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IDENTIFYING HYSTERESIS NON-LINEARITIES IN TRADE: EVIDENCE FROM EUROPEAN WINE EXPORTS TO THE U.S.

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"Identifying Hysteresis Non-linearities in Trade: Evidence from European Wine Exports to the US"

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Abstract

It is obvious that exchange rates influence exports since they add a fluctuating component to the costs or rather to the price in the destination country and therefore influence the international competitive ability. Whether this influence on exports is of a special non-linear path dependence, called hysteresis, is investigated in this paper. To identify hysteresis, three methods are presented and compared. First, the spurt method developed by Belke and Göcke [2001], second, the Preisach addition method which was used by Hallett and Piscitelli [2002] and third, the Preisach replacement technique which can be found in de Prince and Kannebley Junior [2013]. Both Preisach approaches use an algorithm provided by Piscitelli et al. [2000] to derive the so called Preisach variable from the exchange rate time series. After finding hysteresis in export values the question arises if the hysteresis descends from hysteresis in prices or quantities, see Göcke and Werner [2015]. Therefore, the study analyses values, quantities and prices, i. e. unit values, of European wine exports to the USA. As the entry into the US market requires sunk costs, for example for dealing with the extensive regulations, see e. g. Beliveau and Rouse [2010], FTA [2015], the requirements for the appearance of hysteresis are conformed. Indeed, the estimations revealed hysteresis for values in case of Italy and Spain and for prices in case of Italy and France.[1]

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1 Introduction

Recent exchange rate fluctuations which are partially influenced by the different policies of the central banks of Europe and the United States in the last months and the financial crisis before motivate to examine which influence the exchange rate development has on European exports to the USA. Especially, as exchange rate changes can have hysteresis influences on export decisions due to sunk costs, it is important to identify hysteresis effects. Therefore, three methods to reveal hysteresis are presented and compared in this study.

The idea of hysteresis has its origin in physics, strictly speaking in magnetics, see e. g. Preisach [1935]; and describes a special non-linear path-dependence. Characteristic properties of hysteresis are for instance remanence effects. That means that temporary deviations result in lasting new eqilibria. If the Euro, for example, depreciates against the US-Dollar, some companies will take this chance of favorable conditions and enter the export market. As this market entry required sunk investments like costs of informing about regulations, establishing a distribution network or placing advertisements which are lost as soon as the company exits the market, it will stay on the market even if the Euro appreciates against the Dollar once more. Therefore, after a temporary Euro weakness there will be more exporters to the US market. To cause market entries, this Euro weakness has to be of particular magnitude and duration. This shows another characteristic of hysteresis, namely that only large deviations result in effects and small ones are ignored. Economic applications of hysteresis effects are labor market investigations, see e. g. Belke and Göcke [2001], Blanchard and Summers [1986], Cross et al. [2005], Mota et al. [2012] and trade analyses, see e. g. Baldwin [1990], Campa [2004], Dixit [1989a,b], Kannebley Junior [2008], Belke et al. [2013]. More general and detailed information of hysteresis in economics can be found in Cross et al. [2013], Dixit and Pindyck [1994], Franz [1990], Göcke [2002], Grinfeld et al. [2009] for example.

To identify hysteresis in exports, three different methods which are known in the literature are used and compared for the first time in this study. First, a method which linearizes a possible hysteresis loop is presented. The so called spurt method was developed by Belke and Göcke [2001] and used in Belke et al. [2013] and Mota [2008] to search for hysteresis non-linearities in German exports and the Portuguese labor market respectively. Mota [2008] compares his outcomes with the ones of the Preisach approach and finds hysteresis especially in case of small firms. The Preisach model goes back to Preisach [1935] and it was thoroughly studied in Mayergoyz [2003]. The implementation in this study here is based on Piscitelli et al. [2000]. As there are different ways to include the Preisach variable which is calculated as in Piscitelli et al. [2000] to a regression model, two methods are presented. The first method adds the Preisach variable to the standard regression, see Hallett and Piscitelli [2002], like the spurt variable is added in the spurt approach by Belke and Göcke [2001]. The second idea is to replace the underlying independent variable with the Preisach variable, see de Prince and Kannebley Junior [2013]. This extensive modeling allows to compare the performance of the models for the first time and to draw conclusions for future research.

As was shown in Göcke and Werner [2015], hysteresis loops can occur on the supply as well as on the demand side of a market. In addition, hysteresis can appear both in prices and quantities. Therefore, it is tested if there are any hysteresis influences of the exchange rate on export values in Euros. To shed more light on the market structure, export quantities as well as unit values in Euro are examined after that. If hysteresis is found for values in Euros, it is expected that there is hysteresis in quantities and/or prices (unit values) as well.

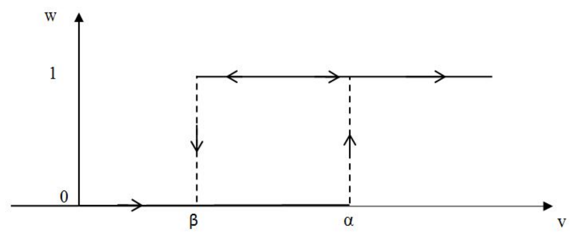
The important role which real exchange rate changes have in global wine export shares and competitiveness was analyzed and predicted by Anderson and Wittwer [2013]. They describe the negative impact of the financial crisis 2008 on the Australian wine producers and a positive impact on US and European producers as a result of the appreciation of the Australian Dollar. Next, they project different scenarios on the global wine market where changes of the real exchange rate as well as an increasing import demand of China play crucial roles.

Italy, Spain and France are the three biggest wine producers in the world and they are among the first five importers to the US market, see for instance OIV [2014], Anderson and Nelge [2011].

As the wine consumption in this traditional wine countries is declining, see Anderson and Nelge [2011, p. 3], exports become more and more important. Italy and Spain export about 40 % of their national wine production volume, see for example Anderson and Nelge [2011], OIV [2014]. The international wine trade has enlarged for the last twenty five years, especially since 2000 and is going to grow further, see Anderson and Wittwer [2013], Mariani et al. [2012]. Especially, the arising producers of the so called New World (e. g. Argentina, Australia, New Zealand, Chile, South Africa) intensify competition, see e. g. Labys and Cohen [2006], Anderson and Wittwer [2013]. This study estimates the impact of the exchange rate on traded wine values and unit values measured in Euro from 1995 to 2013 and on traded quantities from 1995 to 2014. This period was chosen because during this time the European exporters faced much more competition than before, see for instance Anderson and Nelge [2011, table 23, p. 13; table 29, p. 16] or Mariani et al. [2012].

As there are many regulations to comply with when exporting to the USA, see FTA [2015], Beliveau and Rouse [2010], Anderson [2010], and export relationships are usually long term affairs where exporter and importer know each other personally and trust each other, market entries and exits cause sunk costs, see Dixit and Pindyck [1994]. This is the more the case as enlarging vineyard areas or growing other grape varieties takes time. Especially as the USA are the biggest importer of wine in the world by value, see OIV [2014], Anderson and Nelge [2011], one should expect that small changes of the exchange rate have no influence on the exporter behavior. Whether large changes of the exchange rate do influence the European wine exporters in contrast to small changes in a hysteretic way is investigated in this paper by comparing the results of three

Figure 1: Non-ideal relay



methods which are designed to identify hysteresis.

After introducing the idea of hysteresis in more detail and presenting the applied models in Section 2, as well as the data in section 3, the results are summarized in section 4 and discussed in section 5. Section 6 offers concluding remarks.

2 Hysteresis models

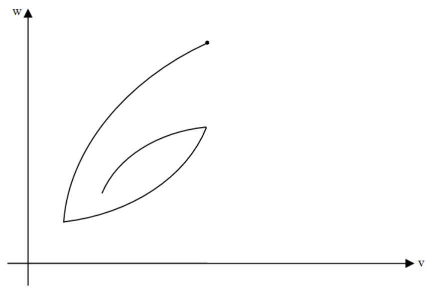
Hysteresis is a special kind of non-linear behavior which focuses on the non-dominated extremum values of the independent resp. input variable, see e. g. Brokate and Sprekels [1996], Mayergoyz [2003], Krasnosel'skii and Pokrovskii [1989], Visintin [1994]. The simplest hysteresis model is the non-ideal relay, see Figure 1 or e. g. Mayergoyz [2003]. Here, the dependent variable w can only be in two conditions (1 and 0; export, no export). The independent variable v moves back and forth and triggers two different thresholds. If it rises, for instance, it will at some point trigger the threshold α which causes the dependent variable w to rise from 0 to 1. Vice versa, if v decreases, there will be a threshold β when the dependent variable will fall from 1 to 0. The salient point is that $\beta < \alpha$ and therefore there is some space, called "band of inaction" $\alpha - \beta$, where the state of the dependent variable does not only depend on the state of the independent variable but on the last non-dominated extremum values of it. Consequently, there is non-Markov path dependence, see e. g. Brokate and Sprekels [1996].

