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A NEW MEASURE TO QUANTIFY HYSTERESIS LOSSES: THE CASE OF ITALIAN WINE EXPORTS TO THE UNITED STATES

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This paper introduces a new measure to capture dynamic losses for exporting firms on markets that exhibit hysteresis on the supply side. Our indicator aims to quantify dynamic losses caused by sunk adjustment costs in case of exchange rate fluctuations. While the standard procedure in welfare analysis is to compare two equilibria, we focus on welfare effects that take place during dynamics. We analyze negative dynamic effects on producers' income that are generated due to writing off sunk adjustment costs. As an example, we investigate Italian wine exports to the United States over the period 1995–2013. After testing for hysteresis on the market, we present the indicator of hysteresis losses. It captures a continuous increase of dynamic losses during the period 2003–2008. Moreover, over-proportionately large hysteresis losses are generated in comparison to the exchange rate changes if the pain threshold of the exchange rate (ca. 1.25$/€) is passed.

Keywords: Dynamic Welfare Losses, Play-Hysteresis, Adjustment Costs, Exchange Rate Effects

1. INTRODUCTION

The events of recent years have made the world economy extremely uncertain. In consequence of various crises (both political and economic), wars and terror, the world markets became unstable and the world trade stagnated. The higher global uncertainty directly influences decision-making processes of worldwide operating (exporting) firms in form of, e.g., exchange rate fluctuations. As an example, the $/€-exchange rate has fluctuated between 0.89 and 1.66 since the introduction of the euro, resulting in high losses of exporters or even in their market exits. This kind of uncertainty incentivizes exporting firms to be more cautious in their decision making and to practice so-called "wait-and-see" strategies. These are associated with two different trigger values of the exchange rate: a favorable

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exchange rate change passing the so-called entry (or expansion) trigger results in firm's entry into the export market (or increase in its sales volume), and an opposite scenario which leads to passing the firm's exit (or reduction) threshold and thus, to its exit from the export market (or reduction of own exports). The interval between those exchange rate trigger values, that are individual for each firm due to individual cost structures, is called the "band of inaction." Modeling of economic activity of exporting firms, especially on markets with high barriers to entry and exit, might be more appropriate using a dynamic framework that takes the firm's economic past into account in order to determine the right current equilibrium. In many cases, firms must incur sunk costs to enter new markets, e.g., for gathering information on the new market and for market research, setting up distribution and service networks, for advertising or establishing a brand name, or for hiring new workers and building of firm-specific human capital, etc. Since these entry investments are firm specific, the firms cannot recoup these costs if they exit. Analogously, a market exit results in exit costs, e.g., for severance payments for fired employees if the production is stopped. These sunk entry and exit costs together with uncertainty result in a path-dependent behavior of firms, which is called "sunk cost hysteresis" [see Baldwin (1989), Baldwin and Krugman (1989), Dixit and Pindyck (1994), Borgersen and Göcke (2007)].[1] This specific type of hysteresis that occurs on the supply side of the market is what we focus on in our paper and we build our hysteresis losses indicator based on the idea of the sunk adjustment costs. However, supply hysteresis may also be caused by other factors, e.g., learning-by-doing that is associated with the reduction of production or intersectoral factor reallocation costs [see Steger (2007)]. Hysteresis may also occur on the demand side being caused by, e.g., demand carry-over effects that result due to imperfectly informed consumers. These effects are associated with experience after consuming goods the consumer did not try before. As a result, the consumer will be willing to pay more for such an experienced good [see Baldwin (1990)]. The analysis of the associated hysteresis losses caused by these other origins of hysteresis requires a modification of our model which is out of scope of this paper.

In addition to comparative statics, which is the standard procedure in welfare analysis, the income effects that take place during dynamics become more and more important in the context of the dynamic world. The main contribution of this study is the introduction of a new income effect measure—the hysteresis losses indicator, which quantifies dynamic losses of exporting firms on markets that exhibit hysteresis on the supply side. The indicator attempts to proportionally quantify dynamic losses caused by sunk adjustment costs in case of a positive exchange rate change, which is an appreciation of the home currency. More precisely, we analyze negative dynamic effects on producers' income that are generated due to writing off sunk adjustment costs. In contrast to Göcke and Matulaityte (2015), who provide first theoretical insights to sunk cost hysteresis losses in economics based on the Preisach model, our hysteresis losses indicator is based on the play-algorithm, which is a linearized form of the Preisach-hysteresis model and was proposed by Belke and Göcke (2001) in order to empirically identify hysteresis on particular markets. In addition, the hysteresis losses indicator enables us to investigate hysteresis losses empirically.

Since hysteresis effects are an empirically proven phenomenon in economics [see, e.g., Belke and Göcke (2001), Kannebley (2008), Piscitelli et al. (1999, 2000), Hallett and Piscitelli (2002), Mota and Vasconcelos (2012), Mota et al. (2012), Prince and Kannebley (2013), Belke et al. (2013, 2014)], the consequences in terms of economic hysteresis losses resulting from exchange rate fluctuations are a relevant question. As an example, we investigate Italian wine exports to the United States. Italy is one of the largest wine producers worldwide. The shrinking home wine consumption incentivizes Italian wine producers to search for consumers abroad and meanwhile they export ca. 40% of their whole production [see Anderson and Nelge (2011)], whereas more than half of all wine exports (about 22%) went to the United States in 2014 [see IWC (2016)]. Moreover, Italy is confirmed to be the leading wine supplier in the United States in 2012 [see Gusti d'Italia (2016)]. Since wine production is associated with high sunk investments and exporting to the United States with exchange rate uncertainty and much effort due to many legal restrictions [different for every state, see, e.g., Beliveau and Rouse (2010)], hysteresis can be expected on the supply side of this market.

We replicate the results of Werner (2016)[2], proving the existence of hysteresis empirically for the sample over 1995–2013. Next, we calculate the indicator of hysteresis losses that shows a continuous increase in hysteresis losses in the time span 2003–2008. Moreover, we observe disproportionately large hysteresis losses in comparison to the exchange rate changes, especially over the quarters 2004Q3–2005Q1.

The paper is organized as follows: In Section 2, the concept of hysteresis is explained. Section 3 deals with hysteresis losses and interprets them graphically. Section 4 introduces the hysteresis losses indicator based on the linearized hysteresis model and compares its values with those in a nonlinear hysteresis model. In Section 5, the empirical analysis is presented and in Section 6, the results are discussed. Section 7 concludes.

2. CONCEPT OF HYSTERESIS IN FOREIGN TRADE

2.1. Hysteresis on Microlevel

First, the simplest form of hysteresis called "non-ideal-relay" [Krasnosel'skii and Pokrovskii (1989, p. 263)] is considered. In international trade, this hysteresis phenomenon occurs due to sunk entry and exit costs [see Baldwin (1989), Baldwin (1990)] inducing a "band of inaction" (see Figure 1). A firm observes the development of a forcing variable and does not change its economic behavior—, i.e., its state of market (in)activity—until the forcing variable changes significantly and passes certain trigger values, specific to each heterogeneous firm. In our special case of international trade, the forcing variable is represented by the exchange rate

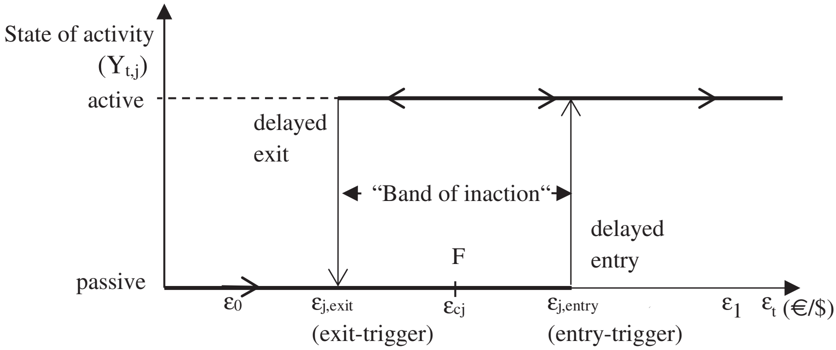

FIGURE 1. Non-ideal-relay with one-period optimization. Source: Own representation according to Belke and Göcke (2001).

in direct quotation (e.g., €/$ for an exporter which is an European Currency Union (ECU) member). A firm delays its entry and exit due to sunk entry and exit costs, which is amplified by an uncertain future exchange rate development. Moreover, once the economic behavior of an exporting firm j has changed (due to large past exchange rate changes or many small changes of the same direction), it will not completely go back to the initial state, even if the exchange rate returns to its initial level [see Göcke (2002, p. 168)].

