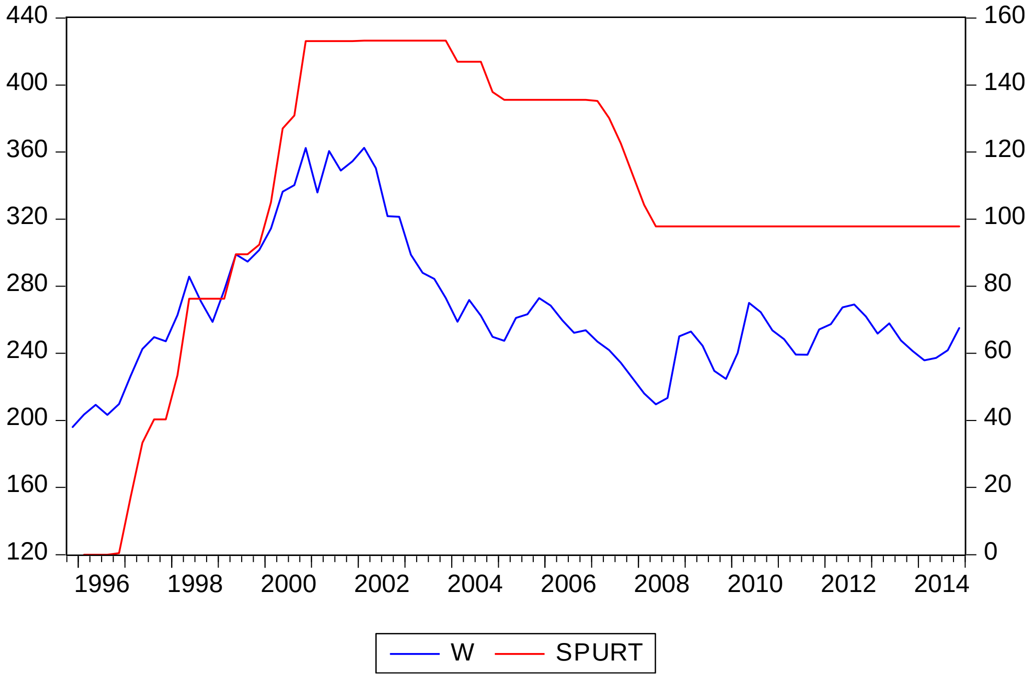


Figure 6b – *Real exchange rate and the resulting spurt variable (γ =22)*

Greek machinery exports to the Euro Area

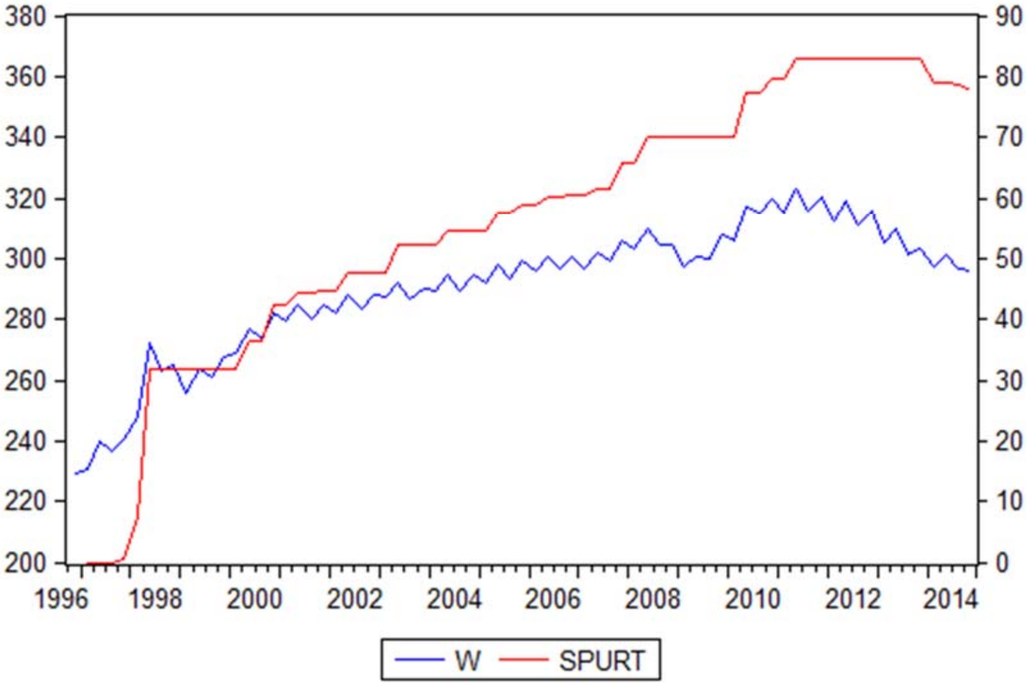


Figure 7 – *R^2 resulting from a one-dimensional grid search over constant play γ*

Greek exports of chemicals and related products to the EA - limited sample

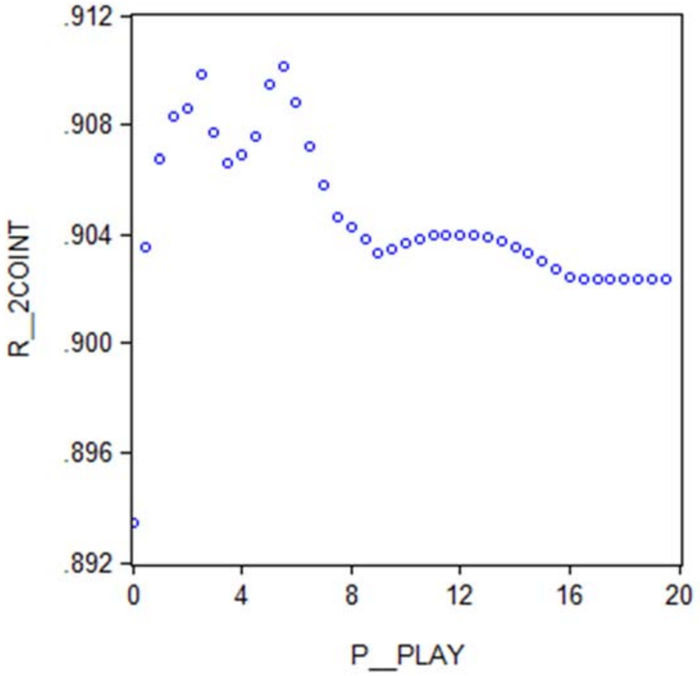


Figure 8 – *Real exchange rate and the resulting spurt variable (γ = 5.5)*

Greek exports of chemicals and related products to the Euro Area – limited sample