The functional dependence can be expressed by the following relationship

$$w_{\alpha,\beta}\left(u\left(t\right)\right) = \begin{cases} 1, & v\left(t\right) \geq \alpha \\ 0, & v\left(t\right) \leq \beta \\ w\left(t-1\right), & \beta < v\left(t\right) < \alpha, t \geq 1 \\ w_{-1}, & \beta < v\left(t\right) < \alpha, t = 0, \end{cases}$$

where w_{-1} is the initial value of w at time $t = 0$ and the time is discretely measured.

Figure 2: Hysteresis loop



Aggregation of many of these non-ideal relays with different threshold values results in a hysteresis loop, see Figure 2.

A typical hysteresis loop has two saturation corners. If one moves from one corner to the other, there will be a part with a slight slope because there will only be few thresholds triggered. Yet, by moving further more and more thresholds will be passed and therefore more and more relays will change their state, so the aggregated number of triggered relays will increase and accordingly the slope of the hysteresis loop.

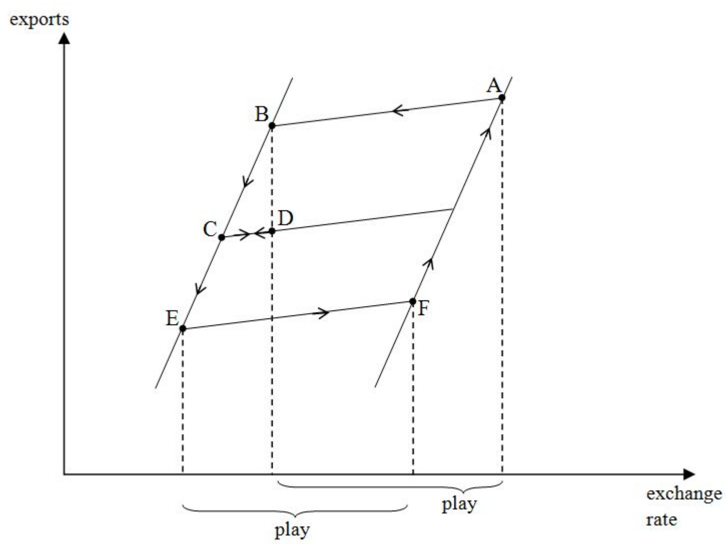
2.1 Spurt method

The idea of Belke and Göcke [2001] was to linearize this typical hysteresis loop and to measure with a regression if there are two different levels of slope which have to be considered, see Figure 3.

Therefore a new variable, called spurt, is computed. It only reflects large changes of the input variable. By starting in a local maximum value of the input for example, the spurt stays at a constant level as long as the input variation remains within a certain band of inaction, called play. As soon as the input variable falls below the initial value minus this play value, the spurt reflects the decreasing of the input until the input changes its direction and starts to rise again. A local minimum has been reached. Then, the spurt remains constant again at this minimum level until the input increases so much that it rises above the minimum plus the play value. In case the input decreases again without reaching the trigger value of minimum plus play, the spurt follows the downward movement of the input until the next local minimum value is reached. In case the input exceeds the minimum plus play value, the spurt reflects the rising input until the next maximum is reached.

As the play is not known in advance in an empirical estimation, a spurt variable for every play width within an interval (see table 1) is calculated and put into a regression. In the end, one of the spurts will provide a model with a higher explanatory power than the other ones. This optimal spurt is reported as “the

Figure 3: Linearized hysteresis loop à la Belke and Göcke [2001]



spurt" and the respective play width is presented in table 1. Figure 6 shows the dependence of the R^2 of the regression on the play width in case of Italian export values.

After calculating this special spurt variable, see figure 5, it is added to a linear regression model and two linear models one with and one without spurt are compared. If the new variable takes over the role of the exchange rate that is the coefficient β of the spurt is significant and has the appropriate sign, then one concludes that there is hysteresis.

In the analysis of hysteresis in the wine export to the US the regressions include beneath the exchange rate the GDP of the US of the previous period, a linear trend and seasonal dummy variables.

$$\begin{aligned} Wine_t = &\quad \alpha_0 c + \alpha_1 RER_t + \alpha_2 GDP\_US_{t-1} + \alpha_3 Trend + \alpha_4 D_1 + \alpha_5 D_2 \\ &\qquad + \alpha_6 D_3 \\ Wine_t = &\quad \alpha_0 c + \alpha_1 RER_t + \beta Spurt_t + \alpha_2 GDP\_US_{t-1} + \alpha_3 Trend + \alpha_4 D_1 \\ &\qquad + \alpha_5 D_2 + \alpha_6 D_3 \end{aligned}$$

where $Wine$ is measured in values (Euro), quantities (100 l) and prices (Euro per kilo) and RER is the real exchange rate (US-Dollar per Euro).

The regressions of the export values and prices start at the first quarter of 1995 and end in the third quarter of 2013. The estimations of the quantities start in 1995 as well, with the exception of Spain. For reasons of data availability the estimation of the Spanish export quantities and prices starts in 2003. The regressions of the quantities end in the third quarter of 2014.

2.2 Preisach method

The procedure of Piscitelli et al. [2000] reflects the model of Preisach [1935] more accurately. The idea behind this approach is the same as described above. Some kind of a filtered input variable is computed, but there is no linearization. The aggregation is run in an exact way but to do this one has to make an assumption regarding the distribution of the (α, β) thresholds. Here, we assume that they are uniformly distributed. But as shown in Piscitelli et al. [2000] the assumption about the distribution will change the results just slightly.

The Preisach model is an aggregation of non-ideal relays

$$P(t) = \iint_{\alpha \geq \beta} \mu(\alpha, \beta) w_{\alpha,\beta}(v(t)) \, d\alpha d\beta$$

where $\mu(\alpha, \beta)$ is a weight function.

The Preisach method can be interpreted geometrically by describing the set $T := \{\alpha \geq \beta\}$ as a triangle and every pair (α, β) as a point in this triangle, see figure 4. Following a varying input function, a staircase border function between the relays in state $+1$, that is set S^+, and the relays in state 0, set S^-, arises. Only the local extremum values of the input affect this border function, so at time t it represents the alternating series of non-dominated maximum M_k and minimum values m_k up to time t. More detailed descriptions and graphics can be found e. g. in Göcke [2002], Mayergoyz [2003], Piscitelli et al. [2000], Brokate and Sprekels [1996], Visintin [1994]. As $w_{\alpha,\beta}(v(t)) = +1$ for all pairs $(\alpha, \beta) \in S^+$ and $w_{\alpha,\beta}(v(t)) = 0$ for all $(\alpha, \beta) \in S^-$, the Preisach operator can be written as

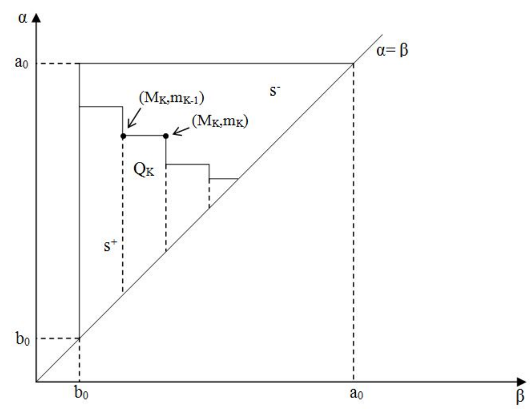
$$\begin{aligned} P(t) = & \iint_{\alpha \geq \beta} \mu(\alpha, \beta) w_{\alpha,\beta}(v(t)) \, d\alpha d\beta \\ = & \iint_{T} \mu(\alpha, \beta) w_{\alpha,\beta}(v(t)) \, d\alpha d\beta \\ = & \iint_{S_t^+} \mu(\alpha, \beta) \, d\alpha d\beta \end{aligned}$$

As next step, this integral is approximated with trapezoids $Q_k(t)$

$$\iint_{S_t^+} \mu(\alpha, \beta) \, d\alpha d\beta = \sum_{k=1}^{n(t)} \iint_{Q_k(t)} \mu(\alpha, \beta) \, d\alpha d\beta$$

where $n(t)$ is the number of trapezoids $Q_k(t)$ in which S^+ can be divided, see figure 4. To calculate these trapezoids one needs to identify the local non-dominated extremum values and the times when they occur. This is done by the

Figure 4: Geometric representation of Preisach method



algorithm provided in the appendix, see 7, which at the same time calculates the sum of the trapezoids, that is the Preisach variable $P(t)$, see figure 5.

As there are different methods in the literature to include the Preisach hysteresis variable in the analysis, two ways are presented here. First, the hysteresis variable is added to the linear regression like the spurt in the model above, see Hallett and Piscitelli [2002].

$$\begin{aligned} Wine_t &= \alpha_0 c + \alpha_1 RER_t + \alpha_2 P_t + \alpha_3 GDP\_US_{t-1} + \alpha_4 Trend \\ &\quad + \alpha_5 D_1 + \alpha_6 D_2 + \alpha_7 D_3 \end{aligned}$$

where P_t is the Preisach variable. This model is referred to as (3) in the tables in the appendix. As all the non-linearities are captured in the Preisach variable, the remaining linear dependence can be estimated.

