Equities' Exposures to Currencies: beyond the loglinear model

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Preliminary — comments welcome

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Abstract

It has been surprisingly difficult to demonstrate non-zero currency exposures for individual stocks, and a recent study even finds that the absolute value of estimated exposure is a better predictor than the value itself. We argue that the value of the international-trade option should be convex in the exchange rate so that exposure depends on the exchange rate level. Since spot rates move slowly, exposure could then differ substantially across samples. Many large companies, in addition, must be ambidextrous—positively exposed in some activities, and negatively in others. We derive a class of tractable regression models and find that the standard loglinear regression is invariably beaten by the proposed alternative. However, too often we detect at least a partial concavity.

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Introduction and Summary

It seems self-evident that exporters benefit from a depreciation of the currency of their export markets: if they are price takers abroad, their profit margin swells, and if they have some market power they can further improve the results by optimally lowering the foreign sales price. Thus, in a regression of stock returns on percentage changes on the exchange rate,¹ the slope coefficient should be positive. By a similar argument, importers should be characterized by negative exposures. Yet, as we document in Section 1, it has been surprisingly difficult to demonstrate non-zero currency exposures for individual stocks, especially if one tries to link the sign of the exposure to e.g. the firm's net trade. Priestley and Odegaard (2007) find that exposure seems to change sign depending on the exchange-rate's direction of change. More generally, estimated exposures seem quite unstable. Our aim is to solve both puzzles.

The core ingredient in this paper is that the notion of constant exposure, whether defined as a partial derivative or an elasticity, can probably be improved upon; that is, we question linearity or loglinearity in levels. Instead, we expect a non-homothetic convex relationship between the firm's value and the real exchange rate (Sercu, 2009, pp 460-461). In cash flow terms, a linear relation would hold only if both the foreign price and production plan remain unaltered regardless of the exchange rate, but that does rarely make sense. Because of the firm's option to adjust pricing and production, the impact of adverse movements can be partially mitigated, and beneficial changes can be exploited further, as already illustrated above for the case of an exporter.

One may rightly object that the above cash-flow picture ignores lump-sum adjustment costs. Especially at the export side, abandoning or re-entering a market is likely to require one-off outlays that are largely irreversible. Lump-sum items do destroy the smoothness of the cash-flow function. But those discontinuities disappear again if we consider not the future cash flows themselves but their PV. In terms of market value, the metric studied in all empirical

¹Throughout the article, the term exchange rate refers to the value of the foreign currency in units of home currency.

work, optimal dynamic management of the option to abandon or re-enter a market implies that, for lower and lower exchange rates, the value of an export business smoothly converges towards its liquidation value, or to the value of the firm as a purely domestic entity if this is the better alternative.² One oft-cited example is International Harvester, which abandoned its export markets after the Reagan dollar hike, and for decades essentially fell back on the U.S. local market. The same holds for an option to import: its value should smoothly shrink with higher and higher real exchange rates for the source country. Thus, in value terms we should still get smooth convex relations even if exercising the real options requires irreversible lump-sum investments. The amended bottom line is that exposure depends on the level of the real exchange rate, a feature missed by the usual loglinear model that is behind the linear regression of returns on percentage changes in exchange rates.

A second ingredient of our approach that the real exchange rate typically exhibits very little mean-reversion. If, once it arrives at a particular level, the rate stays in that neighborhood for a rather long term and if every neighborhood has its own exposure, then if one estimates exposures from different subperiods one could observe very different results.

Two elements could further complicate the view that was just proposed. First, the above story is about an unhedged firm. But many firms do hedge their transaction exposures and their expected cash flows over a chosen horizon. In the mythical case of a linear relation between cashflow C and exchange rate S , all exposures within the hedging horizon can be eliminated by a forward hedge. But if the relation is convex, as we just argued it should, a static linear hedge merely flips a convex schedule into a lopsided U. Only if the firm hedges its entire value, if the exchange rate's path is smooth, and if there is continuous dynamic updating, can the relation between value and exchange rate disappear altogether. While few firms are that ambitious, it is unclear how far they go, so the realized relation may be a sequence of ever-shifting inverse U-shapes that defies easy modeling.