Figure 1 illustrates the decision process of an exporting firm j which can be described as a "non-ideal relay" [see Belke and Göcke (1999, p. 266)]. For reasons of simplicity, we assume that one firm exports one unit of just one sort of products. However, it is entirely possible that the economic behavior of one firm can be modeled using various nonideal relays in order to capture all products that are relevant for the exporter. The ordinate in Figure 1 captures the state of activity of firm j or its supply in the current period t ($Y_{t,\mathrm{j}}$). The abscissa reflects the real exchange rate in direct (price) quotation with respect to the home currency (ϵ_t), which directly and proportionally affects consumer prices on the sales market in case of exchange rate pass-through, or firms profit margin in case of local currency price stabilization (LCPS). A falling exchange rate means appreciation of the home currency and leads to a decreasing export activity of the firm. Depending on the size of sunk costs, the threshold value for an exit ($\epsilon_{j,\mathrm{exit}}$) is lower and the threshold value for an entry ($\epsilon_{j,\mathrm{entry}}$) is higher than the exchange rate value that covers the variable/unit costs ϵ_{cj} (see point F in Figure 1). If the value of the exchange rate varies between the entry/exit-thresholds ($\epsilon_{j,\mathrm{exit}} < \epsilon_t < \epsilon_{j,\mathrm{entry}}$), there are two potential equilibria (either active or passive). The currently valid equilibrium can only be determined if the state of activity in the previous period is known. There is a "band of inaction" between both triggers, since only a move outside this band, passing one of the triggers, will result in a switch in the state of activity. Thus, if the exchange rate varies within the "band of inaction," firm j remains in its state,

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which can be either active or passive. The "band of inaction" is the wider, the higher the sunk costs and the uncertainty are.[3]

For an illustration of the firm's decision making process, we use an example and consider the following exchange rate changes: $\epsilon_0 \rightarrow \epsilon_{cj} \rightarrow \epsilon_1 \rightarrow \epsilon_{cj} \rightarrow \epsilon_0$ (see Figure 1). In the initial situation, the exchange rate equals ϵ_0. This exchange rate value is unambiguously associated with the passive state of firm's activity or, to put it differently, the firm j is not exporting any goods due to the high value of the exchange rate leading to an expensive home production for the foreign consumers expressed in the foreign currency. In this situation, firm j cannot compete with other suppliers on the foreign market and is inactive. A higher exchange rate (lower value of the home currency with respect to the foreign currency) that takes, e.g., the value of ϵ_{cj}, guarantees covering the unit costs of firm j, however, does not cover the sunk entry investments required for the market entry. Consequently, an initially inactive firm stays inactive as long as both—the unit variable and the sunk entry investments—are not covered. The firm enters the market only if the exchange rate exceeds the entry trigger value ($\epsilon_{j,\text{entry}}$). Thus, a home currency depreciation up to ϵ_1 induces firm's entry into the market (see Figure 1). A subsequent appreciation of the home currency leading to a falling exchange rate back to the value ϵ_{cj} does not induce any changes in the firm's activity and the firm remains active. A further decrease in the forcing variable down to ϵ_0 passes the exit trigger, meaning that the loss from production is higher than the sunk exit costs. As a result, firm j shuts down, completing the entry-exit cycle and closing the microhysteresis loop. Therefore, sunk entry investments together with sunk exit costs have to be written off—hysteresis losses are generated. In contrast to Göcke and Matulaityte (2015), who analyzed the relationship between output and prices, we cannot argue that hysteresis losses are proportional to the area within the closed non-ideal-relay loop due to a different model specification. The two-dimensional graphical interpretation of hysteresis losses in an international trade framework requires a modification of the model and some additional assumptions, which is done in Section 3.

2.2. Hysteresis on Macrolevel

As stated above, every firm j has a specific cost structure, which implicates heterogeneity in entry and exit thresholds [every firm has an individual nonideal relay operator ($\mu_{j;\text{entry/exit}}$)]. In the mathematical Preisach aggregation procedure [see Preisach (1935), Cross (1993, pp.85), Mayergoyz (2003, pp. 1), Mayergoyz (2006, pp. 293)] the nonideal relay is the elementary hysteresis operator [Mayergoyz (1986, p.604)]. It illustrates a microelement of an aggregated macrosystem. Based on the Preisach procedure the export supply of heterogeneous firms can be aggregated using entry/exit-trigger diagrams [see, e.g., Amable et al. (1991)] and summing up firms entering or exiting the market due to a certain exchange rate change. The aggregated output corresponds to the number of active firms on the market.

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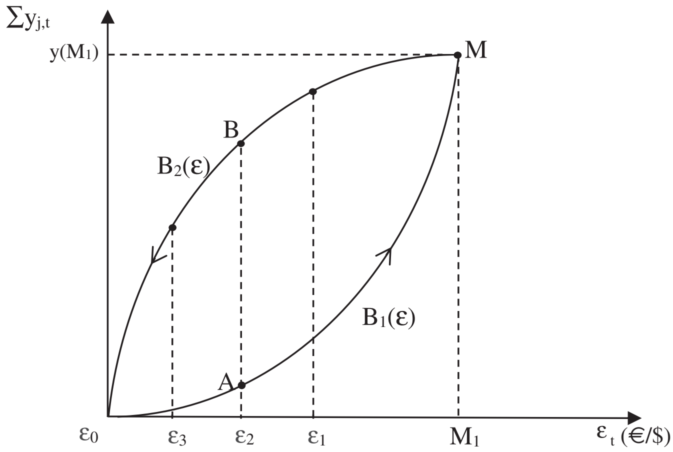

FIGURE 2. Aggregated hysteresis loop. Source: Own representation according to Göcke and Matulaityte (2015).

Figure 2 illustrates the aggregated output depending on the following exchange rate changes: heavy euro depreciation ($\epsilon_0 \rightarrow M_1$) and a following continuous euro appreciation ($M_1 \rightarrow \epsilon_1 \rightarrow \epsilon_2 \rightarrow \epsilon_3 \rightarrow \epsilon_0$), leading to an initial situation in the origin of the coordinate system (ϵ_0; 0). This special example generates a complete (closed) macrohysteresis loop. Every closed hysteresis loop has the form of a lens and consists of an upward [$B_1(\epsilon)$] and a downward leading [$B_2(\epsilon)$] branch (see Figure 2). The upward leading branch captures the positive quantitative effects of a depreciating home currency ($\epsilon_0 \rightarrow M_1$) leading to more market entries of firms. The downward leading branch captures the negative impact of the subsequent home currency appreciation ($M_1 \rightarrow \epsilon_1 \rightarrow \epsilon_2 \rightarrow \epsilon_3 \rightarrow \epsilon_0$).[4] The decreasing level of output means that more and more firms exit the export market.

However, if the initial situation is not located in the origin of the coordinate system but, e.g., in point A, which is located on the upward leading branch, euro depreciation up to M_1 and a subsequent appreciation back to ϵ_2 would not generate a closed hysteresis loop. The output level would be situated in point B, which is located on the downward leading branch. The latter example illustrates the remanence property of hysteresis, showing a positive permanent effect on output. In order to reach the initial output level in A, the system must attain the concrete branch $B_1(\epsilon)$. This is only possible, if euro appreciates down to ϵ_0 and then depreciates up to ϵ_2.

3. HYSTERESIS LOSSES

3.1. Microeconomic Hysteresis Losses

Hysteresis losses are the dynamic losses that are generated due to the hysteretic behavior of a firm after it has left the market. The hysteretic behavior results due to the sunk entry and exit costs.[5] After the firm enters the market, the sunk entry costs are treated as an investment. Further sunk costs have to be paid in case of a following market exit. All sunk costs have then to be written off and thus, are lost. These lost sunk costs are called microeconomic hysteresis losses and they can only be generated when the firm shuts down.

Microeconomic and macroeconomic hysteresis losses are theoretically modeled by Göcke and Matulaityte (2015) for the general *price-output* model. In contrast to our international trade models illustrated in Figures 1 and 2, the dependent variable of the general model is the aggregated output and the forcing variable is the price level. The authors show that hysteresis losses are proportional or even equal to the area inside the particular hysteresis loop/lens depending on the assumptions made in the model, e.g., optimization horizon, variability of the interest rates and uncertainty level. Only in the model with heterogeneous firms that are uniformly distributed in the entry-exit-diagram, with one-period optimization, constant interest rates, and without explicit modeling of uncertainty hysteresis losses are equal to the area inside the hysteresis loop. Relaxing the assumptions leads to the following deviations in regard to our benchmark model: inclusion of additional uncertainty lowers hysteresis losses due to the option value of waiting and the extension of the optimization horizon increases the losses which are positively related to the interest rate in this model. Although the introduction of uncertainty indicates additive effects leading to microhysteresis losses that are not even proportional to the area inside the closed non-ideal-relay loop, the macrohysteresis losses in both cases remain proportional to the area inside the hysteresis loop [see Göcke and Matulaityte (2015)].