Second, the hysteresis variable replaces the underlying exchange rate, see e. g. de Prince and Kannebley Junior [2013], that is the following model is executed

$$Wine_t = \alpha_0 c + \alpha_1 P_t + \alpha_2 GDP\_US_{t-1} + \alpha_3 Trend + \alpha_4 D_1 + \alpha_5 D_2 + \alpha_6 D_3$$

where P_t is the same Preisach variable as above. If the Preisach variable is significant in the regression and the coefficient increases in absolute terms, hysteresis is assumed. This model is numbered as (4) in the appendix 7.

Figure 5 shows the underlying exchange rate of Italy from 1991 to 2013, the spurt variable of Belke and Göcke [2001] and the Preisach hysteresis variable Piscitelli et al. [2000] in case of Italian export values. The spurt variable is started at the first maximum of the exchange rate, whereas the hysteresis variable of the Preisach model starts at the same point in time as the exchange rate. The spurt

Figure 5: Comparison of the exchange rate, the spurt and the Preisach hysteresis variable in case of Italy

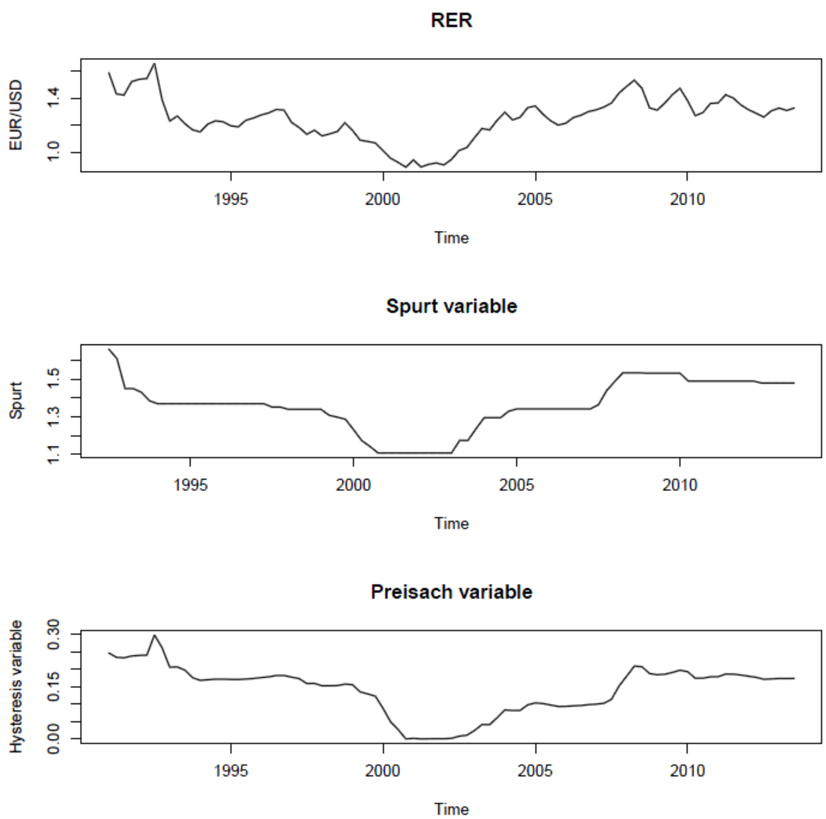
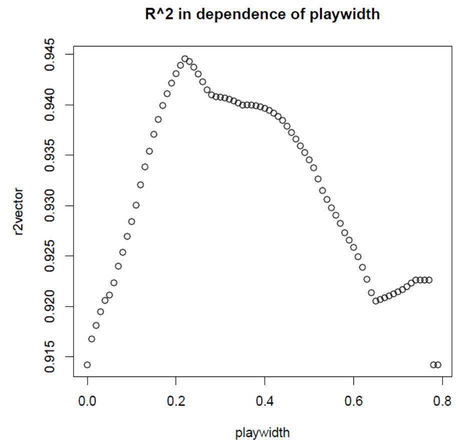


Figure 6: Dependence of R^2 on play width for the model of Italian values



was created under the assumption of a constant play of 0.22, that is we assume that changes smaller than 0.22 are ignored. This play width was estimated and reflects the one for which the addition of the respective spurt is able to improve the regression most. The spurt series is more stepwise and reflects a broader filter than the Preisach hysteresis variable.

3 Data

The data are monthly measured and taken from Eurostat and USDA [2014]. The nominal values in Euro are adjusted using the Consumer Price Index P6 provided by Eurostat. As this index is only available for quarters, the data were summed up to quarters in case of quantities or the average of three months is reported as quarterly values resp. prices. The prices are unit values in Euro calculated by dividing values by quantities. As there are no Spanish export quantities available for 2002, the Spanish data start in 2003Q1. Augmented Dickey Fuller tests show that the exchange rates, the US GDP and the export values as well as the prices are integrated of order 1. The quantities are stationary. Tests of cointegration reveal long-term relationships between the export values and the US GDP as well as the export values and the exchange rates except in case of France and long term relationships between the export values respective prices, the US GDP and the exchange rates.

Figure 7 shows the wine export values in Euros of Spain, Italy and France whereas figure 8 provides an overview of the export quantities. Spain and Italy tend to export rather cheap wine whereas France exports high priced wine, see e. g. Anderson and Nelge [2011, pp. 17, p. 23].

The real exchange rates (RER) are taken for every country because there are slight differences in the time series before the Euro launch. They are measured

Figure 7: Wine export values of Italy, Spain and France

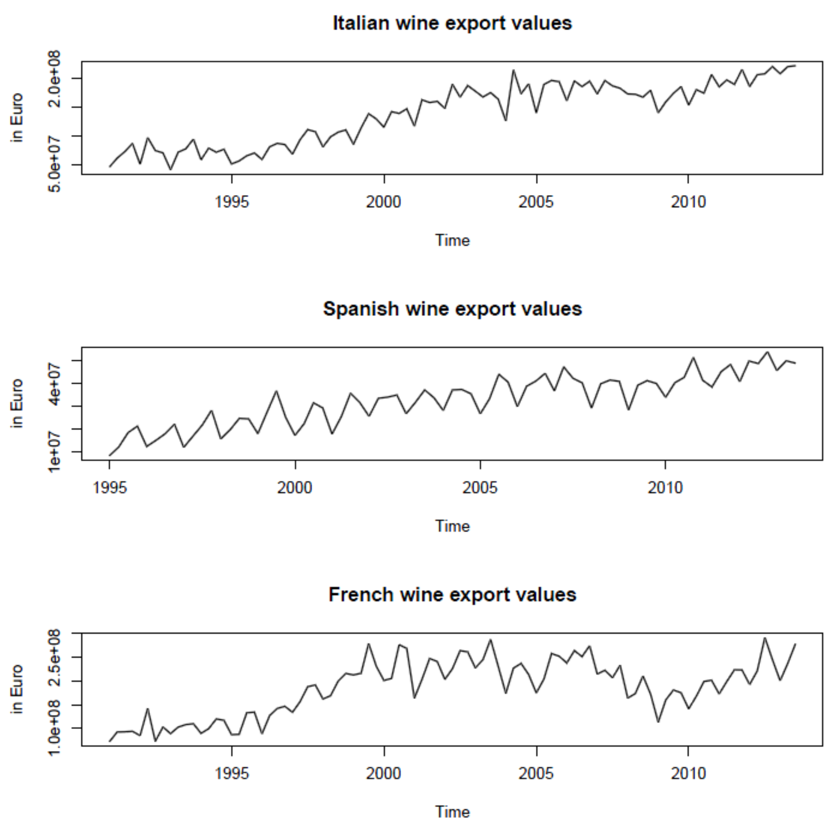
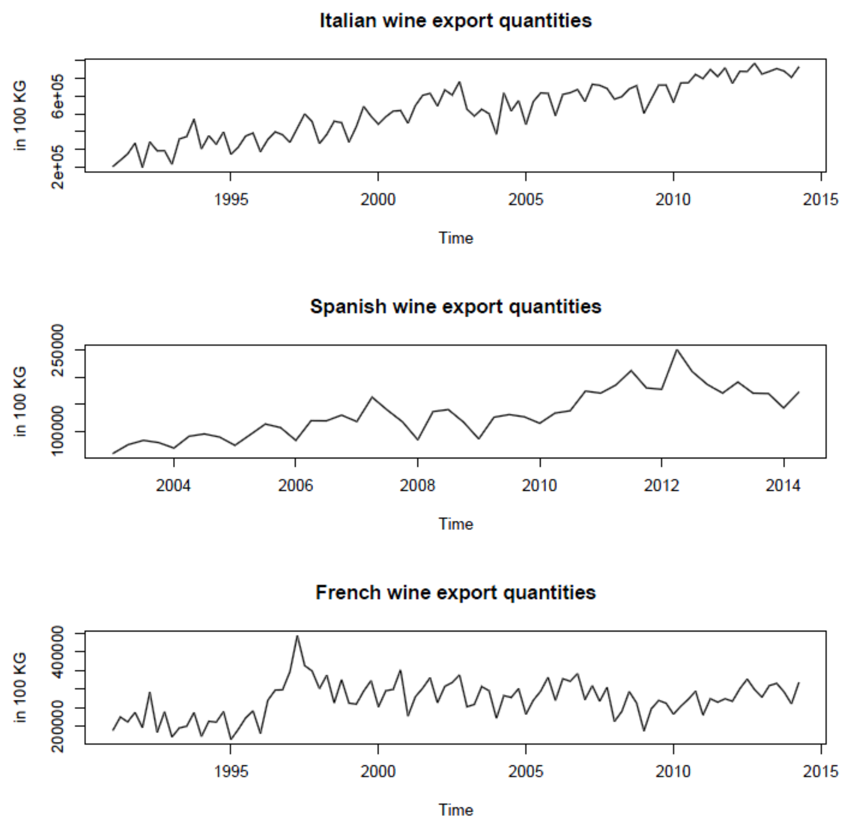