The second element that could similarly obfuscate the situation is that the familiar exporter/importer dichotomy may be outdated. Nowadays, most trade is organized inside multi-

²When the exchange rate approaches the critical level where the firm would optimally switch its operating mode, the likelihood that the fixed adjustment cost will actually occur will smoothly approach the certainty level, so the stock price smoothly adjusts. Smooth pasting as a characteristic of optimization was introduced by Merton (1973). Dixit (198) offers an excellent discussion. Sercu and Van Hulle (1992) apply it to the value of an exporting firm, with a 'mothballing' mode between the active-plant mode and the liquidation mode.

Note that considering values instead of cash flows does not entirely solve the problem of lump-sum switch costs. If there are fixed costs to suspend and re-enter a market, the value function still depends on whether one is actively trading or not. We have to ignore this 'hysteresis' refinement.

national corporations or corporate groups, and these corporations produce and sell worldwide. Most trading firms do have a sizable home activity, of course, which may have low exposure. In addition, many firms may run both import- and export-like divisions or activities. This makes the firm ambidextrous—positively exposed in some activities, and negatively in others. While these distinct exposures are probably occurring for different currencies, the fact is that most studies, since Jorion (1990), use a currency index. Thus, the test really is not a particular bilateral rate but about the effect of a de- or appreciation of the home currency against the rest of the world. When the average foreign currency rises (*i.e.* the dollar weakens, in the case of a U.S. firm), the typical U.S. multinational's export-like business flourish while its import-related activities are hurt. If the separate relations had been linear, the total value would still be linear in the exchange rate and have an unambiguous net slope, positive or negative depending on which business dominates. But with convexity, total value may become a U-shaped function of the exchange rate, with an exposure that has both positive and negative zones next to a potentially important domain with near-zero exposure.³ Again, with long memory in the exchange-rate path, depending on the sample one might find positive, or negative, or zero exposures.

1 Currency exposure: a review of earlier empirical work

One antecedent of the standard loglinear regression is the Johnson (1960) and Stein (1961) minimum-variance hedge problem: if a cash flow or asset worth y is to be hedged using an instrument with value x , then the regression coefficient b in $y = a + bx + e$ is the hedge ratio that minimizes the residual variance of y , that is, the value hedged. Dumas (1978), reiterated in Adler and Dumas (1984), imported this concept into international finance, choosing the future exchange rate as the x variable, and naming this regression coefficient y 's exposure to the exchange rate.

If time series data are used and both y and x are nonstationary, or close to, then the

³While exposures at the individual-firm level are often computed for their own sake, in asset-pricing tests the test data are typically portfolio returns. To test international CAPMs, for instance, one often works with country indices, or three- or four-factor stratified portfolios, or country×industry aggregates. Even if few firms are really ambidextrous individually, this characteristic is still more likely to emerge at an aggregate level. The convexity effect at the company level then also induces changing weights. For instance, if the home currency depreciates, export-like firms flourish and obtain higher weights at the expense of import-like companies, reinforcing the rise in the exposure. While the formal arguments developed below employ a company vocabulary, the exploratory empirical work is actually done on industry index data.

regression has to work with first-differenced numbers, at the very least. Actually, to reduce heteroscedasticity issues, the preferred version is to work with percentage changes rather than dollar changes, implying that the regression coefficient delivers an elasticity rather than the partial-derivative-like number (like a hedge ratio). If excess returns are used, the regression is

$$(\tilde{r}_j - r_d) = \delta_j + \gamma_j(\tilde{s} + r_f - r_d) + e_j, \quad (1)$$

where $\tilde{r}_j$ denotes the return on a risky asset j ; r_d (r_f) is the domestic (foreign) risk-free rate; and $\tilde{s}$ the simple percentage change in the exchange rate, typically expressed in home currency units. In most cases, the risk-free rates are omitted without any noticeable harm. In doing so, the exposure literature followed the CAPM-inspired market-model regression,

$$(\tilde{r}_j - r_d) = \alpha_j + \beta_j(\tilde{r}_m - r_d) + e_j, \quad (2)$$

where $\tilde{r}_m$ denotes the market-index return.