The producer price that triggers firm's entry into the market consists of the sum of its unit variable and its unit sunk costs. The exit price trigger can be quantified as the difference between the firm's unit variable and unit exit costs. Only in this constellation of the model the area inside the simplest non-ideal-relay can be interpreted as hysteresis loss of firm j [see Figure 3(a)]. We build on this and change the perspective of firm j considering it as an exporting firm. However, in order to consider the relevant measurements, we stay close to the original price-output model. For example, firm j is based in one of the euro-zone member countries (e.g., Italy) and exports its products (e.g., wine) to the United States. In order to convert the prices in both currency systems, we use the exchange rate, which is as previously quantified in direct quotation with respect to the home currency (€/$). The trigger values are denominated in euro because this is the home currency of firm j and we assume that all its costs have to be paid in euro.

Thus, the first step of firm's j decision making process can be illustrated in Figure 3(a). For reasons of simplicity, we assume that the prices in euro depend only on prices in dollar and the exchange rates. Consequently, a certain entry or exit price trigger, denominated in euro ($P_{j,\text{trigger}}$), represents different combinations of prices in Dollar (P^*) and exchange rate values (ε) in (€/$):

$$P_{j,\text{trigger}} = P^* \cdot \varepsilon_{j,\text{trigger}}. \quad (1)$$

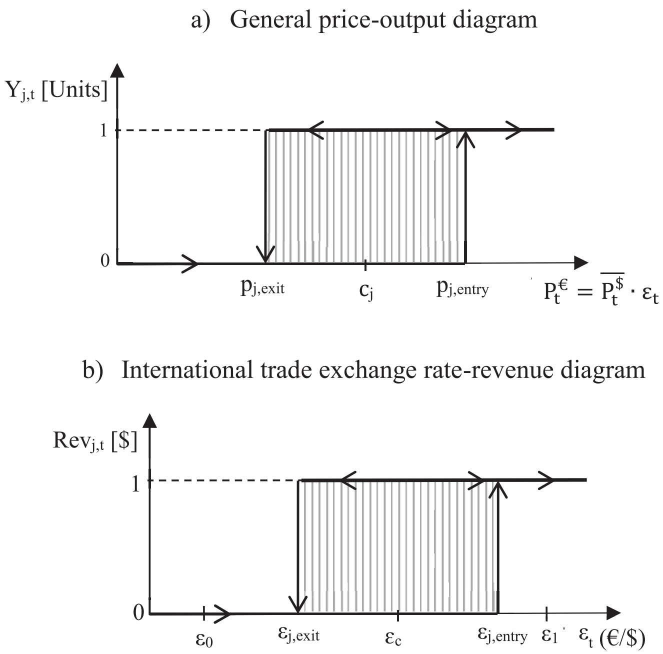

FIGURE 3. General and the special case of international trade in nonideal relay model.

In the next step, we assume that firm j uses a pricing-to-market (PTM) strategy and practices LCPS. To be more precise, it sets and maintains its export price in dollar instead of adjusting the price according to the exchange rate [see Krugman (1986)], e.g., in order to keep its market share. This assumption allows us to keep dollar-prices constant ($\bar{P}^*$) and to graphically analyze the hysteresis losses in international trade using only two dimensions. As a consequence, market entry and exit of an exporting firm j depend only on the exchange rate values:

$$P_{j,\text{entry}} = \bar{P}^* \cdot \varepsilon_{j,\text{entry}}, \tag{2}$$

$$P_{j,\text{exit}} = \bar{P}^* \cdot \varepsilon_{j,\text{exit}}. \tag{3}$$

Göcke and Matulaityte (2015) showed that the hysteresis loss (H_j) of firm j corresponds to the area inside the closed hysteresis loop in the nonideal relay model with price on the abscissa and output on the ordinate [see Figure 3(a)]. Therefore, we can calculate the hysteresis loss, denominated in euro, as follows:

$$H_j = \Delta Y_{j,t} \cdot \left(P_{j,\text{entry}} - P_{j,\text{exit}}\right). \tag{4}$$

Combining equations (2), (3), and (4), the hysteresis loss can be formalized in the following way:

$$H_j = \left(\Delta Y_{j,t} \cdot \ \bar{P}^*\right) \cdot \left(\varepsilon_{j,\text{entry}} - \varepsilon_{j,\text{exit}}\right). \tag{5}$$

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According to equation (5), the hysteresis loss is a product of firms revenue in dollar and the difference between the exchange rate trigger values in €/$. As a result, hysteresis losses can be illustrated in the exchange rate-revenue diagram as shown in Figure 3(b) if we additionally normalize the constant dollar-prices to unity. In contrast to the general case with price as forcing and physical output quantity as dependent variable, the model of international trade uses the exchange rate as forcing and the revenues as dependent variable. The aggregation procedure of this special case of international trade is analogous to the one in the general model presented in Section 2.2.

The relationship between exports and exchange rates in the context of hysteresis losses can also be illustrated using the exchange rate in indirect quotation $/€ and revenues in €. In this case, hysteresis losses would be denominated in $. We use this way of modeling in the empirical part in Section 5.

3.2. Macroeconomic Hysteresis Losses

Hysteresis losses are only generated after a euro depreciation, which induces increasing export activity associated with sunk market entry/expansion costs, and a subsequent euro appreciation that leads to a reduced or stopped export activity associated with sunk exit/reduction costs. In the end, the sunk entry and exit costs have to be written off and they represent the hysteresis losses. In order to determine hysteresis losses graphically a closed hysteresis loop must be generated, as illustrated in Figure 4. As it was shown in Section 2.2, the loop might not necessarily be closed naturally, even if after a shock the exchange rate comes back to its initial level (see Figure 2). Therefore, in such cases, we have to close the loop artificially and this can be done by adding an upward leading fictitious loop that leads back to the local output maximum, e.g., in point M (see Figure 4). By doing so, fictitious inner loops (lenses) can be generated for every potential price decrease in euro, which is per assumption proportional to the euro appreciation. If the assumption that the dollar price equals one still holds, H_1 is the lens capturing the hysteresis loss in case of a euro appreciation from M_1 to ϵ_1, H_2 represents the lens of the hysteresis loss after euro appreciation to ϵ_2 and H_3 captures the hysteresis loss resulting from the euro appreciation to ϵ_3. If the exchange rate falls completely back to ϵ_0, the whole area inside the outer maximum loop captures the hysteresis loss of the complete exchange rate cycle: $\epsilon_0 \to M_1 \to \epsilon_0$.

As Figure 4 suggests, the size of this loss, which is a cubic function of the exchange rate variation, is increasing by degree 3, if we assume a uniform distribution of firms in the entry/exit-diagram used for the aggregation, i.e., doubling (or tripling) the size of an exchange rate cycle ($\epsilon_n \to M_1 \to \epsilon_n$) results in an increase of the generated hysteresis loss by factor 8 (or 27). As in the microeconomic model, the graphical interpretation of hysteresis losses depends on the assumptions of the model. Among the assumptions made on the microeconomic level, the following assumptions are made in the macroeconomic model in order to be able to calculate the hysteresis losses precisely as a benchmark: the exporting firms are

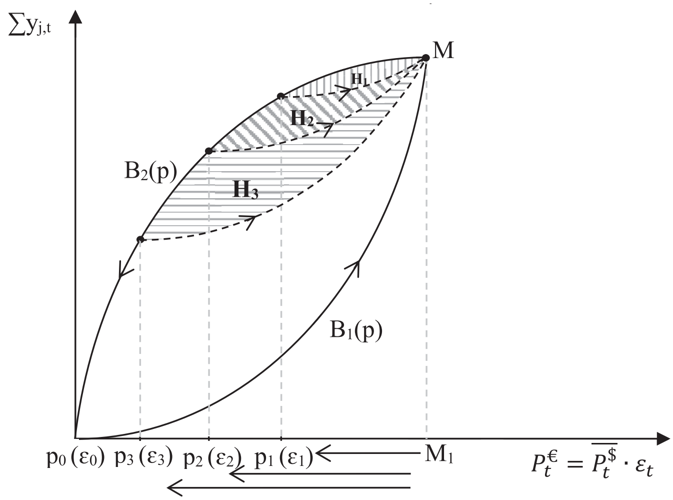

FIGURE 4. Hysteresis losses generated by different exchange rate changes in the Preisach model. Source: Own representation according to Göcke and Matulaityte (2015).

heterogeneous, the distribution of the firms in the entry/exit-diagram is uniform and the interest rate is constant. If we account for multiperiod optimization, the hysteresis loss turns out to be larger than the area inside the hysteresis loop because of the interest costs on the sunk adjustment costs. In contrast to that, the explicit modeling of uncertainty might lead to lower hysteresis losses because of the option value of waiting [see Göcke and Matulaityte (2015)]. Under uncertainty the firms make more cautious decisions (they wait longer) and therefore, less market exits can be observed if the band of inaction is widened. A decrease in uncertainty leads either to a narrower band of inaction or to a shift of it. In case of narrower band of inaction more entries and exits result due to lower entry and higher exit triggers if the exchange rate fluctuates as before. In the context of a shift of the band of inaction, e.g., if the foresight of the exchange rate expectation rises, we have to differentiate between positive and negative expectations with regard to the exchange rate development.