Figure 8: Wine export quantities of Italy, Spain and France



in Dollar against one Euro, so a negative coefficient of RER in the regression output is to be expected as it reflects decreasing exports as a result of a Euro appreciation. The real exchange rate is used to take out the general price trend.

4 Results

The tables of the outcomes are presented in the appendix 7. First, one can mention that the exchange rate coefficient has the expected negative sign in all models without any hysteresis variable, these are models (1). That is, an Euro appreciation tends to lower export quantities, prices and values. For Spanish quantities this coefficient is not significant but still negative.

The outcomes of the spurt approach (model (2)) as well as the Preisach replacement method (model (4)) show hysteresis influences of the exchange rate in the export values for all three European countries. Model (3) which adds the

Preisach variable to the linear model reveals hysteresis only for Italy and Spain.

Looking at the results of Italian wine exports values in more detail, one has to notice that the coefficient $-153,654,978$ of the spurt in model (2) is significant and has the expected negative sign. As the addition of the spurt variable is also able to improve the regression, one can conclude that there are hysteresis reactions on export values due to exchange rate changes. In the first Preisach approach, model (3), the Preisach variable is significant and the coefficient $-258,639,810$ is in absolute terms higher than the coefficient $-66,031,297$ of the real exchange rate in model (1). In model (4), the approach, where the Preisach variable replaces the exchange rate entirely, the Preisach variable is as well significant and has the appropriate negative sign which indicates that an Euro appreciation will decrease wine exports to the US. A comparison of the adjusted R^2 reveals that the addition of the hysteretic non-linear variables is able to improve the model as well. So, also the Preisach methods indicate hysteresis.

The outcomes of the regressions for the models referring to Spanish export values show similar results as for Italian values, see table 5 in the appendix. For France the spurt method as well as the Preisach replacement method find hysteresis. The other Preisach modeling procedure finds no hint for hysteresis. In addition, the Preisach variable which replaces the exchange rate does not improve the linear model, on the contrary, it reduces the adjusted R^2 from 0.728 to 0.71. So, in case of France only the spurt method is able to find hysteresis in export values.

Next, the results of the export quantities are analyzed. In case of quantities the outcomes are mixed. For Italy the spurt as well as the Preisach replacement method indicate hysteresis but for Spain none of the models shows an hysteresis effect. In case of France, the coefficient of the spurt as well as of the additional Preisach variable is significant but has a positive sign. In the Preisach replacement model the coefficient of the Preisach variable is negative and significant but the adjusted R^2 of model (4) is even lower than that of model (1). That is, the exchange rate provides a better fit for the French export quantities than the Preisach variable, therefore there seems to be no hysteresis in this case. The relatively low R^2 points out that there are other influences which should be taken into consideration beside the exchange rate to explain French wine export quantities.

Looking at the export prices, the outcomes are more uniform. For Italian and French prices all three methods find hysteresis. Contrary to this, both Preisach models reject hysteresis in case of Spanish export prices, whereas the spurt method finds a significant positive spurt coefficient.

The intervals and chosen play widths of the spurt approach are presented in table 1. The play range of France in case of values is just 0-0.6. Otherwise the chosen play width by the algorithm would be 0.64 and the respective spurt would just be a dummy which reflects the structural break of the financial crisis, here at 2008Q1.

Table 2 provides an overview about the hysteresis findings where "(-)" means

Table 1: Play ranges and chosen play widths

	Play range	Play width (Values)	Play width (Quantities)	Play width (Prices)
Italy	$0-0.8$	0.22	0.15	0.36
Spain	$0-0.75$	0.31	0.5	0.48
France	$0-0.6$	0.24	0.16	0.21

that even though the Preisach coefficient is significant, the adjusted R^2 of model (4) is less than the adjusted R^2 of model (1). The table shows the hysteresis findings in a clearly structured way. Hysteresis is fund for Italian and Spanish export values with all three models. Export quantities seem not to be suspect to hysteresis. All models find hysteresis for Italian and French unit values. These findings are summarized in table 3.

Considering the trend variable, one remarks that is has a positive influence on Italian and Spanish export values and quanities whereas a negative one on French export values and quantities. Regarding unit prices on the other hand, the trend variable has a common negative impact which is most significant for Spain.

The quarterly dummies d1, d2 and d3 express the influence of the first, second and third quarter compared to the fourth quarter. In case of export values and quantities, especially the first quarter shows a negative and significant sign whereas the second quarter has often a negative and significant sign, too. The coefficient of the third quarters is not significant in any model. It is worth noting, that the amounts of the coefficients do not vary much. In case of price there is more variation among the countries. For Italy there are positive coefficients of d1 and d2 which are mostly not significant and negative coefficients of d3 which are also not significant. In contrast to this, the coefficients of the Spanish unit price quarterly dummies are all negative and mostly significant. However, in case of France, one finds significant positive coefficients of d3, positive but not significant coefficients of d1 and negative and not sigificant coefficients of d2.

5 Discussion

Table 2 provides a comparison of the outcomes of the models with regard to the countries and dependent variables. The spurt and the Preisach replacement method concur with one another. As both represent the development of the Preisach triangle, this result is not unexpected. The Preisach addition method which is similar designed to the spurt method is the most conservative estimate

Table 2: Comparison of models

	Spurt method	Preisach (addition)	Preisach (replacement)
	model 2	model 3	model 4
Values			
Italy	yes	yes	yes
Spain	yes (5%-level)	yes	yes
France	yes (5%-level)	–	(–)
Quantities			
Italy	yes (10%-level)	–	(–)
Spain	–	–	–
France	wrong sign	wrong sign	(–)
Prices			
Italy	yes	yes	yes
Spain	wrong sign	–	–
France	yes	yes	yes

Table 3: Summary of hysteresis outcomes

	Values	Quantities	Prices
Italy	Hysteresis	Hysteresis only with spurt method	Hysteresis
Spain	Hysteresis	–	–
France	Hysteresis only with spurt method	Wrong sign, low R^2	Hysteresis

of all three models and indicates hysteresis only if the both other methods agree on their result. Therefore it can be used to testify and confirm the hysteresis findings of the other models.

Table 3 summarizes the hysteresis findings. It shows that hysteresis is more likely to be found in values than in quantities or prices alone. As there can be hysteresis in both, quantities and prices, see Göcke and Werner [2015], this result is reasonable. Export values aggregate the non-linearities of both hysteresis sources. Table 3 hints that hysteresis is rather found in prices in the exporter's currency than in wine export quantities. This could mean that the quantities react with no delay to exchange rate changes, that is without hysteresis. On the other hand, in case of Italy and France, exporters seem to change their export prices in Euro only after large exchange rate influences. This could mean that the competition on the US market does not allow to pass-through every exchange rate movement and that the exporters rather tend to reduce their mark-up. This could be a hint for strategic pricing which could be amplified by the coefficients of the quarterly dummies of the unit price models which reveal a vague picture for Italy and a strategic behaviour of France in the third quarter. In this case the pricing to market behavior could also be subject to hysteresis. Thus, quantities still change but to a smaller extend as they would if no strategic pricing occured.

For Italy, hysteresis is mainly found in prices and values. That could mean that it is enough that one variable shows hysteresis to induce the values to reveal hysteresis as well. In case of France there is hysteresis in prices and in quantities but in the latter case with a wrong sign reported by two of the three models. As there is rather no hysteresis in values one could conclude that this opposite effects are able to cancel each other out. On the other hand, in case of Spain, one finds hysteresis neither in quantities nor in prices but in values. The non-linear pattern is only found in the aggregated variable. This seems to be the opposite case to France. There, the hysteresis in quantities and prices cancels each other out, whereas in case of Spain hysteresis arises by multiplying quantities and prices. So, the three countries reveal very different patterns to deal with hysteresis non-linearities.