A more direct link with asset pricing theory emerged when Sercu (1980), generalizing Solnik's (1973) International CAPM, realized that Dumas' exposures, in their multivariate guise, could be used to develop a quasi one-factor CAPM for stocks hedged against exchange risk. Adler and Dumas (1983) estimate the equation. In an alternative version, Sercu (1980) merges the CAPM for bonds with that for hedged stocks into a standard multifactor CAPM-*cum*-regression, where the market portfolio shows up next to the exchange-rate changes of all countries. In the two-country case, for instance, the model is

$$E(\tilde{r}_j - r_d) = \beta'_j E(\tilde{r}_w - r_d) + \gamma'_j E(s + r_f - r_d), \quad (3)$$

where $\tilde{r}_w$ denotes the return on the world market w and where β'_j and γ'_j are the trivariate slope coefficients from

$$(\tilde{r}_j - r_d) = \beta'_j(\tilde{r}_w - r_d) + \gamma'_j(\tilde{s} + r_f - r_d) + e_j. \quad (4)$$

In multi-country models, each and every exchange rates percentage change shows up in the CAPM and in its associated regression as a separate regressor.

Since Jorion (1990), these separate, bilateral exchange-rate changes are often replaced by a single return on a bucket of currencies, typically trade-weighted. Again, in most applications the risk-free rates are omitted from the regression; in practice, lastly, the world market is often replaced by stock j 's home-country market index return, denoted $\tilde{r}_{m_j}$. The motivation is to reconcile the Dumas regression with the national market model, often still seen as the premier

return-generating model, and to obtain more precision by controlling for a host of factors that affect all stocks in similar ways. The Jorion regression, in short, is

$$\tilde{r}_j = \beta_j' \tilde{r}_{m_j} + \gamma_j' \bar{s} + e_j, \quad (5)$$

with $\bar{s}$ denoting the percentage price change for the basket, an average of the currency-by-currency percentage price changes.

Most of the subsequent literature has worked with variants of this regression. Much of the tinkering was motivated by the, in a way, disappointing results for the model: with U.S. data, surprisingly few companies came up with significant exposures (see e.g. Jorion 1990, 1991; Bodnar and Gentry, 1993; Amihud, 1994; Choi and Prasad, 1995). Non-U.S. data, from supposedly more open countries, provided mixed results: He and Ng (1998) report one stock out of four to be exposed in Japan, and Kiymaz (2003) one out of two for Turkey, but others found only weak evidence of currency exposure for Australia (Khoo, 1994) or broad samples of countries including Japan (Griffin and Stulz, 2001; Dominguez and Tesar, 2006. Chue and Cook (2008) estimate the exposure of emerging countries and find the depreciation of domestic currencies has a negative impact on stock returns.

All of these studies look at stocks as priced in their home stock market. Translated asset prices, however, in the sense of assets where most or all the price-setting happens in the foreign market, are clearly exposed; see e.g. Jorion's results for foreign multinationals listed in the U.S., or Adler, Dumas and Simon's (1986) findings for dollar returns on foreign market indices. Thus, the picture seems to be disconcertingly close to Solnik's original CAPM, where each stock has a clear nationality in the sense that its value, when expressed in its home currency, moves independently of exchange rates against that home currency.

This may reflect systematic and successful covering against exchange risk. Multinationals can do so via long-run operational hedges (Logue, 1995; Bartam, Brown and Minton, 2010) or via financial hedges. To test this, exposures γ have been modeled as linear in variables that probably correlate with the firm's desire to hedge, like the firm's foreign sales or operations as a fraction of the total, the fraction of exports and imports, its leverage, its liquidity, and so on. There is some evidence that firms that have higher operating exposures or are more vulnerable do hedge more, resulting in a lower residual exposure; but the effect is not strong (Allayannis, 1995; Goa, 2000; Pantzalis, 2001; Carter, Pantzalis and Simkins, 2001; Williamson, 2001; De Jong, Ligterink, and Macrae, 2002; Crabb, 2002). A related literature relates the gammas to firm characteristics, sometimes with some success (Bodnar and Gentry, 1993; Williamson,

2001) and sometimes without much useful insights (Amihud, 1994; Fraser and Pantzalis, 2004).

Exposure may also be unstable. Many authors run subperiod regressions (Jorion, 1990; Amihud, 1995; He and Ng, 1998; Glaum, Brunner and Holger, 2000; Williamson, 2001; Doukas, Hall and Lang, 2003), or work with rolling or moving data windows (Glaum, 2000; Entorf and Jamin, 2002, 2007), or relate changes in exposure to the shifting weight of exports and imports (Allayannis, 1995).