On the one hand, if the exporters expect a long-lasting depreciation of the home currency the band of inaction would shift to the left for example. The individual entry thresholds decrease and exporters may enter the market even if they cannot cover the sunk entry costs. If the expectations about the exchange rate development hold true, no firms will exit the market and therefore, no hysteresis losses will be generated. If however, the exchange rate development does not meet the expectations, the hysteresis losses depend on the behavior of the firms. They could adjust their expectations and shift the exit trigger to the right. Therefore, more firms would probably exit the market. As a result, hysteresis losses would rise. In addition, due to wrong expectations and too low entry triggers even inefficient

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firms would have had entered the market leading to more hysteresis losses in case of their market exits.

On the other hand, if the exporters expect a long-lasting appreciation of the home currency, the band of inaction would be shifted to the right. As above, the effects on the hysteresis losses depend on many factors: the actual exchange rate development, the individual trigger values, their degree of adjustment to the expectations and the resulting shifts in the individual trigger values.

The effects of expectations on the threshold values are ambiguous and cannot be determined without further research due to the complexity of this issue and possible asymmetric effects on the triggers. Furthermore, the exchange rate could start fluctuating after the firms have entered the market. We could differentiate between strong and weak exchange rate fluctuation scenarios that would again lead to ambiguous outcomes.[6]

Changing the distribution of the firms in the entry/exit-diagram or considering payments in foreign currency indicates changes in the form of the macroeconomic hysteresis loop, meaning that the branches of the hysteresis loop are not quadratic functions anymore. The higher the power of the branch-function is, the higher are the hysteresis losses.[7] Since in all these cases the macroeconomic hysteresis losses remain proportional to the area inside the macrohysteresis loop, the latter remains an important measurement of dynamic adjustment effects on producer's income.

In order to simplify the macrohysteresis approach and to make it feasible for empirical analysis, Belke and Göcke (2001) worked out a linear approximation of the macroeconomic hysteresis dynamics capturing strong and weak economic reactions, the so-called play-hysteresis. Figure 5 illustrates a geometric interpretation of play-hysteresis with a constant play width. Comparing Figures 4 and 5 helps to capture the idea of Belke and Göcke. Starting in point M in Figure 4, an appreciation of the exchange rate reduces the output along the downward-leading branch $B_2(p)$. During the first part of this decline, e.g., $[M_1 \rightarrow p_1(\epsilon_1)]$ the slope of the downward-leading branch $B_2(p)$ is gentle, whereas during the second part of the decline $[p_1(\epsilon_1) \rightarrow p_0(\epsilon_0)]$ the slope is steep. The gentle slope in the first section $[M_1 \rightarrow p_1(\epsilon_1)]$ reflects a moderate reaction of the output to the exchange rate reduction. Due to the physical/mechanical origin of the model, this section is called "play area." In Figure 5, the regarding equivalence is line $(A \rightarrow B)$. Similar to the band of inaction in the micromodel in Figure 1, it is characterized by none or just weak reactions of the output to movements in this interval $[\epsilon_{1,} M_1]$, i.e., using this play area, we simplify the model and ignore small inner loops like $H_{1.}$ The second part of the decline $[p_1(\epsilon_1) \rightarrow p_0(\epsilon_0)]$ shows a steeper slope. This part of the downward leading branch is summarized in the "spurt down" line in Figure 5. However, after reaching a local minimum value $[p_0(\epsilon_0)$ in Figure 4 and ϵ_4 in Figure 5, respectively] a rising exchange rate causes an increase in output. This increase is at first moderate; therefore, the play-hysteresis model captures it with a play area. After passing this interval, a strong reaction along the "spurt up" line takes place. Inner loops like, e.g., H_3 in Figure 4, are reported by smaller full loops,

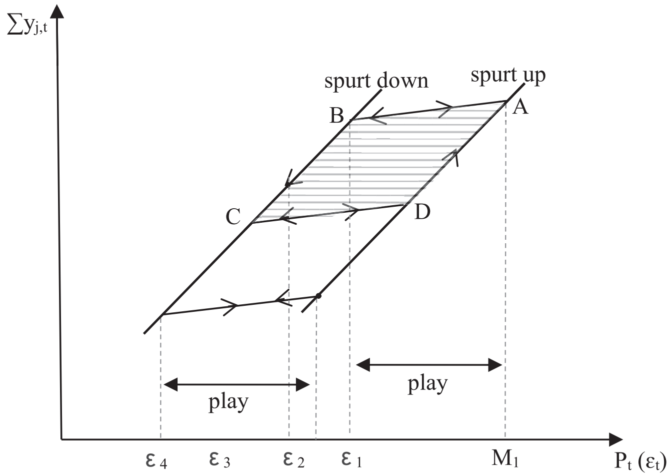

FIGURE 5. Play-hysteresis: linear spurt lines and constant play. Source: Own representation according to Belke and Göcke (2001).

that means, the shaded area in Figure 5 corresponds to H_3 in Figure 4. These inner loops are also characterized by a division where the first part triggers only weak reactions of the output, whereas the second part has a strong effect on output. This division is depicted in Figure 5 by the lines ($C \rightarrow D$) and ($D \rightarrow A$). Therefore, the spurt up and spurt down lines in Figure 5 are fixed, whereas a new play line occurs at every differing turning point of the spurt up and spurt down lines. Based on play-hysteresis, an algorithm was developed, that describes the play and the corresponding switches between the areas due to changes in the forcing variable. This allows an empirical investigation of hysteretic systems by implementing it in a regression framework [see Belke and Göcke (2001)].

The idea of the play-algorithm is to describe the behavior of the system if there is hysteresis induced by the input variable. Therefore, a new variable, called Spurt is created by the algorithm. If the initial point is, e.g., in a maximum of the input variable, corresponding to point *A* in Figure 5, and the input decreases, only weak reactions of output to this decrease will take place because only few exporters change their export participation. These are the exporters who have nonideal relays with high exit triggers [see Figure 3(b)]. If the input variable further decreases and passes the “bands of inaction” of several firms, which is represented by the aggregated band of inaction called play in Figure 5, a strong reaction will follow because more and more exporters will exit the market. As long as the exchange rate declines, this strong reaction will continue until the exchange rate starts to increase once more. At this switching point, point *C* in Figure 5, the system will change its direction and the output will start to increase. However, as long as the exchange rate is in the range “value at point *C* plus the width of the play area,” no or just few reactions of exporters are expected. As soon as this range is passed

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at point D in Figure 5, the system penetrates the upward leading spurt line and reacts strongly to even moderate euro depreciations.

The play-algorithm of Belke and Göcke (2001) starts with the assumption of a fixed play width that corresponds to the assumption that the position of the spurt up and spurt down lines is fixed, see Figure 5. The procedure of building the Spurt variable begins in a maximum or minimum of the input variable, e.g., points A or C in Figure 5, and investigates how the reaction would be if the input variable behaved as described above. That is, e. g., when starting in the maximum point A, there is no reaction expected as long as the exchange value is in the range "start value in point A minus play width." As soon as the exchange rate value is less than this in ϵ_1, the Spurt variable follows exactly the decline of the exchange rate until a minimum is reached. The following increase of the exchange rate is depicted in the Spurt just as a flat line as long as the exchange rate is within the band of inaction. If the exchange rate value exceeds "minimum value plus play width" the Spurt reflects the input variable again. Therefore, the generation of the spurt variable needs many case differentiations; the code can be found in Belke and Göcke (2001).