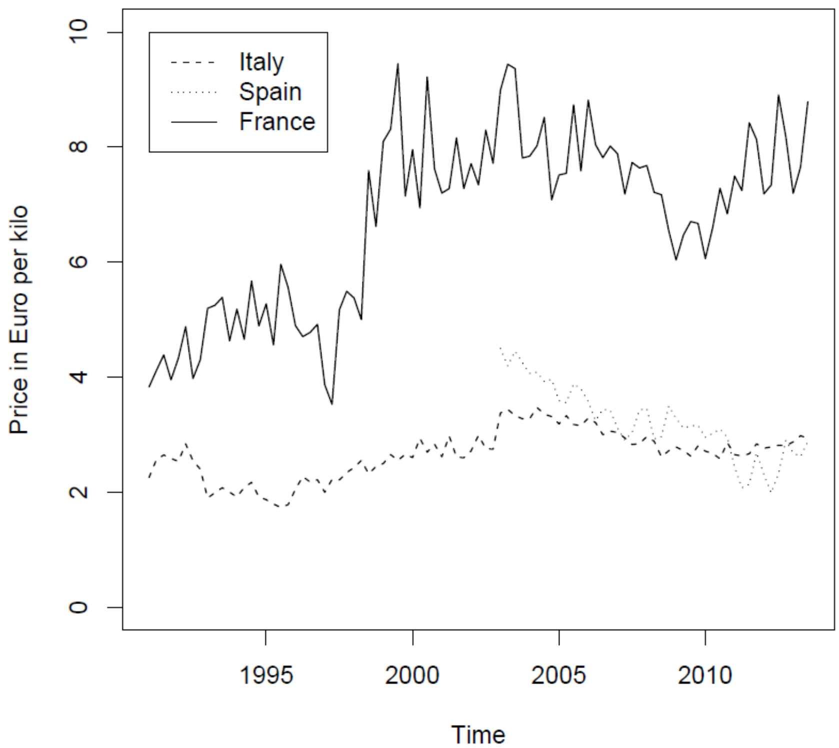
Table 1 which presents the chosen play values by the spurt approach sheds a new light on the findings. First, it is to mention that the play widths of the estimation of quantities of Italy and France are 0.15 resp. 0.16 which corresponds to the standard deviations of the exchange rates which are 0.16 resp. 0.15. That means, an additional spurt variable which ignores changes in order of the standard deviation, which occur after a change of direction of the exchange rate, is able to improve the estimation of the quantities. This result supports the choose of the standard deviation as threshold by Fedoseeva [2014]. In that study the exchange rate is decomposed into three sectors, large positive, large negative and small changes, to differentiate effects of appreciation and depreciation in a trade investigation. In addition, her outcomes suggest, that European exporters benefit from Euro depreciations and are negatively effected by appreciations, especially in the agricultural sector. The results above testify the presumption of hysteresis for Italian, Spanish and French exports to the US for the wine market which Fedoseeva [2014] expressed. The estimated play width for Italian and French prices suggests that Fedoseeva [2014] could have used two times the standard deviation instead of the standard deviation to search for asymmetric behavior in German export beer prices. The play values for Spanish quantities and prices are rather large. This suggests that the accompanying spurts are stepped and indicate structural breaks. Looking at the play widths of the values it is again noticeable that the plays of Italy and France are similar whereas the one of Spain is larger. The special behavior of Spain is due to the shorter time span of the estimation. In an earlier version of this paper the model for Spanish values was estimated for the same time span as for Italy and France. In this case the play for values was 0.25 which is very similar to the other ones.

Interpreting the coefficients of the trend variable, one finds similar results for Italy and Spain, namely positive and significant coefficients for values and quantities but indefinit ones for France. These results are supported by the time series, see figures 7 and 8. Having in mind the rising competition of the new world producers (e. g. Australia, New Zealand, South Africa or Chile), which could have been reflected by the time trend, one could argue that Italy and Spain were less influenced than France. On the other hand, the price models of all countries show negative trend and often negative dummy coefficients, which could reflect that the growing competition reduced the prices over time for all countries. The reason of this different pattern of the counties could be that the French wine price level is always higher than the Italian or Spanish one, see figure 9.

6 Conclusion

This study presented and compared three techniques to search for hysteresis. Beside the spurt method of Belke and Göcke [2001], the Preisach approach with two ways of application is introduced. By using this methods, hysteresis was identified in European wine exports to the USA between 1995 and 2013. Not only in values but also in prices, i. e. unit values, and on a limited scale in quantities as well. This extensive approach allows to draw conclusions about the sources of hysteresis and the underlying structure of the export market as was shown in Göcke and Werner [2015]. Hysteresis was found in case of values mainly for Italy and Spain whereas in case of prices it was found for Italy and France. In quantities there seems to be less hysteresis which lets one assume that either the quantities adjust immediately to exchange rate changes or that, on the contrary, they react not at all which could hint for pricing to market. On the other hand, there has been a change in the quality of wine exported to the US during the analyzed time span, see e. g. Mariani et al. [2012], OIV [2014]. Instead of shipping superfluous wines to the US, the European exporter behave more market-oriented, see e. g. Mariani et al. [2012]. Although Italy and France differ in the price categories of their export wine, the hysteresis results are quite similar. For both countries hysteresis was found in prices and the play widths

Figure 9: Adjusted wine export unit prices of Italy, Spain and France



of the spurt algorithm which represent the amount of changes which get ignored are very similar. The deviation in the Spanish results can be due to the shorter time span, though.

It is an important result that the spurt method and the Preisach replacement method are mostly in agreement with one another. Because Hallett and Piscitelli [2002] showed that an earlier version of the spurt method, published in Göcke [1994], was not able to narrow down hysteresis in comparison to other non-linear phenomenons. The improved version of Belke and Göcke [2001] on the contrary seems just to be slightly to vague and more in line with the thorough method of Preisach. The Preisach addition method on the other hand seems to be more conservative as the other ones and can therefore be used as a confirmation. Therefore, I recommend to use the Preisach replacement method in future studies if the condition of uniformly distributed trigger values is justified and to use the spurt method if the width of the band of inaction is of primary interest.

As this study found hysteresis in export values and prices it is important to keep this special path-dependence in mind when analyzing or predicting exchange rate influences. Hysteresis means that it is not sufficient just to know the actual state of the exchange rate but that the last local extremum values have to be taken into account. Hysteresis effects due to sunk costs slow down adjustment processes but they do not prevent them. They produce "wait-and-see" strategies on the exporters, see e. g. Dixit and Pindyck [1994]. That is, small up and down changes have in case of hysteresis no effect on export prices, for instance, but large, long lasting or many small changes in one direction have effects.

In addition, it was shown that hysteresis in prices (unit values) can have very different effects on values. For the case of Italy where hysteresis in quantities was revealed by one method, the hysteresis of prices and eventually quantities intensified each other such that there were very strong hysteresis evidences by all three methods. For France, on the contrary, the quantities showed a hysteresis pattern with a positive coefficient. As for values only the less conservative estimation technique suggested hysteresis for values, one can conclude that the hysteresis effects of prices and quantities neutralized each other.

As there are so interesting results for wine exports it would be important to enlarge the analyzed products and countries. It would be exciting to know if similar neutralizing or amplification effects occur on other markets as well. Firm level data would be very useful to analyze market exit and entries but they are not available.

Three methods of identifying hysteresis in exports due to exchange rate fluctuations were presented and hysteresis was revealed for values, prices and to a smaller extend for quantities of European wine exporters to the US market.

References

Kym Anderson. Excise and import taxes on wine versus beer and spirits: An international comparison. *Economic Papers*, 29(2):215–228, 2010.

Kym Anderson and Signe Nelge. *Global wine markets, 1961 to 2009: a statistical compendium*. University of Adelaide Press, 2011. URL `http://www.adelaide.edu.au/press/titles/global-wine/Global-Wine-2009-EBOOK.pdf`. 13.02.2015.

Kym Anderson and Glyn Wittwer. Modeling global wine markets to 2018: Exchange rates, taste changes, and China's import growth. *Journal of Wine Economics*, 8(2):131–158, 2013.

R. Baldwin. Hysteresis in trade. *Empirical Economics*, 15:127–142, 1990.

Barbara C. Beliveau and M. Elizabeth Rouse. Prohibition and repeal: A short history of the wine industry's regulation in the United States. *Journal of Wine Economics*, 5(1):53–68, 2010.

A. Belke and M. Göcke. Exchange rate uncertainty and employment: an algorithm describing "play". *Applied Stochastic Models in Business and Industry*, 17:181–204, 2001.

A. Belke, M. Göcke, and Martin Günther. Exchange rate bands of inaction and play-hysteresis in German exports - sectoral evidence for some OECD destinations. *Metroeconomica*, 64(1):152–179, February 2013.