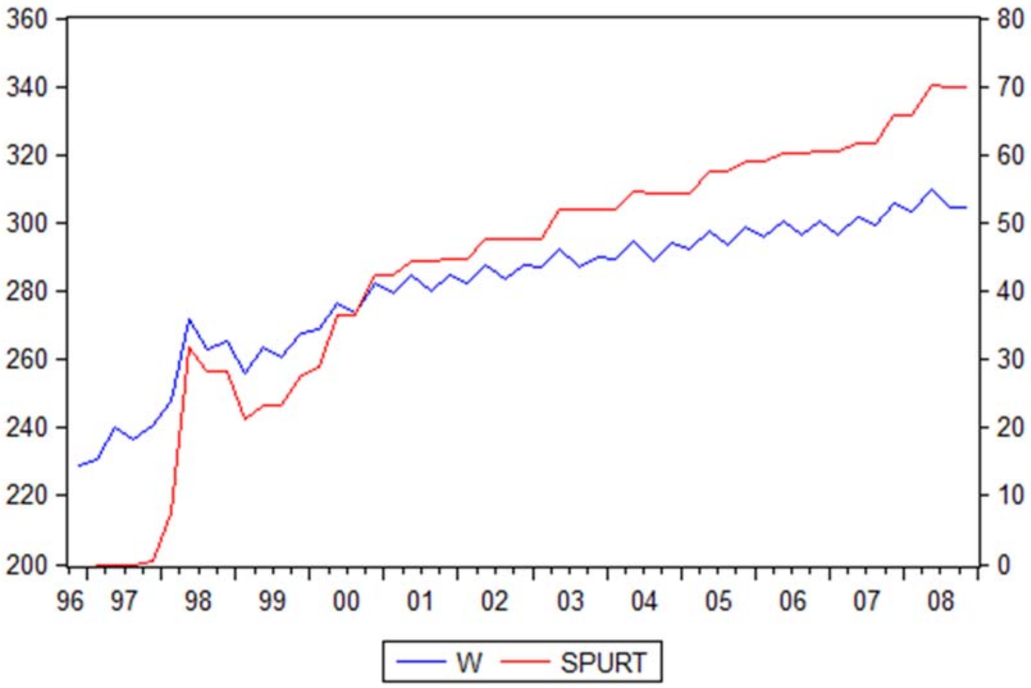


Figure 9 – *R^2 resulting from a one-dimensional grid search over constant play γ*