After creating this Spurt variable, which can be seen as a filtered exchange rate, it is tested if this variable is able to improve the regression framework, which reflects the trade model (see Section 5.2). This process is done for many possible play widths and the one with the best explaining power in the regression is reported.

4. HYSTERESIS LOSSES INDICATOR

In the following, we address the problem of how to quantify hysteresis losses in the linear play-hysteresis model by expanding the play-algorithm [see Belke and Göcke (2001)].

The aggregation of hysteresis losses over heterogeneous firms has shown that these dynamic losses are proportional to the area inside the closed lens-formed hysteresis loop [see Göcke and Matulaityte (2015)]. The area inside the trapezoid that linearizes the lens-formed hysteresis curve (see Figure 5) represents an approximation of the area within the corresponding hysteresis loop (see Figure 4). Consequently, using the same logic as Göcke and Matulaityte (2015), we argue that hysteresis losses are also proportional to the area inside a trapezoid (see Figure 5). Since the play area reflects the aggregated bands of inaction (see Figure 1), associated with no reactions of individual firms, no hysteresis losses are generated if exchange rate changes take place in the play area. The same result comes out if we observe favorable exchange rate changes (depreciation of the home currency) in the upward-leading spurt area, which captures firms entering the market. Only the appreciation of the home currency results in hysteresis losses because it leads to a market exit of individual firms, which, on the macrolevel, is captured by the downward-leading spurt. Consequently, two conditions must be fulfilled in order to generate hysteresis losses: exchange rate changes must be negative (meaning appreciation of the home currency) and they (or a part of them) have to take place in the downward-leading spurt area (see Figure 5).

The calculation of hysteresis losses (ΔH_t) in the play-hysteresis model in period t is done according to the following equation:

$$\Delta H_t = \frac{d}{\cos\left[\arctan\left(\alpha\right)\right]} \cdot \sqrt{\Delta y_t^2 + \left(-\Delta s_t^2\right)} \cdot \sin\left[\arctan\left(\alpha + \beta\right) - \arctan\left(\alpha\right)\right]. \quad \mathbf{(6)}$$

Here, d denotes the constant play width, α and $\alpha + \beta$ are the slopes of the play and spurt lines respectively, Δy_t is the output change in comparison to the last period and Δs_t denotes negative exchange rate changes in period t with movements in the spurt-down area, e.g., exchange rate changes $\epsilon_1 \rightarrow \epsilon_2 \rightarrow \epsilon_3 \rightarrow \epsilon_4$ in Figure 5. The function for cumulated hysteresis losses takes the following form:

$$\Delta H_t = \begin{cases} \Delta H_t, \text{ if } H_{t-1} = 0 \text{ and } \Delta s_t > 0 \\ H_{t-1} + \Delta H_t, \text{ if } H_{t-1} > 0 \text{ and } \Delta s_t,\ \Delta s_{t-1} > 0 \text{ and } \varepsilon_t > \varepsilon_{t-1} \\ 0, \text{ if else.} \end{cases} \quad \mathbf{(7)}$$

Thus, in case that the exchange rate was increasing in previous periods leading to more exports and zero dynamic losses, an exchange rate decrease in period t results in hysteresis losses generated only in the current period (ΔH_t). If, however, the exchange rate change was negative in the previous period, leading to some hysteresis losses (H_{t-1}), and it keeps decreasing in period t, we cumulate the losses of both periods. In the end, we can calculate hysteresis losses for the whole time span in which the exchange rate was decreasing or moving in the play area. If the exchange rate development changes its direction, crosses the play, and penetrates the spurt-up area, no hysteresis losses are generated and the losses indicator takes the value of zero.

Figure 6 illustrates overestimation and underestimation areas of the hysteresis losses indicator due to the approximation of the curved Preisach-loops by the angular-loops of the play-hysteresis model. It captures the relationship between hysteresis losses and the extent of the exchange rate change (corresponds to its decrease). The dashed curve schematically captures the hysteresis losses as, e.g., area ABCD in the play-hysteresis model (see Figure 5) and the solid curve represents the losses as an area in the Preisach model as illustrated in Figure 2. Since the lens-formed hysteresis curve is considered to illustrate the more appropriate dynamics of the system (with a certain distribution of firms in the entry/exit-diagram) and play-hysteresis is the linear approximation of this hysteresis curve, we can capture some intervals of overestimation and underestimation of hysteresis losses. If the exchange rate is in a local maximum M_1 and starts falling (see Figures 4 and 5), there is no or just a little reaction of the system according to the play-hysteresis model, since exchange rate changes take place in the play area ($M_1 \rightarrow \epsilon_1$) in which no hysteresis losses are generated. In contrast to this, the lens-formed hysteresis curve shows some negative output reaction leading to hysteresis losses by the extent of area H_1. Thus, in this interval our indicator underestimates the dynamic

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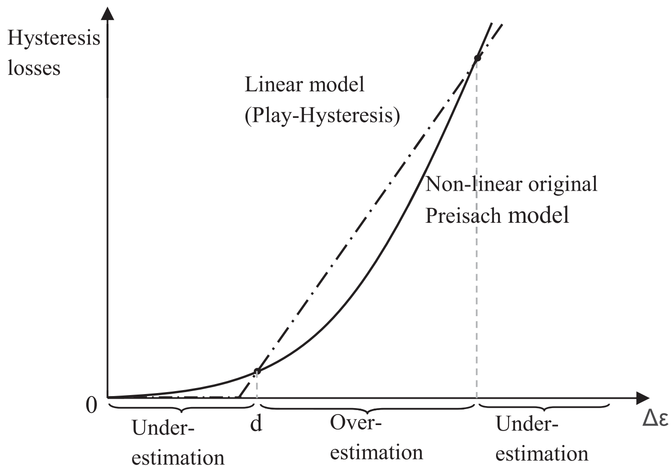

FIGURE 6. Areas of over estimation and underestimation of play-hysteresis in comparison to a nonlinear original Preisach model.

losses. After penetrating the spurt down area ($\Delta\epsilon > d$), we slightly overestimate the losses. If, however, negative exchange rate changes are of a very large extent, the area within the lens becomes larger than the area in the play-hysteresis trapezoid. This, again, leads to an underestimation of hysteresis losses. By interpreting the values of the indicator we are able to recognize the intervals illustrated in Figure 6, since the width of the play area can be estimated using the play-algorithm. However, due to the fact that some determinants of hysteresis cannot be measured (e.g., level of uncertainty), the calculated hysteresis losses in both models can only be interpreted as indicators.

The main point of criticism regarding the hysteresis losses indicator could be the fact that the hysteresis losses can only be interpreted as negative welfare effects if we assume that the level of uncertainty as well as the risk-free interest rate does not vary over time, which is quite unrealistic. Changes in uncertainty and/or interest rates shift the entry and exit triggers of individual firms leading to changes in the width of their band of inaction or its location. On the macrolevel these microeconomic changes induce modifications in the location and curvature of the hysteresis loops and result in quantitatively different areas inside the hysteresis loops.

5. EMPIRICAL ANALYSIS

5.1. Data and Motivation

As an example for an empirical application of the hysteresis indicator, we investigate Italian wine exports to the United States. Our market choice is based on many factors: First of all, we are interested in markets that exhibit hysteresis on

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the supply side. Agricultural and commodity markets are typically associated with relatively high sunk adjustment costs (in form of investments and disinvestments) that producers have to face after the shocks. Therefore, we expect the suppliers on these markets to behave hysteretically. Being an agricultural good, wine was qualified for our estimation. Second, we chose a market, which is important due to its high volume of sales. According to Eurostat, in 2008, Italy was the largest wine producer worldwide by volume (ca. 46 M hl per year).[8] Approximately 40% of the whole Italian wine production is exported, whereby more than half of all exports go to the United States [see IWC (2016)]. On top of that, Italy is confirmed in 2012 to be the leading wine supplier in the United States [see Gusti d'Italia (2016)].