Olivier J. Blanchard and Lawrence H. Summers. Hysteresis in unemployment. *NBER Working Paper Series*, (2035):1–12, October 1986.

Martin Brokate and Jürgen Sprekels. *Hysteresis and Phase Transitions*, volume 121 of *Applied Mathematical Sciences*. Springer, New York, 1996.

Jose Manuel Campa. Exchange rate and trade: How important is hysteresis in trade? *European Economic Review*, 48:527–548, 2004.

R. Cross, Julia Darby, L. Piscitelli, and Jonathan Ireland. *The Science of Hysteresis*, volume 1, chapter Hysteresis and unemployment: a preliminary investigation, pages 667–699. Academic Press, 2005.

R. Cross, H. A. McNamara, Leonid Kalachev, and A. V. Pokrovskii. Hysteresis and post Walrasian economics. *Discrete and Continuous Dynamical Systems Series B*, 18(2):377–401, 2013.

Diogo de Prince and Sergio Kannebley Junior. Strong hysteresis in Brazilian imports: a panel cointegration approach. *Journal of Economic Studies*, 40 (4):528–548, 2013.

Avinash Dixit. Hysteresis, import penetration, and exchange rate pass-through. *The Quarterly Journal of Economics*, 104(2):205–228, May 1989a.

Avinash Dixit. Entry and exit decisions under uncertainty. *Journal of Political Economy*, 97(3):620–638, June 1989b.

Avinash K. Dixit and Robert S. Pindyck. *Investment under uncertainty*. Princeton University Press, Princeton, 1994.

Svetlana Fedoseeva. Are agricultural exports any special? Exchange rate nonlinearities in European exports to the US. *German Journal of Agricultural Economics*, 63(4):259–270, 2014.

Wolfgang Franz. Hysteresis in economic relationships: An overview. *Empirical Economics*, 15(2):109–125, 1990. doi: DOI:10.1007/BF01973448.

FTA. State wine excise tax rates. online, January 2015. URL `http://www.taxadmin.org/fta/rate/wine.pdf`. (Federation of Tax Administrators) 13.02.2015.

M. Göcke and Laura Werner. Play-hysteresis in supply or in demand as part of a market model. *Metroeconomica*, pages 1–36, 2015. doi: 10.1111/meca.12074.

Matthias Göcke. An approximation of the hysteresis-loop by linear partial functions - econometric model and estimation. *Jahrbücher für Nationalökonomie und Statistik*, 213(5):572–596, 1994.

Matthias Göcke. Various concepts of hysteresis applied in economics. *Journal of Economic Surveys*, 16(2):167–188, 2002.

M. Grinfeld, R. Cross, and H. Lamba. Hysteresis and economics - taking the economic past into account. *IEEE Control Systems*, 29(1):30–43, 2009.

A. J. Hughes Hallett and Laura Piscitelli. Testing for hysteresis against nonlinear alternatives. *Journal of Economic Dynamics and Control*, 27:303–327, 2002.

S. Kannebley Junior. Tests for the hysteresis in Brazilian industrialized exports: A threshold cointegration analysis. *Economic Modelling*, 25:171–190, 2008.

Mark A. Krasnosel'skii and Aleksei V. Pokrovskii. *Systems with Hysteresis*. Springer, Berlin, 1989.

Walter C. Labys and Bruce C. Cohen. Trends versus cycles in global wine export shares. *The Australian Journal of Agricultural and Resource Economics*, 50: 527–537, 2006.

Angela Mariani, Eugenio Pomarici, and Vasco Boatto. The international wine trade: Recent trends and critical issues. *Wine Economics and Policy*, 1:24–40, 2012.

Isaak D. Mayergoyz. *Mathematical Models of Hysteresis and their Applications*. Elsevier Series in Electromagnetism. Elsevier, 2003.

Paulo R. Mota, José Varejao, and Paulo B. Vasconcelos. Hysteresis in the dynamics of employment. *Metroeconomica*, pages 1–32, April 2012.

Paulo Ricardo Tavares Mota. *Weak and Strong Hysteresis in the dynamics of Labor Demand*. PhD thesis, Faculdade Economica Universidade do Porto, 2008.

OIV. Weltkonjunkturbericht. Report, Mai 2014. URL `http://www.infovin.org/content/wp-content/uploads/2014/05/Konjunkturnote-OIV-M%C3%A4rz-2014.pdf`. (Organisation Internationale de la Vigne et du Vin) 30.06.2016.

Laura Piscitelli, Rod Cross, Michael Grinfeld, and Harbir Lamba. A test for strong hysteresis. *Computational Economics*, 15:59–78, 2000.

Ferenc Preisach. Über die magnetische Nachwirkung. *Zeitschrift für Physik*, 94: 277–302, 1935.

USDA. Real monthly country exchange rates, 12 2014. URL `http://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set.aspx`. (United States Department of Agriculture) 16.01.2015.

Augusto Visintin. *Differential Models of Hysteresis*. Number 111 in Applied Mathematical Sciences. Springer, Berlin, 1994.

7 Appendix

Table 4: Linear regression models of Italian wine export values

	Dependent variable:			
	ExpV			
	(1)	(2)	(3)	(4)
RER	−66,031,297.00***	29,668,428.00	17,656,795.00	
	(12,943,883.00)	(18,954,038.00)	(19,809,385.00)	
Spurt		−153,654,978.00***		
		(25,356,805.00)		
Preisachvariable			−258,639,810.00***	−221,115,043.00***
			(50,767,982.00)	(28,329,942.00)
GDP	118.11***	51.98***	38.25*	47.92**
	(18.92)	(18.81)	(22.53)	(19.72)
trend	145,930.40	1,382,115.00***	1,324,946.00***	1,207,405.00***
	(337,574.10)	(341,067.70)	(370,030.10)	(345,211.40)
d1	−26,585,933.00***	−25,577,587.00***	−25,717,366.00***	−25,866,726.00***
	(4,667,843.00)	(3,783,203.00)	(3,996,054.00)	(3,986,501.00)
d2	−2,557,228.00	−1,568,521.00	−1,845,493.00	−2,045,945.00
	(4,676,287.00)	(3,789,893.00)	(4,002,077.00)	(3,989,710.00)
d3	−5,555,623.000	−5,199,324.000	−5,009,964.000	−5,173,762.00
	(4,672,343.00)	(3,783,643.00)	(3,997,700.00)	(3,987,434.00)
Constant	−109,691,355.00**	127,589,465.00**	9,880,484.00	2,934,969.00
	(49,352,571.00)	(55,947,593.00)	(48,297,675.00)	(47,592,850.00)
Observations	75	75	75	75
R^2	0.914	0.945	0.938	0.937
Adjusted R^2	0.907	0.939	0.932	0.932
Res. Std. Error	14,185,828.00 ($df = 68$)	11,486,233.00 ($df = 67$)	12,133,167.00 ($df = 67$)	12,114,818.00 ($df = 68$)
statistic	120.76*** ($df = 6; 68$)	163.13*** ($df = 7; 67$)	145.20*** ($df = 7; 67$)	169.79*** ($df = 6; 68$)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 5: Linear models of Spanish wine export values

	Dependent variable:			
	ExpV			
	(1)	(2)	(3)	(4)
RER	$-19,264,764.00^{***}$	$-3,232,625.00$	$876,532.90$	
	(5,805,356.00)	(8,124,733.00)	(9,623,654.00)	
Spurt		$-28,861,539.00^{**}$		
		(10,961,774.00)		
Preisachvariable			$-55,953,589.00^{**}$	$-54,288,926.00^{***}$
			(22,104,937.00)	(12,260,975.00)
GDP	23.34^{***}	15.65^{**}	15.005^{*}	15.39^{**}
	(7.55)	(7.58)	(7.77)	(6.41)
trend	$207,861.40^{**}$	$536,159.20^{***}$	$483,269.50^{***}$	$474,851.10^{***}$
	(82,919.73)	(146,459.50)	(133,475.60)	(94,960.05)
d1	$-9,497,724.00^{***}$	$-9,288,968.00^{***}$	$-9,329,943.00^{***}$	$-9,341,786.00^{***}$
	(1,336,179.00)	(1,240,596.00)	(1,247,645.00)	(1,223,640.00)
d2	$-2,424,082.00^{*}$	$-2,460,147.00^{*}$	$-2,406,570.00^{*}$	$-2,410,368.00^{*}$
	(1,330,982.00)	(1,233,321.00)	(1,241,057.00)	(1,223,152.00)
d3	$-1,021,994.00$	$-1,054,990.00$	$-946,695.30$	$-957,043.20$
	(1,338,223.00)	(1,240,017.00)	(1,248,144.00)	(1,225,723.00)
Constant	$-11,300,754.00$	$26,343,481.00$	$-7,716,256.00$	$-7,899,905.00$
	(20,931,130.00)	(24,094,590.00)	(19,567,958.00)	(19,193,836.00)
Observations	43	43	43	43
R^2	0.835	0.863	0.861	0.861
Adjusted R^2	0.808	0.835	0.833	0.838
Residual Std. Error	$3,035,686.00 (df = 36)$	$2,812,767.00 (df = 35)$	$2,830,541.00 (df = 35)$	$2,791,282.00 (df = 36)$
F statistic	$30.43^{***} (df = 6; 36)$	$31.37^{***} (df = 7; 35)$	$30.92^{***} (df = 7; 35)$	$37.09^{***} (df = 6; 36)$