Greek exports of machinery and related products to Turkey – exports as weights

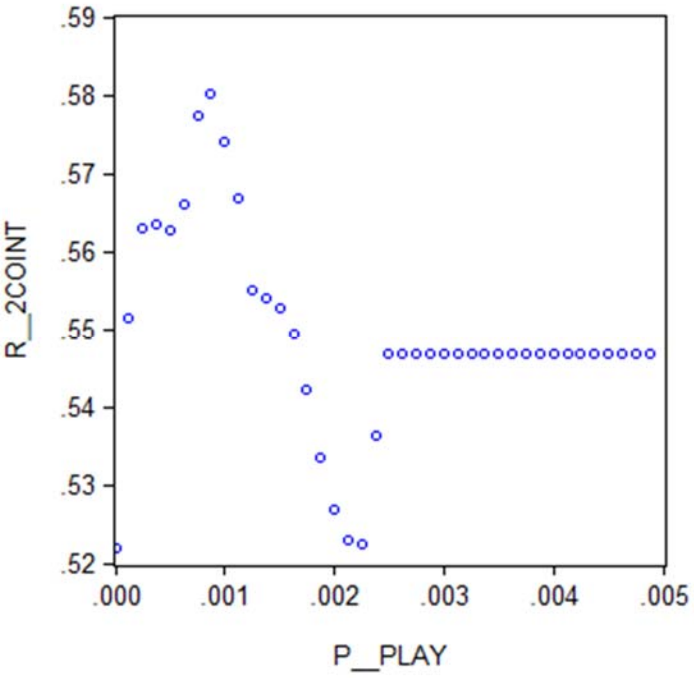


Figure 10 – *Real exchange rate and the resulting spurt variable (γ = 5.5)*

Greek exports of machinery and related products to Turkey – exports as weights

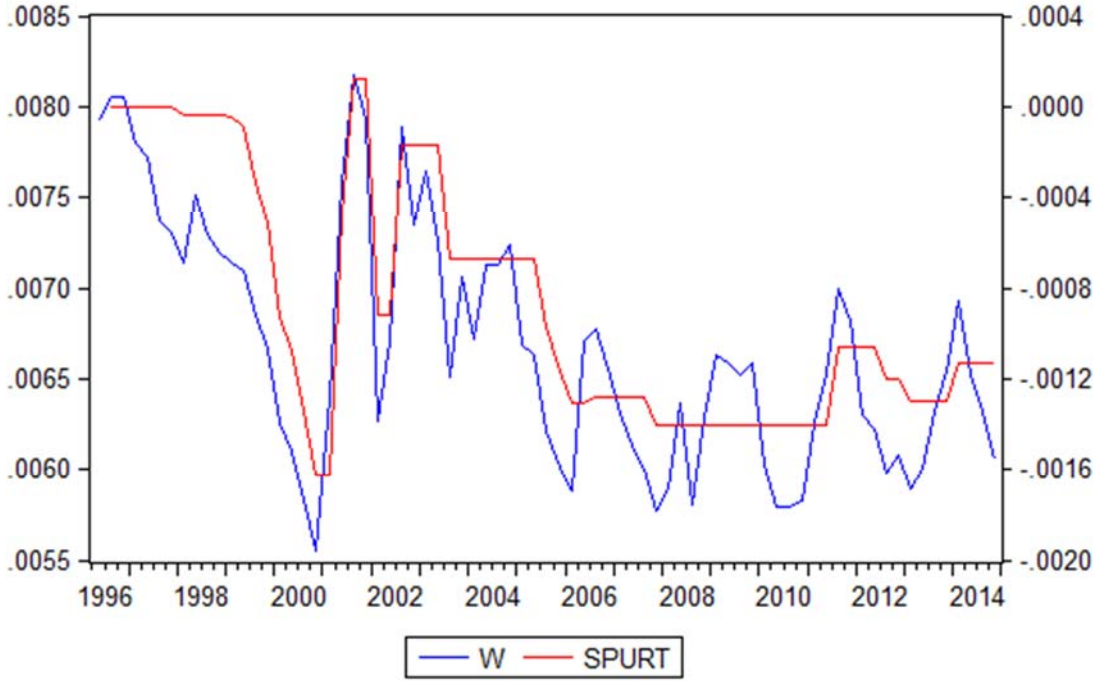


Figure 11- *Variable Play Turkey Manufacturing in KG*

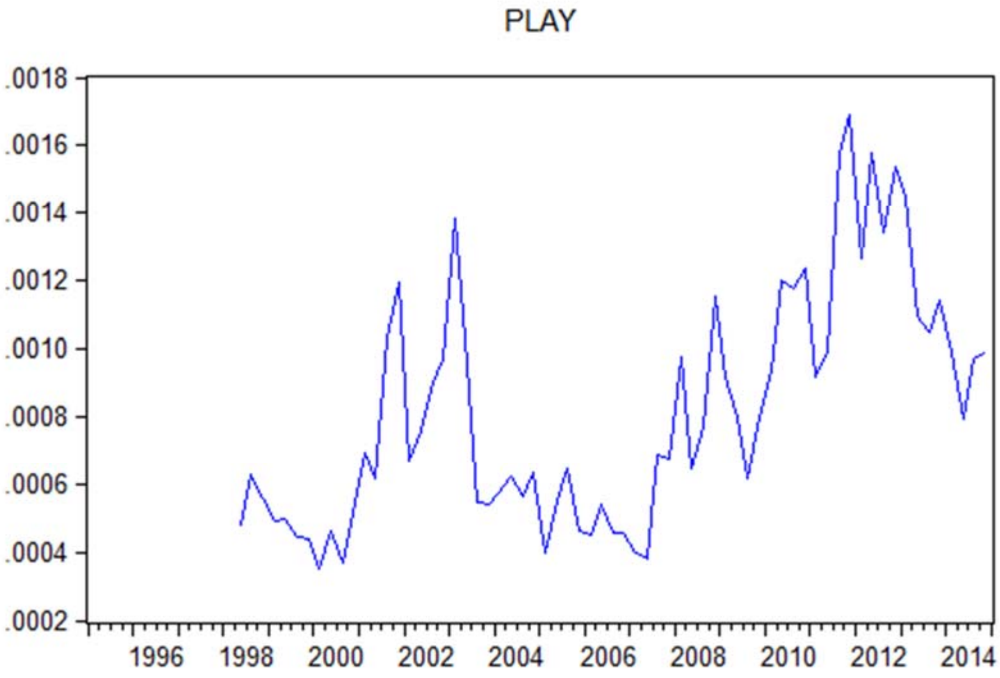


Figure 12 - *Variable Play EA-Chemicals Subsample*

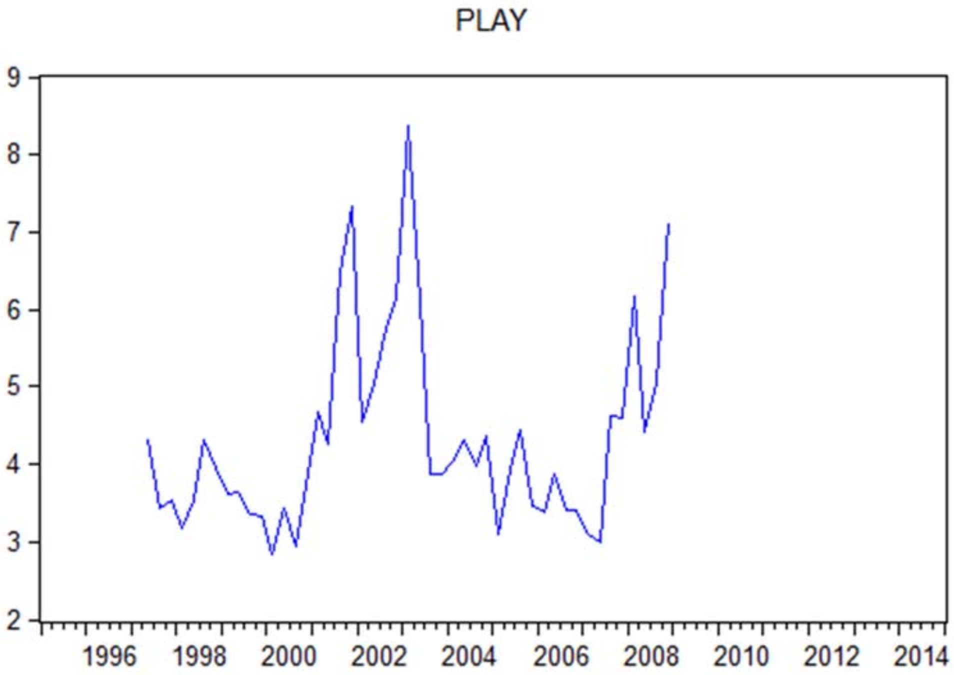
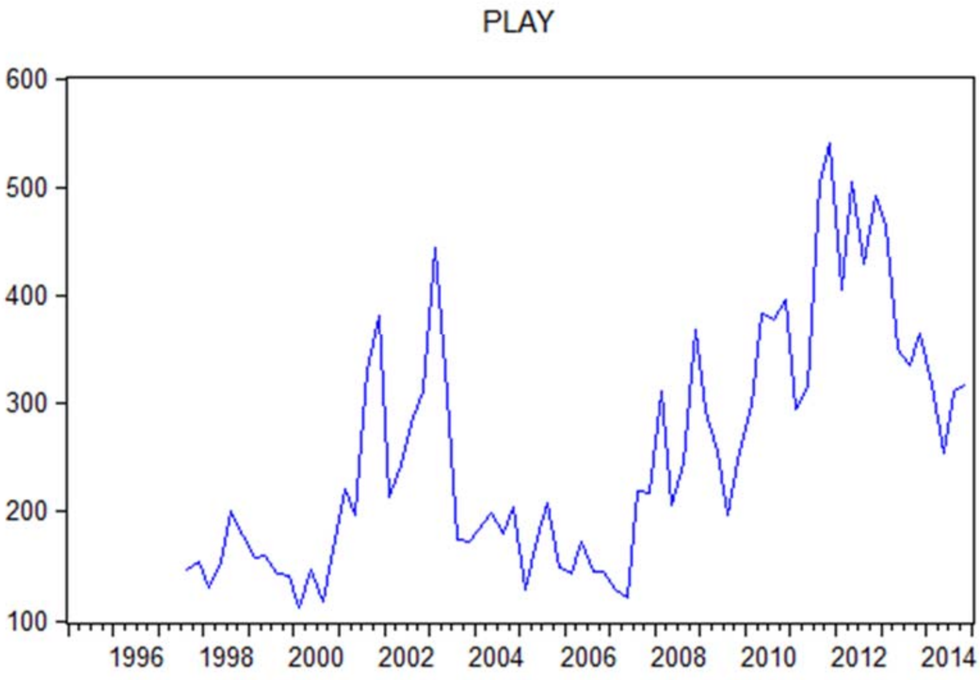