For our estimation, we use three time series: Italian wine exports to the United States denoted in current euro and deflated by the export price deflator; real United States gross domestic product (US GDP) in Mill. euro, converted on basis of the exchange rate from the year 2000 and real $/€-spot exchange rates as monthly averages. All data are aggregated on quarterly basis for two reasons: First, the monthly data are not available for all variables, and the interpolation of economic data is quite problematic. Second, quarterly data are used due to the lower likeliness of a measuring error. According to Canova and De Nicolo (1995), the likeliness of a measuring error would be much higher if we used monthly data. The first two time series are seasonally and work day adjusted, and taken from the Eurostat database [Eurostat (2015a)]. Exchange rate time series stem from the USDA (2014). All three time series are integrated of order one. The US GDP and the Italian wine export time series (representing US Italian wine imports) are cointegrated. For the regression analysis, we do not transform the data and estimate them in levels because otherwise the interpretation of the results would be problematic. Our sample ranges from 1995Q1 to 2013Q3. Figure A.1 in the appendix gives an overview about the volume and the development in time of the following time series: Italian wine exports to the United States and the US GDP during the time span 1991–2014.

5.2. Methods

The calculation of the hysteresis losses indicator underlies a two-step procedure: at first we test if the market that we are interested in exhibits hysteresis. If this is the case, hysteresis losses become relevant—we calculate the hysteresis losses indicator using certain estimated parameters from the first step (the estimated slopes of the play, α, and spurt lines, $\alpha + \beta$). For our purpose, we prefer a method that describes the path-dependence of the system and is based on "strong"/macrohysteresis. There are just two of them so far—the Preisach model [see Piscitelli et al. (2000)]—and the already mentioned play-algorithm [see Belke and Göcke (2001)].[9] In this paper, we choose the second approach in order to be consistent with the logic of the indicator construction.

In order to test the hysteresis hypothesis, we run the following ordinary least square (OLS) equations:

$$\mathrm{EX}_t = \mathrm{Cons} + \alpha \cdot \mathrm{RER}_t + \gamma \cdot Z_t + \epsilon_{1,t}, \quad (8)$$

$$\mathrm{EX}_t = \mathrm{Cons} + \alpha \cdot \mathrm{RER}_t + \beta \cdot \mathrm{SPURT}_t\,(d) + \gamma \cdot Z_t + \epsilon_{2,t}. \quad (9)$$

The regression specification is kept simple and includes the following variables: Italian wine export values in euro as the dependent variable (EX_t), the real \$/€-exchange rate (RER_t), other explanatory variables, summarized in vector Z_t, and the error term $\epsilon_{1,t}$. Z_t includes the US GDP as a measure for the market demand with one lag (GDP_{t-1}) in order to avoid reverse causality, a trend variable (Trend_t) and seasonal dummies for the first three quarters (D_1, D_2, D_3). From the regression in equation (8), we expect the US GDP to have a positive and the exchange rate to have a negative impact on the export values. Equation (9) contains an additional SPURT variable, which is generated by the play-algorithm. It captures only large changes of the exchange rate leading to output reactions, thus, the small exchange rate changes (movements in the play area d) are filtered out. Calculation of the most appropriate play width is made in the following way: based on the exchange rate time series, we define the interval which probably entails the appropriate play width (d). The algorithm identifies the switching points (e.g., A, B, C, or D in Figure 5) and generates the SPURT variable for each play width from the defined interval. We assume that the most appropriate play width is associated with the maximum R^2 of the regression specified as described in equation (9) as in Belke et al. (2013).

In order to find out if the Italian wine export market in the United States exhibits hysteresis, we test the null hypothesis (H_0: $\beta = 0$) against the alternative (H_1: $\beta \neq 0$). Rejecting the null hypotheses means that the SPURT variable significantly contributes to the explanation of the export variability. On top of that, we compare the estimation results of equations (8) and (9) to be sure that equation (9) produces the better fit than equation (8). From regression (9), we expect the US GDP to have a positive and the exchange rate to have a negative impact on the export values. The original exchange rate variable should become insignificant as the slope of the original exchange rate variables reflects the play (band of inaction) area. Moreover, the effects of the SPURT should be stronger than the ones of the exchange rate variable in regression (8). If hysteresis is identified, hysteresis losses become relevant and the hysteresis losses indicator is calculated as described in Section 4.

On the microlevel a modified nonideal relay model is considered in order to illustrate hysteresis losses in international trade. The developing procedure and differences between the general output-price model are pointed out in Section 3.1. Hysteresis losses are now proportional to the area inside the nonideal relay loop defining the relationship between export values in € (or revenues) and exchange rate in contrast to the theoretical model, in indirect quotation (\$/€). Positive exchange rate changes are associated with € appreciation against the \$

and consequently, with higher export prices denominated in \$. Developing the microeconomic model of hysteresis losses in international trade, a pricing-to-market (PTM) strategy of firms (in this example—Italian wine producers) was assumed (see Section 3.1) in order to simplify the model to the two-dimensional hysteresis approach. As a result, a euro appreciation can be interpreted as a decrease of the profit margins of the exporting firms. The use of this assumption is legitimate, since PTM of Italian exporting firms was empirically proved in several studies, e.g., Fedoseeva (2014) found PTM in agricultural exports of several European countries including Italy and Verheyen (2013) found exchange rate nonlinearities in European Monetary Union (EMU) exports to the United States. Especially Fertö and Balogh (2016) found PTM in Italian wine exports.

In order to check for robustness of the results, we used four approaches. First, we changed the specification of the regression and excluded the trend variable in a first step and the seasonal dummies and the trend in a second step. The estimation results can be found in Tables A.1–A.3, as well as in Figure A.2 in the appendix. Second, we tested for sensitivity of the results to small changes in the play width. In both approaches our results turned out to be robust. Third, we took some steps to validate the hysteresis identifying procedure and replaced the spurt variable by white noise. We executed a Monte Carlo simulation with 1,000 and 100,000 replications. In approximately 90% of the estimations, the coefficient of the white noise was insignificant meaning that no hysteresis was detected if we consider the 10% significance level. If, however, the underlying significance level is 1%, the white noise turns out to be insignificant in more than 99% of the cases. Finally, we addressed the issue of searching for the optimal SPURT variable associated with the highest R^2 of the regression. As before, we replaced the SPURT variable by white noise, and ran 80 replications (as in the R^2—search for the optimal SPURT). We selected the equation out of 80 with the highest R^2 and checked if the white noise is significant and if the other criteria for hysteresis are satisfied. We repeated this procedure 25 times. Although in most cases the white noise variable associated with the highest R^2 is statistically significant, the other criteria regarding the direction and the magnitude of the influence of the variables are not satisfied. Summarizing the outcomes of this test, we find evidence that our estimation procedure is able to differentiate between the spurt variable and the white noise.[10]

6. RESULTS

Table A.1 summarizes the results from the OLS regressions (see appendix). The first column of the table shows the results from the linear regression without the SPURT-variable. They meet our expectation: the exchange rate is highly significant and exerts a strongly negative influence on the exports. The influence of the US GDP is positive and significant. The second column summarizes the results of the regression with the SPURT-variable and here we have a completely different, however, expected and theory conform picture: the coefficient of the SPURT-variable (which is a filtered RER) is significant, negative, and higher in absolute values than the coefficient of the exchange rate variable in the first regression; the coefficient of US GDP is significant and positive again; the RER is no longer significant, since its coefficient represents only the slope of the play lines. Thus, the SPURT variable undertakes the explaining power and improves the value of the adjusted R^2 making the second regression statistically better. Therefore, we conclude that the Italian wine export market exhibits hysteresis and the wine exporters experience hysteresis losses in case of positive exchange rate changes. The same result was found by Werner (2016) using a different method of describing the path-dependence of the Italian wine exports to the United States.

According the annual vineyard surveys of the International Organisation of Vine and Wine (OIV 2014, 2015, 2016), the vineyards in Italy are shrinking from year to year. In 2003, there were 868 thousand hectares of vineyard, whereas in 2009 for example there were just 812 thousand hectares and 705 thousand hectares in 2013. In addition, the number of winegrowers in 2010 was smaller more than by half compared to the year 2000. All this is associated with market exits of many wine producers and thus, lost sunk (dis)investments that are relatively high in wine production. These facts support our results captured by the hysteresis losses indicator. It shows a continuous increase in losses in the time span from 2003Q1 to 2008Q1 captured by the dark gray curve in Figure 7. According to the OIV (2014, 2015, 2016), the area under wine-grape vines in production has contracted by about 6.5% during the years 2003–2009. The black line in Figure 7 represents the development of the \$/€ exchange rate. The time series of the artificial SPURT variable is captured by the light gray and hysteresis losses indicator by the dark gray line. During the whole sample we cumulate the hysteresis losses as described in equation (7). The exchange rate fluctuates during the whole estimation period. However, if we filter out the small fluctuations and consider only strong exchange rate changes leading to some reactions of the export volume (see development of the SPURT variable), the picture becomes quite simple. Following the light gray line in Figure 7, we can distinguish three periods: the period of predominantly negative exchange rate changes and nonnegative export reactions going from 1995Q1 to 2001Q4; the period of predominantly positive exchange rate development with heavy hysteresis losses during the time span from 2003Q1 to 2008Q2 and finally, the period of fluctuating but slightly negative exchange rate changes (depreciation of home currency) from 2008Q3 to the end of the sample. Only the period of predominantly positive exchange rate development is interesting for us, since we focus on negative dynamic losses caused by sunk adjustment costs and taking place due to positive exchange rate changes.