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 6: Linear models of French wine export values

	Dependent variable:			
	ExpV			
	(1)	(2)	(3)	(4)
RER	−146,680,756.00***	−85,916,195.00**	−99,809,847.00**	
	(19,631,886.00)	(34,870,092.00)	(39,544,522.00)	
Spurt		−104,750,694.00**		
		(50,218,237.00)		
Preisachvariable			−168,609,141.00	−440,265,425.00***
			(123,736,658.00)	(63,410,536.00)
GDP	172.81***	119.16***	132.68***	81.73*
	(34.41)	(42.31)	(45.13)	(41.92)
trend	−1,910,857.00***	−962,873.40	−1,224,754.00	−381,938.80
	(594,417.70)	(737,076.20)	(776,180.50)	(727,823.10)
d1	−43,704,146.00***	−42,845,114.00***	−43,251,289.00***	−42,448,684.00***
	(8,271,254.00)	(8,085,182.00)	(8,226,348.00)	(8,538,639.00)
d2	−20,904,312.00**	−20,581,215.00**	−20,633,471.00**	−19,867,219.00**
	(8,281,003.00)	(8,085,689.00)	(8,231,721.00)	(8,544,790.00)
d3	10,244,066.00	10,275,377.00	10,504,503.00	11,337,916.00
	(8,278,860.00)	(8,082,126.00)	(8,229,410.00)	(8,541,323.00)
Constant	−32,970,978.00	158,587,173.00	19,035,573.00	41,444,417.00
	(90,757,922.00)	(127,607,588.00)	(97,934,366.00)	(101,309,325.00)
Observations	75	75	75	75
R^2	0.750	0.765	0.757	0.734
Adjusted R^2	0.728	0.741	0.731	0.710
Res. Std. Error	25,137,882.00($df = 68$)	24,540,480.00($df = 67$)	24,980,994.00($df = 67$)	25,948,725.00($df = 68$)
F statistic	34.00***($df = 6; 68$)	31.20***($df = 7; 67$)	29.77***($df = 7; 67$)	31.21***($df = 6; 68$)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 7: Linear models of Italian export quantities

	Dependent variable:			
	ExpQ			
	(1)	(2)	(3)	(4)
RER	−203, 078.900***	−56, 673.170	−167, 349.000**	
	(36, 158.550)	(83, 284.990)	(64, 960.590)	
Spurt		−196, 188.900*		
		(100, 976.200)		
Preisachvariable			−110, 584.200	−466, 779.300***
			(166, 729.700)	(96, 801.630)
GDP	0.002	−0.023	−0.032	−0.125*
	(0.052)	(0.053)	(0.074)	(0.067)
trend	5, 956.571***	6, 496.199***	6, 465.581***	7, 618.033***
	(917.160)	(941.638)	(1, 198.683)	(1, 155.378)
d1	−96, 263.250***	−94, 301.030***	−95, 877.690***	−94, 419.240***
	(12, 728.790)	(12, 527.880)	(12, 792.510)	(13, 277.580)
d2	−28, 460.560**	−25, 935.740**	−28, 179.750**	−26, 334.810*
	(12, 755.190)	(12, 580.300)	(12, 812.800)	(13, 290.870)
d3	−5, 808.541	−4, 188.663	−5, 606.580	−4, 266.949
	(12, 897.690)	(12, 680.240)	(12, 952.440)	(13, 445.920)
Constant	600, 637.500***	729, 437.600***	652, 220.800***	721, 496.700***
	(136, 379.000)	(149, 312.600)	(157, 466.700)	(161, 194.700)
Observations	78	78	78	78
R^2	0.917	0.922	0.918	0.910
Adjusted R^2	0.911	0.914	0.910	0.903
Residual Std. Error	39, 719.480($df = 71$)	38, 965.320($df = 70$)	39, 877.080($df = 70$)	41, 429.750($df = 71$)
F statistic	131.579***($df = 6; 71$)	117.730***($df = 7; 70$)	111.955***($df = 7; 70$)	119.983***($df = 6; 71$)
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 8: Linear models of Spanish export quantities

	Dependent variable:			
	YY			
	(1)	(2)	(3)	(4)
RER	−37, 873.780	17, 284.470	21, 478.190	
	(40, 897.390)	(55, 099.540)	(73, 548.270)	
Spurt		−142, 401.900		
		(96, 993.880)		
Preisachvariable			−155, 659.300	−116, 772.400
			(160, 267.500)	(88, 131.420)
GDP	0.042	−0.033	0.015	0.025
	(0.053)	(0.073)	(0.060)	(0.049)
trend	2, 403.914***	4, 001.999***	3, 162.039***	2, 966.119***
	(599.023)	(1, 238.280)	(984.195)	(711.603)
d1	−19, 691.540**	−18, 747.340**	−19, 151.470**	−19, 453.990**
	(9, 234.473)	(9, 123.338)	(9, 257.905)	(9, 091.238)
d2	10, 425.060	10, 173.120	10, 464.210	10, 373.750
	(9, 201.859)	(9, 070.125)	(9, 208.641)	(9, 094.859)
d3	8, 884.171	9, 487.572	9, 571.192	9, 247.123
	(9, 423.359)	(9, 295.881)	(9, 456.706)	(9, 280.582)
Constant	−10, 981.600	332, 527.100	8, 312.975	2, 577.420
	(148, 729.300)	(276, 093.100)	(150, 157.400)	(147, 111.200)
Observations	46	46	46	46
R^2	0.783	0.794	0.788	0.787
Adjusted R^2	0.749	0.756	0.749	0.755
Residual Std. Error	21, 962.090(df = 39)	21, 643.800(df = 38)	21, 978.060(df = 38)	21, 718.790(df = 39)
F statistic	23.389***(df = 6; 39)	20.950***(df = 7; 38)	20.153***(df = 7; 38)	24.063***(df = 6; 39)
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 9: Linear models of French export quantities

	Dependent variable:			
	ExpQ			
	(1)	(2)	(3)	(4)
RER	−104,131.500***	−267,997.700***	−196,732.100***	
	(28,498.590)	(70,918.010)	(56,819.990)	
Spurt		218,668.500**		
		(87,234.010)		
Preisachvariable			332,744.100*	−202,412.100**
			(177,644.500)	(94,098.060)
GDP	0.007	0.049	0.086	−0.014
	(0.049)	(0.050)	(0.064)	(0.061)
trend	−36.666	−756.314	−1,375.103	275.039
	(839.736)	(859.499)	(1,091.646)	(1,055.380)
d1	−60,310.180***	−61,892.040***	−61,215.230***	−59,638.530***
	(11,705.720)	(11,310.690)	(11,514.400)	(12,363.670)
d2	−17,924.750	−19,928.530*	−18,392.710	−16,978.270
	(11,721.960)	(11,336.950)	(11,522.920)	(12,374.730)
d3	−14,453.960	−16,140.550	−15,032.690	−13,373.850
	(11,861.480)	(11,463.100)	(11,661.430)	(12,520.770)
Constant	420,221.200***	237,035.900	319,081.800**	362,191.600**
	(130,429.300)	(145,513.000)	(139,093.000)	(148,869.000)
Observations	78	78	78	78
R^2	0.392	0.442	0.421	0.321
Adjusted R^2	0.340	0.386	0.363	0.264
Residual Std. Error	36,528.880 ($df = 71$)	35,241.170 ($df = 70$)	35,900.200 ($df = 70$)	38,578.290 ($df = 71$)
F statistic	7.615*** ($df = 6; 71$)	7.910*** ($df = 7; 70$)	7.259*** ($df = 7; 70$)	5.603*** ($df = 6; 71$)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 10: Linear regression models of Italian wine export prices