Figure 13 - *Variable Play US-Vegetables in KG*



Tables

Table 1a – *Standard LS regression without play (restriction $\beta = 0$)*
Greek mineral fuel exports to the US

Dependent Variable: US_MIN
Method: Least Squares

Sample (adjusted): 1995Q2 2014Q4
Included observations: 79 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-430633.4	362060.6	-1.189396	0.2382
W	-630.6682	187.9844	-3.354896	0.0013
US_GDP(-1)	69.45545	37.40070	1.857063	0.0675
@TREND	-3486.775	3428.684	-1.016943	0.3126
SHIFT	143500.6	49246.91	2.913901	0.0048
D1	-9813.298	19360.37	-0.506876	0.6138
D2	46246.97	19307.94	2.395231	0.0193
D3	21974.15	19109.26	1.149921	0.2540

R-squared	0.739079	Mean dependent var	255571.1
Adjusted R-squared	0.713355	S.D. dependent var	112802.4
S.E. of regression	60393.56	Akaike info criterion	24.95092
Sum squared resid	2.59E+11	Schwarz criterion	25.19086
Log likelihood	-977.5612	Hannan-Quinn criter.	25.04705
F-statistic	28.73050	Durbin-Watson stat	0.890273
Prob(F-statistic)	0.000000		

Table 2b – *Standard LS regression without play (restriction $\beta = 0$)*
Greek machinery exports to the Euro Area

Dependent Variable: EU_MACH
Method: Least Squares

Sample (adjusted): 1996Q4 2014Q4
Included observations: 73 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3.97E+08	1.02E+08	-3.881220	0.0002
W	327451.4	383733.1	0.853331	0.3966
EU_GDP(-1)	257.2648	63.55377	4.047987	0.0001
@TREND	-4442509.	1558294.	-2.850879	0.0058

SHIFT	2352937.	20739920	0.113450	0.9100
D1	-56813971	11611206	-4.893029	0.0000
D2	6088511.	10216373	0.595956	0.5533
D3	-31845855	9493905.	-3.354347	0.0013

R-squared	0.734497	Mean dependent var	2.12E+08
Adjusted R-squared	0.705905	S.D. dependent var	52192783
S.E. of regression	28304445	Akaike info criterion	37.25804
Sum squared resid	5.21E+16	Schwarz criterion	37.50905
Log likelihood	-1351.919	Hannan-Quinn criter.	37.35807
F-statistic	25.68835	Durbin-Watson stat	0.976966
Prob(F-statistic)	0.000000		

Table 3a – *LS regression with constant play p = γ = 97.5*
Greek mineral fuel exports to the US

Dependent Variable: US_MIN
Method: Least Squares

Sample (adjusted): 1996Q1 2014Q4
Included observations: 76 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1351542.	395086.9	-3.420872	0.0011
W	222.5751	299.7543	0.742525	0.4604
SPURT	-1491.222	393.1385	-3.793122	0.0003
US_GDP(-1)	143.5107	37.41155	3.835999	0.0003
@TREND	-7378.156	3119.979	-2.364810	0.0209
SHIFT	128053.3	43623.10	2.935448	0.0046
D1	-1537.893	17155.54	-0.089644	0.9288
D2	61235.40	17324.83	3.534546	0.0007
D3	34379.10	17145.74	2.005110	0.0490

R-squared	0.802404	Mean dependent var	259565.1
Adjusted R-squared	0.778811	S.D. dependent var	112043.9
S.E. of regression	52695.09	Akaike info criterion	24.69323
Sum squared resid	1.86E+11	Schwarz criterion	24.96924
Log likelihood	-929.3429	Hannan-Quinn criter.	24.80354
F-statistic	34.00956	Durbin-Watson stat	0.958871
Prob(F-statistic)	0.000000		

Table 6b – *LS regression with constant play p = γ = 22*
Greek machinery exports to the Euro Area