The shady parts of Figure 7 capture the three periods of increasing hysteresis losses: 2003Q1–2004Q1, 2004Q3–2005Q1, and 2007Q2–2008Q1. These periods are associated with the "pain (exit) thresholds" of exporting firms. As illustrated in Figure 5, the "pain threshold" is not a constant trigger level, but is path-dependent, since the play lines are vertically shifted by movements along the spurt lines [Belke et al. (2013)]. Figure 7 shows that despite the increasing exchange rate during the last quarters of the year 2002 the export volume is not changing—the

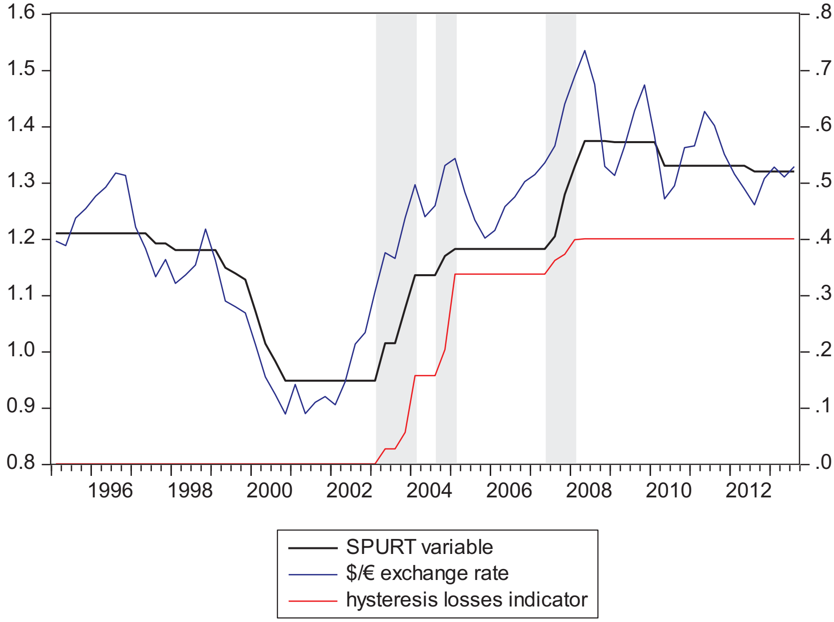

FIGURE 7. Hysteresis losses, exchange rate, and the SPURT variable.

SPURT runs horizontally meaning that the system moves in the play area (see Figure 5). Consequently, the hysteresis losses indicator has the value of 0 and slightly underestimates the dynamic losses of exporters (see Figure 6). The further on increasing exchange rate leaves the play area and penetrates the downward leading spurt in 2003Q1 passing the pain threshold of the least efficient exporters, corresponding to the exchange rate value of about 1.1$/€. These exporters have probably entered the market during the times of extremely low exchange rates (e.g., during the years 2000 and 2002) and made misleading forecasts concerning the exchange rate development, or even became very unproductive over the years. Until 2004Q1, the exchange rate increased by 0.2$/€ and accounted for increased hysteresis losses indicator by 0.15. The second period of hysteresis losses increase starts in 2004Q3 and ends in 2005Q1 leading to exit of high number of exporters and thus, to extremely heavy dynamic losses. A quite moderate exchange rate increase by 0.1$/€ (only half as large as the previous shock) this time induces over proportionally large increase in hysteresis losses indicator by 0.2 (which is by one-third larger than previous increase). The subsequent negative exchange rate changes starting in 2005Q1 lead to a horizontal run of the SPURT associated with exchange rate movements within the play area which can only be crossed in 2007Q2. Since the pain threshold of efficient firms is passed (corresponds to the exchange rate value 1.33$/€) further exits take place and additional losses are generated. However, the effect of this exchange rate increase is far from the extent

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of effects caused by the two previous periods of exchange rate increase. Summing up, a rising exchange rate corresponds to heavy hysteresis losses if the exchange rate has not yet reached an extremely high level (e.g., 1.35$/€ in our example) at which only the most productive firms (that is, firms with high exit threshold values) can survive on the market. Since such a level is reached only moderate hysteresis losses are generated.

However, despite of the long period of increasing exchange rate, shrinking vineyards and extremely decreasing number of winegrowers, the Italian wine export value rises during the whole sample. This could mean, e.g., higher wine prices due to lower consumption and/or higher quality [Mariani et al. (2012)].

7. CONCLUSIONS

The first and main contribution of this study is the introduction of a new welfare effect measure—the hysteresis losses indicator, which captures the dynamic losses of exporting firms on markets that exhibit hysteresis on the supply side. The new indicator describes dynamic losses caused by sunk adjustment costs in case of exchange rate appreciations. We analyzed negative dynamic effects on producers' welfare that are generated due to writing off the sunk adjustment costs. As an example, we investigated Italian wine exports to the United States.

As a first step, hysteretic dynamics of firm-level reactions based on one-period optimization was considered. Here, the hysteretic behavior of one exporting firm was explained according to the existing literature on hysteresis in economics [see Krasnosel'skii and Pokrovskii (1989), Baldwin (1989, 1990), Dixit (1990, 1992), Dixit and Pindyck (1994), Göcke (2002)]. Since the unit/marginal costs as well as sunk entry and exit (dis)investments are firm specific, for heterogeneous firms individual entry and exit exchange rate trigger values result, leading to a "non-ideal-relay" reaction pattern to exchange rate changes. The distance between these triggers constitutes the so-called "band of inaction" (see Figure 1). Considering that firms are heterogeneous, we presented the aggregated supply hysteresis loop of all heterogeneous firms related to exchange rate changes as an outcome of an adequate aggregation procedure [see Amable et al. (1991), Göcke (2002)]. Göcke and Matulaityte (2015) showed theoretically that hysteresis losses in economics are proportional to the area inside a closed hysteresis loop (see Figure 2), whose quantitative expression is a cubic function of price change in a certain period of time. Using the same logic we further on assumed that hysteresis losses are also proportional to the area inside the approximated linear hysteresis curve (see Figure 5), calculated the indicator based on play-hysteresis [see equation (9)], and integrated it into the play-algorithm [see Belke and Göcke (2001)] in order to investigate hysteresis losses empirically, which is the main contribution of our paper.

As an example, we calculated the hysteresis losses for Italian wine exports to the United States, which is the second contribution of this paper. At first, we proved the hysteresis hypothesis of the market empirically by running two OLS regressions—one with and the other without the path-dependent component (artificial SPURT variable). The existence of hysteresis on the market incentivized us to calculate the indicator for the hysteresis losses that captures a continuous increase in hysteresis losses in the time span from 2003Q1 to 2008Q2. According to Eurostat, the vineyards in Italy are shrinking from year to year. In addition, the number of winegrowers in 2010 was smaller more than by half compared to the year 2000. All this is associated with lost sunk (dis)investments that are relatively high in wine production. These facts supported our results captured by the indicator. Moreover, we observed disproportionately large hysteresis losses in comparison to exchange rate changes.

There can be various applications of the hysteresis losses indicator: on the one hand, we can investigate how sensitive the exporters are to exchange rate changes, where the pain thresholds of firms are, and how large the hysteresis losses are in comparison to exchange rate changes—all this is done in the paper; on the other hand it is conceivable to include this indicator into a certain utility function in order to account for hysteresis losses while making certain policy decisions.

Hysteresis losses should be taken into account because they increase welfare losses in a way which was not yet considered. Since hysteresis is an empirically proven phenomenon not only in foreign trade, but also in other economic fields like labor markets [see, e.g., Mota et al. (2012) for empirical analyses or Raurich et al. (2006) for a theoretical modeling], the new indicator has many applications. It can also be calculated for a very general case using price changes as a forcing variable.