	Dependent variable:			
	ExpPrices			
	(1)	(2)	(3)	(4)
RER	-0.403^{*}	0.644^{***}	1.066^{***}	
	(0.213)	(0.216)	(0.317)	
Spurt		-2.617^{***}		
		(0.362)		
Preisachvariable			-4.539^{***}	-2.274^{***}
			(0.812)	(0.487)
GDP	0.00000^{***}	0.00000^{*}	0.00000^{***}	0.00000^{***}
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
trend	-0.031^{***}	-0.0004	-0.011^{*}	-0.018^{***}
	(0.006)	(0.006)	(0.006)	(0.006)
d1	0.004	0.018	0.019	0.010
	(0.077)	(0.058)	(0.064)	(0.069)
d2	0.099	0.103^{*}	0.111^{*}	0.099
	(0.077)	(0.058)	(0.064)	(0.069)
d3	-0.054	-0.049	-0.044	-0.054
	(0.077)	(0.058)	(0.064)	(0.069)
Constant	-3.210^{***}	3.720^{***}	-1.112	-1.531^{*}
	(0.812)	(1.137)	(0.773)	(0.818)
Observations	75	75	75	75
R^2	0.691	0.827	0.789	0.754
Adjusted R^2	0.664	0.808	0.767	0.732
Residual Std. Error	0.233 ($df = 68$)	0.176 ($df = 67$)	0.194 ($df = 67$)	0.208 ($df = 68$)
F statistic	25.359^{***} ($df = 6; 68$)	45.627^{***} ($df = 7; 67$)	35.858^{***} ($df = 7; 67$)	34.692^{***} ($df = 6; 68$)
Note:				$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 11: Linear models of Spanish adjusted export prices

	Dependent variable: ExpPrices			
	(1)	(2)	(3)	(4)
RER	−0.787	-1.786^{***}	-1.792^{**}	
	(0.482)	(0.618)	(0.845)	
Spurt		2.437^{**}		
		(1.024)		
Preisachvariable			2.791	−0.612
			(1.940)	(1.143)
GDP	0.00000	0.00000	0.00000	0.00000^{**}
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
trend	-0.031^{***}	-0.060^{***}	-0.044^{***}	-0.027^{***}
	(0.007)	(0.014)	(0.012)	(0.009)
d1	-0.215^{*}	-0.232^{**}	-0.224^{**}	-0.200^{*}
	(0.111)	(0.105)	(0.110)	(0.114)
d2	-0.366^{***}	-0.367^{***}	-0.367^{***}	-0.360^{***}
	(0.111)	(0.104)	(0.109)	(0.114)
d3	−0.184	-0.191^{*}	-0.188^{*}	−0.166
	(0.111)	(0.105)	(0.110)	(0.114)
Constant	8.487^{***}	2.750	8.308^{***}	8.684^{***}
	(1.738)	(2.913)	(1.718)	(1.789)
Observations	43	43	43	43
R^2	0.865	0.884	0.873	0.857
Adjusted R^2	0.843	0.861	0.847	0.833
Residual Std. Error	0.252($df = 36$)	0.237($df = 35$)	0.248($df = 35$)	0.260($df = 36$)
F statistic	38.565^{***}($df = 6; 36$)	38.148^{***}($df = 7; 35$)	34.333^{***}($df = 7; 35$)	35.823^{***}($df = 6; 36$)
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 12: Linear models of French wine export prices

	Dependent variable:			
	ExpPrices			
	(1)	(2)	(3)	(4)
RER	−2.852***	1.528	0.338	
	(0.662)	(1.202)	(1.275)	
Spurt		−6.868***		
		(1.640)		
Preisachvariable			−11.478***	−10.557***
			(3.990)	(1.955)
GDP	0.00001***	0.00000**	0.00000**	0.00000**
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
trend	−0.063***	−0.015	−0.016	−0.019
	(0.020)	(0.021)	(0.025)	(0.022)
d1	0.013	0.064	0.044	0.041
	(0.279)	(0.250)	(0.265)	(0.263)
d2	−0.138	−0.105	−0.119	−0.122
	(0.279)	(0.251)	(0.265)	(0.263)
d3	0.717**	0.730***	0.735***	0.732***
	(0.279)	(0.250)	(0.265)	(0.263)
Constant	−3.766	6.215*	−0.226	−0.302
	(3.060)	(3.635)	(3.158)	(3.124)
Observations	75	75	75	75
R^2	0.625	0.703	0.667	0.666
Adjusted R^2	0.592	0.672	0.632	0.637
Residual Std. Error	0.848 ($df = 68$)	0.760 ($df = 67$)	0.806 ($df = 67$)	0.800 ($df = 68$)
F statistic	18.915*** ($df = 6; 68$)	22.664*** ($df = 7; 67$)	19.129*** ($df = 7; 67$)	22.615*** ($df = 6; 68$)
Note:				*p<0.1; **p<0.05; ***p<0.01

7.1 Play algorithm

The calculation of the spurt is done in R version 2.14.2 and is implemented as in Belke and Göcke [2001]:

```
## Algorithm ##————
my.spurt.alg <- function( x, y, z){
## this function calculates the Spurt variable for the
## vector x with the initial point y which is ("lu" or "ro")
## and the Play width z (or here, the play vector z).
xx <- x ## underlying vector for which the spurt is calculated
ap <- y ## initial point, either "lu" = minimum or "ro" = maximum
pp <- z ## Play width (here as a vector)
ss <- numeric(length(xx)) ## Variable, which saves the Spurt
ss[1] <- c(xx[1]) ## Initialize the first point ss[1] to the first value of xx
if( ap == "lu") ## If inquiry to check if the initial point
##is a minimum "lu" or not (then it is a maximum "ro")
{
if(( xx[2] - ss[1]) < 0)
{
ss[2] <- xx[2]
}
else
{
if(( xx[2] - ss[1]) > pp[2])
{
ss[2] <- xx[2]-pp[2]
}
else
{
ss[2] <- ss[1]
}
}
for ( i in 3:length(xx)){
if( ss[i-1] == xx[1])
{
if( (xx[i] - ss[i-1]) <0)
{
ss[i] <- xx[i]
```

```
}
else
{
if( (xx[i] - ss[i-1]) > pp[i])
{
ss[i] <- xx[i] - pp[i]
}
else
{
ss[i] <- ss[i-1]
}
}
}
else
{
if( (xx[i] - ss[i-1]) < 0)
{
ss[i] <- xx[i]
}
else
{
if( (xx[i] - ss[i-1]) > pp[i])
{
ss[i] <- xx[i] - pp[i]
}
else
{
ss[i] <- ss[i-1]
}
}
}
}
}
else
{
if(( xx[2] - ss[1]) > 0)
{
```

```
ss[2] <- xx[2]
}
else
{
if(( xx[2] - ss[1]) < -pp[2])
{
ss[2] <- xx[2] + pp[2]
}
else
{
ss[2] <- ss[1]
}
}
for ( i in 3:length(xx)){
if( ss[i-1] == xx[1])
{
if( (xx[i] - ss[i-1]) > 0)
{
ss[i] <- xx[i]
}
else
{
if( (xx[i] - ss[i-1]) < -pp[i])
{
ss[i] <- xx[i] + pp[i]
}
else
{
ss[i] <- ss[i-1]
}
}
}
else
{
if( (xx[i] - ss[i-1]) > 0)
{
ss[i] <- xx[i]
```

```
}
else
{
if( (xx[i] - ss[i-1]) < -pp[i])
{
ss[i] <- xx[i] + pp[i]
}
else
{
ss[i] <- ss[i-1]
}
}
}
}
}
return(ss)
}
```

7.2 Preisach method

The calculation of the Preisach variable is done in R version 2.14.2 and implemented according to Piscitelli et al. [2000]:

```
## Algorithm ##———–
PreisachAlg <- function( XX){
## XX is a vector for which the Preisach hysteresis
## variable shall be computed
a_0 <- abs(max(XX, na.rm = TRUE)) ## max of Input
b_0 <- abs(min(XX, na.rm = TRUE)) ## min of Input
## empty matrix M for saving the local maximum values:
M <- matrix(rep(0, times = (length(XX)*length(XX)+length(XX))), ncol =
length(XX))
## empty matrix m for saving the local minimum values:
m <- matrix(rep(0, times = (length(XX)*length(XX)+length(XX))), ncol =
length(XX))
## numeric vector for saving the time index
## of the local maximum values:
tp <- numeric( length(XX))
## numeric vector for saving the time index
```

```
## of the local minimum values:
tm <- numeric( length(XX))
## numeric vector for saving the output of the
## algorithm, that is the Preisach hysteresis
## variable computed for the input XX:
T <- numeric ( length(XX))
for( t in 1:length(XX))
{
k <- 1
M[k,t] <- max( XX[1:t])
tp[k] <- which.max( XX[1:t])
if( min(XX, na.rm = TRUE) > 0 )
{
T[t] <- (( M[k,t] - b_0 )^2 )/2
}
else
{
T[t] <- ( ( M[k,t] + b_0 )^2 )/2
}
tt <- tp[k]
while( tt < t)
{
z <- XX[tp[k]:t]
m[k,t] <- min(z)
tm[k] <- tp[k] -1 + which.min(z)
T[t] <- T[t] - ((M[k,t] - m[k,t])^2)/2
if( tm[k] < t)
{
w <- XX[tm[k]:t]
M[k+1,t] <- max(w)
tp[k+1] <- tm[k] - 1 + which.max(w)
T[t] <- T[t] + (( M[k+1,t] - m[k,t] )^2 )/2
tt <- tp[k+1]
k <- k+1
}
else
{
```

```
tt <- tm[k]
k <- k+1
}
}
}
T
}
```