Dependent Variable: EU_MACH

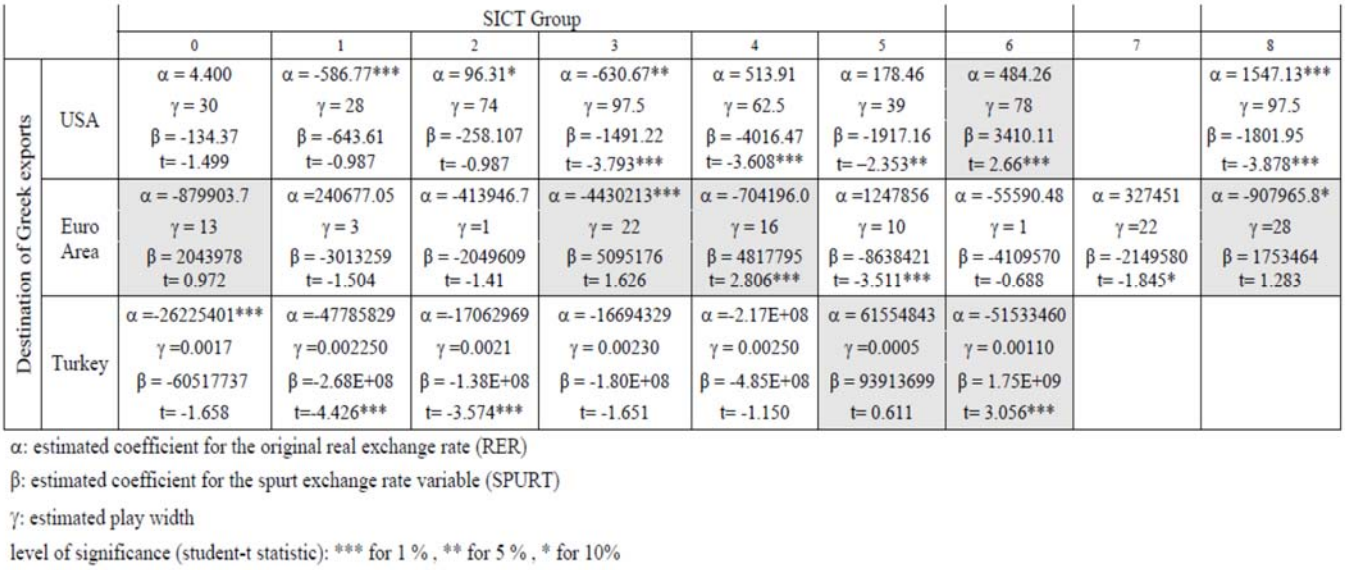
Method: Least Squares

Sample (adjusted): 1997Q1 2014Q4
Included observations: 72 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.51E+08	1.69E+08	-3.851187	0.0003
W	1891697.	917672.3	2.061407	0.0434
SPURT	-2149580.	1162691.	-1.848798	0.0692
EU_GDP(-1)	188.5204	72.93656	2.584717	0.0121
@TREND	-1793828.	2091872.	-0.857523	0.3944
SHIFT	-16379092	22861830	-0.716438	0.4764
D1	-45251295	13213120	-3.424724	0.0011
D2	2286443.	10342244	0.221078	0.8257
D3	-23975636	10388847	-2.307825	0.0243

R-squared	0.742633	Mean dependent var	2.13E+08
Adjusted R-squared	0.709951	S.D. dependent var	51957646
S.E. of regression	27982405	Akaike info criterion	37.24852
Sum squared resid	4.93E+16	Schwarz criterion	37.53310
Log likelihood	-1331.947	Hannan-Quinn criter.	37.36181
AddinF-statistic	22.72330	Durbin-Watson stat	1.012477
Prob(F-statistic)	0.000000		

Table 7 – *Overview of the regression results with constant play for different countries receiving Greek exports and different sectors*



		SICT Group								
		0	1	2	3	4	5	6	7	8
Destination of Greek exports	USA	α = 4.400 γ = 30 β = -134.37 t= -1.499	α = -586.77*** γ = 28 β = -643.61 t= -0.987	α = 96.31* γ = 74 β = -258.107 t= -0.987	α = -630.67** γ = 97.5 β = -1491.22 t= -3.793***	α = 513.91 γ = 62.5 β = -4016.47 t= -3.608***	α = 178.46 γ = 39 β = -1917.16 t= –2.353**	α = 484.26 γ = 78 β = 3410.11 t= 2.66***		α = 1547.13*** γ = 97.5 β = -1801.95 t= -3.878***
	Euro Area	α = -879903.7 γ = 13 β = 2043978 t= 0.972	α =240677.05 γ = 3 β = -3013259 t= -1.504	α = -413946.7 γ =1 β = -2049609 t= -1.41	α = -4430213*** γ = 22 β = 5095176 t= 1.626	α = -704196.0 γ = 16 β = 4817795 t= 2.806***	α =1247856 γ = 10 β = -8638421 t= -3.511***	α = -55590.48 γ = 1 β = -4109570 t= -0.688	α = 327451 γ =22 β = -2149580 t= -1.845*	α = -907965.8* γ =28 β = 1753464 t= 1.283
	Turkey	α =-26225401*** γ =0.0017 β = -60517737 t= -1.658	α =-47785829 γ =0.002250 β =-2.68E+08 t=-4.426***	α =-17062969 γ =0.0021 β = -1.38E+08 t= -3.574***	α = -16694329 γ = 0.00230 β = -1.80E+08 t= -1.651	α =-2.17E+08 γ = 0.00250 β = -4.85E+08 t= -1.150	α = 61554843 γ =0.0005 β = 93913699 t= 0.611	α = -51533460 γ = 0.00110 β = 1.75E+09 t= 3.056***		

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

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

γ: estimated play width

level of significance (student-t statistic): *** for 1 % , ** for 5 % , * for 10%

Table 4 – *Robustness check I: Excluding the crisis period*

		SITC Group			
		4	5	6	7
Destination of Greek Exports	USA	α= 3921,151 γ = 54 β = -4262,339 t= -2,9645***	α = 1955,216 γ = 44 β = -2108,390 t = -2,3411**	α = -2146,917 γ = 64 β = 3038,943 t = 1,6376	α = -164,6412 γ = 127,5 β = 294,2207 t = 2,0586**
	Euro Area	α = -6520520 γ = 17 β = 5479963 t = 2,8290***	α = 6392258 γ = 5,5 β = -7912980 t = -2,1134**	α = 4975255 γ = 1 β = -5070346 t = -0,7462	α = -4368115,5 γ = 1 β = -552291,7 t = -0,1507
	Turkey	α = -5.03E+08 γ = 0.001275 β = 8.06E+08 t = 1.4645	α = -3.79E+08 γ = 0,0003755 β = 5.97E+08 t = 1.3589	α = -2.63E+08 γ = 0.0025 β = -2,90E+09 t = -3.0298***	

α = estimated coefficient for the original real exchange rate (RER)
β = estimated coefficient for the spurt exchange rate variable (SPURT)
γ = estimated play width
level of significance (student- t statistic): ***for 1%, ** for 5%, *for 10%