NOTES

1. Hysteresis originally stems from physics (ferromagnetism, plasticity, etc.) and also occurs in several phenomena in chemistry, biology, engineering [see Visintin (2006), p. 3)], and in economics, especially in international trade and labor markets [see Göcke (2001)]. Amable et al. (1992), Cross (1993), Göcke (2002) and Cross et al. (2009, 2010) provide an overview of hysteresis in economics. The term hysteresis is derived from the Greek verb “hysteros” meaning “lagging behind” or “that which comes later” (Cross 1993, p. 53) and describes an effect that persists after the cause that brought it about has been removed.

2. Werner (2016) found supply-hysteresis in Italian wine exports to the United States using the method based on the original Preisach-model. In contrast to this, we use the play-algorithm proposed by Belke and Göcke (2001).

3. Nevertheless, one could argue that rising uncertainty about the input variable (here: exchange rate) will not alter the trigger values immediately because trigger values may depend on other firm specific influences (like a full storehouse or sources of finance). Therefore, it could be possible that the determination of the trigger values is a subject to hysteresis too.

4. For more information to the aggregation procedure see Amable et al. (1991), Göcke and Matulaityte (2015).

5. In this paper, we analyze the sunk cost hysteresis on the supply side. However, the origin of hysteresis may be different, e.g., learning-by-doing. Hysteresis may also be caused by demand side factors, e.g., associated with demand carry-over effects [see Baldwin (1990)].

6. According to Dixit and Pindyck (1994), the uncertainty over future development of the input variable creates a value of waiting for new information. This is another important cause of hysteresis.

7. For detailed analysis of the effects of relaxing the benchmark model assumptions on the form of the hysteresis loop and hysteresis losses see Adamonis (2018).

8. The data for total production of wine is available on Eurostat until 2008.

9. For the overview about different methods describing economic path-dependence see Belke et al. (2014).

10. We thank the anonymous referee for the suggestion of the play sensitivity and the procedure validation tests.

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APPENDIX

TABLE A.1. Linear regression of Italian wine export values to the United States with and without the SPURT variable

	Dependent variable: Italian wine export values	
	Without SPURT	With SPURT
RER	−66,031,297.00***	29,668,428.00
	(12,943,883.00)	(18,954,038.00)
SPURT	–	−153,654,978.00***
		(25,356,805.00)
GDP	118.11***	51.98***
	(18.92)	(18.81)
Trend	145,930.40	1, 382,115.00***
	(337,574.10)	(341,067.70)
*d*1	−26, 585,933.00***	−25,577,587.00***
	(4,667,843.00)	(3,783,203.00)
*d*2	−2,557,228.00	−1,568,521.00
	(4,676,287.00)	(3,789,893.00)
*d*3	−5,555,623.00	−5,199,324.00
	(4,672,343.00)	(3,783,643.00)
Constant	−112,000,000.00**	−150,000,000.00***
	(44,255,942.00)	(36,369,913.00)
Observations	75	75
R^2	0.914	0.945
Adjusted R^2	0.907	0.939
S.E. of regression (df = 68)	14,185,828.00	11,486,233.00
F-statistic (df = 6; 68)	120.76	163.13

Note *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Source: Own calculations with data from Eurostat (2015b) and USDA (2014).

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TABLE A.2. Linear regression of Italian wine export values to the United States with and without the SPURT variable (robustness check 1: exclusion of trend variable)

	Dependent variable: Italian wine export values	
	Without SPURT	With SPURT
RER	−63,949,290.00***	38,914,707.00
	(11,943,498.00)	(25,258,054.00)
SPURT	–	−133,000,000.00***
		(29,650,400.00)
GDP	125.99***	128.96***
	(5.05)	(4.52)
*d*1	−26,548,160.00***	−25,133,758.00***
	(4,639,444.00)	(4,117,800.00)
*d*2	−2,438,593.00	-428,342.6
	(4,640,639.00)	(4,131,156.00)
*d*3	−5,469,813.00	−4,321,421.00
	(4,640,538.00)	(4,114,647.00)
Constant	−130,000,000.00***	−313,000,000.00***
	(15,377,365.00)	(42,957,056.00)
Observations	75	75
R^2	0.914	0.934
Adjusted R^2	0.908	0.928
S.E. of regression (df = 68)	14,101,995.00	12,479,634.00
F-statistic (df = 6; 68)	146.60	159.35

Note *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Source: Own calculations with data from Eurostat (2015b) and USDA (2014).

TABLE A.3. Linear regression of Italian wine export values to the United States with and without the SPURT variable (robustness check 2: exclusion of trend and seasonal variables)

	Dependent variable: Italian wine export values	
	Without SPURT	With SPURT
RER	−64,927,645.00***	41,958,122.00
	(14,818,962.00)	(32,588,272.00)
SPURT	–	−138,000,000.00***
		(38,260,121.00)
GDP	126.84***	129.92***
	(6.27)	(5.86)
Constant	−140,000,000.00***	−329,000,000.00***
	(18,670,909.00)	(54,979,461.00)
Observations	75	75
R^2	0.862	0.883
Adjusted R^2	0.858	0.878
S.E. of regression (df = 68)	17,509,637.00	16,203,767.00
F-statistic (df = 6; 68)	224.11	178.82

Note *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Source: Own calculations with data from Eurostat (2015b) and USDA (2014).

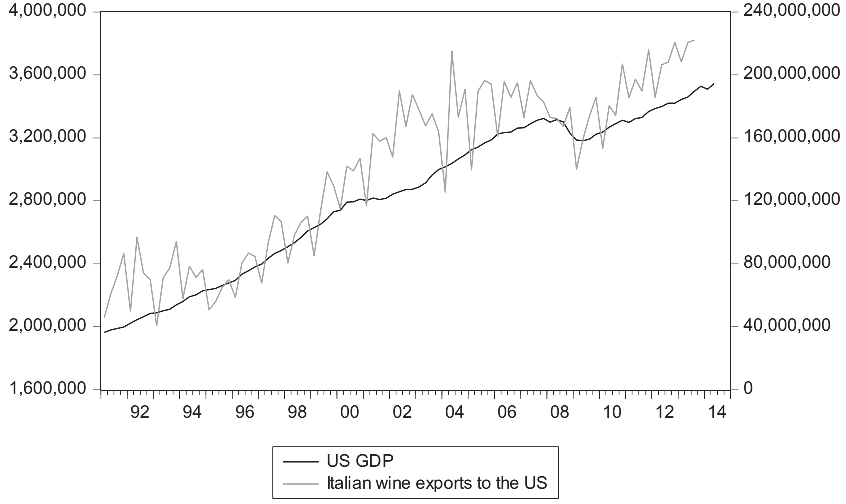

FIGURE A.1. Italian wine exports to the United States vs. US GDP (1991–2014). US GDP is measured in Mill. euros, converted on basis of the exchange rates from 2000; the Italian wine exports are measured in euros. Source: Eurostat (2015a).

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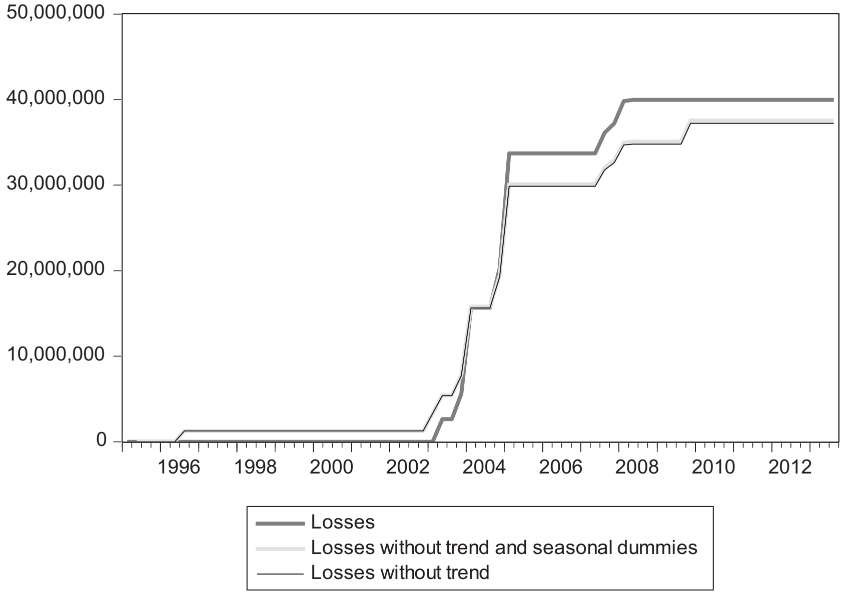

FIGURE A.2. Hysteresis losses in euro (robustness checks). Hysteresis losses indicator is not normalized to 1.

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