Table 5 - *Standard LS regression without play (restriction β = 0)*
Greek exports of chemicals and related products to the Euro Area – limited sample

```
Dependent Variable: EU_CHE
Method: Least Squares

Sample (adjusted): 1996Q4 2008Q4
Included observations: 49 after adjustments
==============================================================================
        Variable         Coefficient    Std. Error    t-Statistic      Prob.
==============================================================================
            C              7.32E+08      3.26E+08      2.245640       0.0300
            W             -1089404.      790380.7     -1.378328       0.1754
        EU_GDP(-1)        -289.8662      141.7422     -2.045023       0.0472
         @TREND            17710005      4364414.      4.057820       0.0002
            D1             23345032      21855463      1.068155       0.2916
            D2            -2267138.      16918206     -0.134006       0.8940
            D3            -2150296.      16622943     -0.129357       0.8977
==============================================================================
R-squared                  0.901422    Mean dependent var           2.29E+08
Adjusted R-squared         0.887340    S.D. dependent var           1.20E+08
S.E. of regression         40429224    Akaike info criterion        37.99957
Sum squared resid          6.86E+16    Schwarz criterion            38.26983
Log likelihood            -923.9894    Hannan-Quinn criter.         38.10210
F-statistic                64.01004    Durbin-Watson stat           0.814468
```

Prob(F-statistic)	0.000000

Table 6 – *LS regression with constant play p = γ = 5.5*
Greek exports of chemicals and related products to the Euro Area – limited sample

Dependent Variable: EU_CHE
Method: Least Squares

Sample (adjusted): 1997Q1 2008Q4
Included observations: 48 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-9.66E+08	8.51E+08	-1.134744	0.2632
W	6392258.	3562884.	1.794124	0.0804
SPURT	-7912980.	3744144.	-2.113429	0.0409
EU_GDP(-1)	-345.4675	139.7651	-2.471773	0.0178
@TREND	19922019	4364340.	4.564726	0.0000
D1	46128330	23816482	1.936824	0.0599
D2	-8431026.	16854328	-0.500229	0.6197
D3	25173278	20491379	1.228481	0.2264

R-squared	0.908391	Mean dependent var	2.32E+08
Adjusted R-squared	0.892360	S.D. dependent var	1.19E+08
S.E. of regression	39184711	Akaike info criterion	37.95648
Sum squared resid	6.14E+16	Schwarz criterion	38.26835
Log likelihood	-902.9556	Hannan-Quinn criter.	38.07434
F-statistic	56.66278	Durbin-Watson stat	0.892946
Prob(F-statistic)	0.000000		

Table 7 – *Robustness check II: Estimating Greek real exports in kg*

		SITC Group			
		4	5	6	7
Destination of Greek Exports	USA	α= 46.16312 γ = 155 β = -63.07155 t= -3.5995***	α = 600.2509 γ = 7 β = -711.973 t = -0.4321	α = 77769.7 γ = 8 β = -76064.8 t = -1.8996*	α = 496.1906 γ = 2 β = -511.0102 t = -1.2139
	Euro Area	α = -22173.61 γ = 16 β = 26369.16 t = 4.0625***	α = 58814.39 γ = 1 β = -55145.08 t = -1.3363	α = 46272.96 γ = 0.625 β = -79050.38 t = -0.5416	α = 8563.97 γ = 3 β = -3852.476 t = -0.1048
	Turkey	α = -3659474 γ = 0.002188 β = 22929260 t = 1.6726*	α = 37119239 γ = 0.002625 β = -1960000000 t = -3.2504***	α = -61498771 γ = 0.002313 β = 493000000 t = 1.8520*	α = 4462262 γ = 0.000875 β = -147439990 t = -2.8356***

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

β = estimated coefficient for the spurt exchange rate variable (SPURT)
γ = estimated play width
level of significance (student- t statistic): ***for 1%. ** for 5%. *for 10%

Table 8 - *Standard LS regression without play (restriction $\beta = 0$)*
Greek exports of machinery and related products to Turkey – exports as weights

Dependent Variable: TR_MACH
Method: Least Squares
Sample (adjusted): 1998Q4 2014Q4
Included observations: 65 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5196.736	21340.21	0.243518	0.8084
W	-3757119.	2566136.	-1.464115	0.1485
TR_GDP(-2)	1.95E-06	3.18E-07	6.112063	0.0000
D1	-1612.522	3707.176	-0.434973	0.6652
D2	-2304.964	3692.700	-0.624195	0.5349
D3	-7681.879	3692.764	-2.080252	0.0419

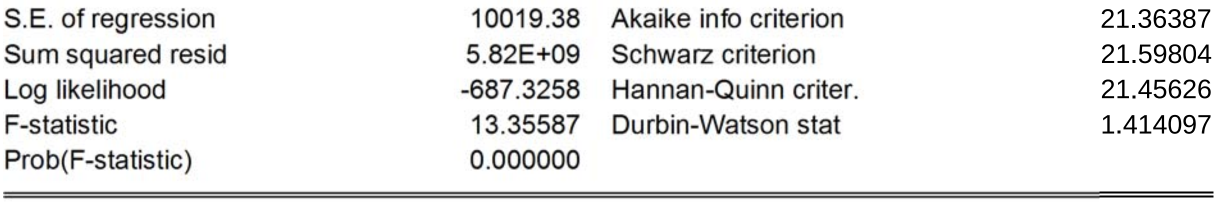
R-squared	0.521915	Mean dependent var	22391.55
Adjusted R-squared	0.481399	S.D. dependent var	14719.84
S.E. of regression	10600.33	Akaike info criterion	21.46292
Sum squared resid	6.63E+09	Schwarz criterion	21.66364
Log likelihood	-691.5450	Hannan-Quinn criter.	21.54212
F-statistic	12.88181	Durbin-Watson stat	1.256816
Prob(F-statistic)	0.000000		

Table 9 – *LS regression with constant play $p = \gamma = 0{,}000875$*
Greek exports of machinery and related products to Turkey – exports as weights

Dependent Variable: TR_MACH
Method: Least Squares
Sample (adjusted): 1998Q4 2014Q4
Included observations: 65 after adjustments

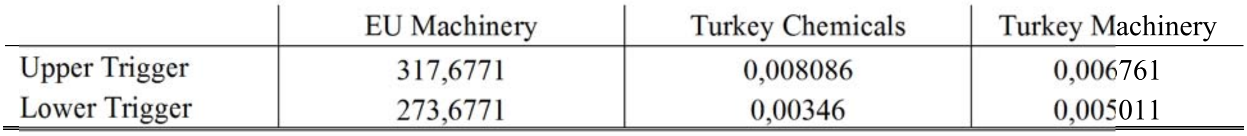
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-52952.82	28764.66	-1.840899	0.0708
W	4462262.	3779607.	1.180615	0.2426
SPURT	-14743990	5199689.	-2.835552	0.0063
TR_GDP(-2)	1.51E-06	3.37E-07	4.478416	0.0000
D1	-2066.206	3507.655	-0.589056	0.5581
D2	-2869.061	3495.986	-0.820673	0.4152
D3	-7797.486	3490.619	-2.233840	0.0294

R-squared	0.580122	Mean dependent var	22391.55
Adjusted R-squared	0.536686	S.D. dependent var	14719.84



S.E. of regression	10019.38	Akaike info criterion	21.36387
Sum squared resid	5.82E+09	Schwarz criterion	21.59804
Log likelihood	-687.3258	Hannan-Quinn criter.	21.45626
F-statistic	13.35587	Durbin-Watson stat	1.414097
Prob(F-statistic)	0.000000		

Table 10 – Export Triggers for real exchange rate with constant play



	EU Machinery	Turkey Chemicals	Turkey Machinery
Upper Trigger	317,6771	0,008086	0,006761
Lower Trigger	273,6771	0,00346	0,005011

Note: The triggers are calculated by using the play values for Machinery Exports into the Euro Area, Chemical Exports to Turkey (expressed in weights) and Machinery Exports to Turkey (expressed in weights)

Table 11 – *LS regression with constant play $p = \gamma = 22$ and uncertainty as a regressor Greek machinery exports to the Euro Area*

Dependent Variable: EU_MACH
Method: Least Squares

Sample (adjusted): 1997Q1 2014Q4
Included observations: 72 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6.70E+08	1.63E+08	-4.113001	0.0001
W	2073745.	886737.3	2.338624	0.0226
SPURT	-2055479.	1120176.	-1.834961	0.0713
POL_U	-210436.0	86245.42	-2.439967	0.0176
EU_GDP(-1)	183.7322	70.25534	2.615206	0.0112
@TREND	-1831652.	2014246.	-0.909349	0.3667
SHIFT	-2508014.	22735051	-0.110315	0.9125
D1	-45948278	12725633	-3.610687	0.0006
D2	-974958.4	10047473	-0.097035	0.9230
D3	-25504435	10022641	-2.544682	0.0134

R-squared	0.765181	Mean dependent var	2.13E+08
Adjusted R-squared	0.731094	S.D. dependent var	51957646
S.E. of regression	26943226	Akaike info criterion	37.18461
Sum squared resid	4.50E+16	Schwarz criterion	37.50081
Log likelihood	-1328.646	Hannan-Quinn criter.	37.31049
F-statistic	22.44810	Durbin-Watson stat	1.252447
Prob(F-statistic)	0.000000		

Tab. 12 - LS regression with variable play $p = \gamma = 0.5 + 0.1*U$
Greek machinery exports to the Euro Area

Dependent Variable: EU_MACH
Method: Least Squares
Sample (adjusted): 1997Q1 2014Q4
Included observations: 72 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-9.78E+08	1.95E+08	-5.019097	0.0000
W	3511055.	998631.7	3.515865	0.0008
SPURT	-3990118.	1171941.	-3.404709	0.0012
EU_GDP(-1)	151.7266	67.22873	2.256871	0.0275
@TREND	-310450.1	1891866.	-0.164097	0.8702
SHIFT	-47746398	24317828	-1.963432	0.0540
D1	-37236660	12488556	-2.981663	0.0041
D2	-1218410.	9795582.	-0.124384	0.9014
D3	-17450312	9938843.	-1.755769	0.0840

R-squared	0.770836	Mean dependent var	2.13E+08
Adjusted R-squared	0.741735	S.D. dependent var	51957646
S.E. of regression	26404737	Akaike info criterion	37.13245
Sum squared resid	4.39E+16	Schwarz criterion	37.41704
Log likelihood	-1327.768	Hannan-Quinn criter.	37.24575
F-statistic	26.48899	Durbin-Watson stat	1.121739
Prob(F-statistic)	0.000000		

Table 13 - *LS regression with variable play* $p = \gamma = 0 + 6.25E\text{-}06*U$
Greek machinery exports to Turkey – in kg

Dependent Variable: TR_MACH
Method: Least Squares
Sample (adjusted): 1998Q4 2014Q4
Included observations: 65 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-64796.46	23676.55	-2.736736	0.0082
W	7732037.	3302104.	2.341549	0.0227
SPURT	-16914225	3617763.	-4.675327	0.0000
TR_GDP(-2)	8.38E-07	3.62E-07	2.316825	0.0241
D1	-2246.490	3189.342	-0.704374	0.4840
D2	-2963.166	3177.136	-0.932653	0.3549
D3	-8041.594	3175.002	-2.532784	0.0140

R-squared	0.652775	Mean dependent var	22391.55
Adjusted R-squared	0.616855	S.D. dependent var	14719.84
S.E. of regression	9111.386	Akaike info criterion	21.17388
Sum squared resid	4.82E+09	Schwarz criterion	21.40804
Log likelihood	-681.1510	Hannan-Quinn criter.	21.26627
F-statistic	18.17312	Durbin-Watson stat	1.642072

Prob(F-statistic)	0.000000

Table 14 - *LS regression with variable play* $p = \gamma = 0 + 2*U$
Greek vegetable exports to the US – in kg

Dependent Variable: US_VEG
Method: Least Squares
Sample (adjusted): 1997Q2 2014Q4
Included observations: 71 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-26433.64	7700.527	-3.432705	0.0011
W	41.03452	11.59839	3.537951	0.0008
SPURT	-76.49409	18.31443	-4.176712	0.0001
US_GDP(-3)	2.356018	0.473903	4.971516	0.0000
D1	1072.531	756.9299	1.416949	0.1613
D2	1375.520	745.7778	1.844410	0.0698
D3	-632.3388	745.6093	-0.848083	0.3996

R-squared	0.351039	Mean dependent var	9829.268
Adjusted R-squared	0.290199	S.D. dependent var	2653.868
S.E. of regression	2235.875	Akaike info criterion	18.35604
Sum squared resid	3.20E+08	Schwarz criterion	18.57912
Log likelihood	-644.6394	Hannan-Quinn criter.	18.44475
F-statistic	5.769867	Durbin-Watson stat	1.320745
Prob(F-statistic)	0.000076		

Table 15 - *LS regression with variable play* $p = \gamma = 0.0975 + 0.0333*U$
Greek chemical exports to the Euro Area - Subsample

Dependent Variable: EU_CHE
Method: Least Squares
Sample (adjusted): 1997Q1 2008Q4
Included observations: 48 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.65E+09	9.55E+08	-1.732574	0.0909
W	9039901.	3905688.	2.314548	0.0259
SPURT	-10437841	4000119.	-2.609383	0.0127
EU_GDP(-1)	-310.1616	134.2703	-2.309979	0.0261
@TREND	18635592	4140864.	4.500412	0.0001
D1	47243031	22775839	2.074261	0.0445
D2	-7047648.	16244817	-0.433840	0.6667
D3	31557822	20254560	1.558060	0.1271

R-squared	0.912975	Mean dependent var	2.32E+08
Adjusted R-squared	0.897746	S.D. dependent var	1.19E+08
S.E. of regression	38191735	Akaike info criterion	37.90515
Sum squared resid	5.83E+16	Schwarz criterion	38.21702
Log likelihood	-901.7236	Hannan-Quinn criter.	38.02300
F-statistic	59.94852	Durbin-Watson stat	0.965648
Prob(F-statistic)	0.000000		

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Annex: An algorithm for calculating the spurt variable

In the following we present a detailed algorithm based on Belke and Göcke (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.

$$M_t^{\downarrow} = \begin{cases} 1 & \text{if} \quad \Delta s_{t-1} < 0 \\ 1 & \text{if} \quad (\Delta s_{t-1} = 0) \wedge (\Delta x_{t-1} = 0) \wedge (\Delta a_{t-1} = 0) \\ 0 & \text{else} \end{cases} \tag{7}$$

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

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.

$$B_t^{\downarrow} = \begin{cases} 1 & \text{if} \quad \Delta s_{t-1} < 0 \\ 1 & \text{if} \quad (\Delta s_{t-1} = 0) \wedge (B_{t-1}^{\downarrow} = 1) \\ 0 & \text{else} \end{cases} \tag{8}$$

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

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.

$$b_t = B_t^{\downarrow} \cdot (1 - M_t^{\downarrow}) \cdot (a_{t-1} + \Delta x_t) + B_t^{\uparrow} \cdot (1 - M_t^{\uparrow}) \cdot (a_{t-1} - \Delta x_t) \tag{9}$$

$$a_t = \begin{cases} b_t \quad \text{if} \quad 0 < b_t \leq p_t \\ \Delta x_t \quad \text{if} \quad (M_t^{\downarrow} = 1) \wedge (\Delta x_t > 0) \wedge (\Delta x_t < p_t) \\ -\Delta x_t \quad \text{if} \quad (M_t^{\uparrow} = 1) \wedge (\Delta x_t < 0) \wedge (-\Delta x_t < p_t) \end{cases} \tag{10}$$

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

$$\Delta s_t = \begin{cases} b_t \cdot [B_t^{\downarrow} \cdot (1 - M_t^{\downarrow}) - B_t^{\uparrow} \cdot (1 - M_t^{\uparrow})] & \text{if} \quad b_t < 0 \\ (b_t - p_t) \cdot [B_t^{\downarrow} \cdot (1 - M_t^{\downarrow}) - B_t^{\uparrow} \cdot (1 - M_t^{\uparrow})] & \text{if} \quad b_t > p_t \\ \Delta x_t \quad \text{if} \quad [(M_t^{\downarrow} = 1) \wedge (\Delta x_t < 0)] \vee [(M_t^{\uparrow} = 1) \wedge (\Delta x_t > 0)] \\ \Delta x_t - p_t \quad \text{if} \quad (M_t^{\downarrow} = 1) \wedge (\Delta x_t > p_t) \\ \Delta x_t + p_t \quad \text{if} \quad (M_t^{\uparrow} = 1) \wedge ((-\Delta x_t) > p_t) \end{cases} \tag{11}$$

The width of the play p_t was not addressed up to now. In a simple case p_t is defined as a constant parameter p_t=p=γ witch has to be estimated. However, it is easy to gereralize the model in a way where the play width p_t is determined by other variables. For instance, the higher an 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:

$$p_t = \gamma + \delta \cdot u_t \qquad \text{with:} \ \gamma, \delta \geq 0 \ \text{and} \ u_t \geq 0 \ \Rightarrow \ p_t \geq 0 \tag{12}$$

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

```
SMPL 69.1 98.4

'INPUT AREA
GENR s_up=1      'set 1 for a maximum as an initial extremum (else 0)
!an = 73.3       'first estimation quarter (time of the first extremum in a
spurt area)
!en = 96.1       'last estimation quarter
!n = 24*4+1      'number of sample point (calculated from !an to !en)
!g = 10          'precision of the grid search for the constant play compo-
nent
!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 = 10          'precision of the grid search for the variable play compo-
nent
!y = 0           'minimum of the grid search for the variable play component
!v =30           'maximum of the grid search for the variable play component
GENR w =  HYINPUT   'hysteretic input variable
GENR u = UINPUT  'determination of the uncertainty realisation
%ST11= "HYOUTPUT"                                       'dependent variable
```

```
%ST12= "C HYINPUT GDP(-1) TREND D1 D2 D3"  'independent variables of the re-
gression
'END OF INPUT AREA

'INITIALISATION
SMPL 69.1 98.4
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 %ST11 %ST12
 ELSE
 EQUATION eq1.LS %ST11 spurt  %ST12        'OLS ESTIMATION
 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
```

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.

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