Regarding the data type, there may be an intervalling effect. Some report better results when using daily data rather than the usual monthly (Chamberlain, Howe and Popper, 1997; Di Ioro and Faff, 2000; Glaum, Brunner and Holger, 2000), while others advocate longer holding periods (Bartov and Bodnar, 1994; Chow, Lee and Solt, 1997; Chow and Chen, 1998; Griffin and Stulz, 2001; Dominguez and Tesar, 2001; Di Ioro and Faff, 2000; Muller and Verschoor, 2006). Even adding lagged exchange-rate changes has been considered (Bartov and Bodnar, 1994; Allayannis, 1996) with mixed results.

Others have tweaked the input data. Regarding the market return, Bodnar and Wong (2003) experiment with equal versus value weighting. Others replace the market by a number of macro variables (Gao, 2000), return determinants (Chow and Chen, 1998) or Fama-French factors (Doukas, Hall and Lang, 1999). A branch of research has worked with orthogonalized regressors, either constructing in-sample-hedged $\tilde{r}_m$ variates (Kiymaz, 2003) or market-corrected $\tilde{s}$ data (Elton and Gruber, 1991; Choi and Prasad, 1995). The effect of using this particular type of constructed variables is that the coefficient of the undoctored regressor becomes equal to the simple regression slope, while the coefficient of the orthogonalized regressor remains equal to the multiple-regression slope (the Frisch-Waugh (1933) theorem). Undesirably, however, the regular t-statistics no longer apply, so this is not a recommendable procedure.

Much attention has been given to the exchange-rate variable, especially to the use of a fixed basket *à la* Jorion. The objective is to avoid multicollinearity between the various exchange rate changes, which all share a common component (the reference-currency factor). There would be no loss of information if all firms have bilateral exposures to the various currencies that are proportional to the weights used in the basket. This is unlikely, of course: firms trade with different countries, chose their own selective hedging policies, face different demand elasticities depending on their industry etc. So if the implicit assumption of proportional exposures is not met, the use of a basket comes at a cost: the regressor measures the ideal basket with error, inducing a standard attenuation-towards-zero bias. Domingues and Tesar (2001b) find that using bilateral rates beats the currency basket. Similarly, some obtain better results when

multiple, more focused buckets are used, constructed e.g. via factor analysis (Miller and Reuer, 1998) or on a regional basis (Muller and Verschoor, 2006). Khoo (1994) collects firm-by-firm trade data and builds a firm-specific basket. This is unusually painstaking, but still ignores other determinants of exposure, like demand elasticity and hedging policies. A last issue is whether one should not use real returns, and changes in the real exchange rate, rather than nominal units. In practice, using real data hardly affects the conclusions (Bodnar and Gentry, 1993). Nor do two-step procedures where the variates are first regressed on lagged variables with some predictive power, like lagged changes (Amihud, 1994) or macro variables (Gao, 2000) to filter out the predictable part of changes.

A last point of debate has been the use of portfolio data versus individual stock data as the left-hand side variable. The attraction of aggregate data is that there is likely to be diversification, meaning a lower total variance and, it is hoped, especially a lower residual variance, implying more precise estimates. In addition, one can easily build balanced panels without creating a survivalship-biased sample, as one would have to do with individual stock data. The obvious risk is firm heterogeneity: if the component stocks have different exposures, and specially of their gammas differ in sign, the resulting aggregate may have too little exposure to be detectable. Many authors, on balance, come down against portfolios (Allayannis, 1994, 1996; Khoo, 1994; Choi and Prasad, 1995; Muller and Verschoor, 2006). Yet the context of the test matter too. For a stand-alone exercise, individual stock data may be recommendable. But for CAPM tests, portfolio data are much more wieldy. Griffin and Stulz (2001), Dumas and Solnik (1995) and De Santis and Gerard (1998), for instance, work with country indices. In this paper we adopt a compromise, working with industry portfolios per country: these are likely to be less heterogenous than country

There are some disconcerting results, like when He and Ng (1998) and Dominguez and Tesar (2006) find the direction of exposure depends on specific exchange rate level or when Priestley and Odegaard (2007) find a nonlinear relation where exchange rate exposure changing in terms of depreciation to appreciation periods. By and large, though, the empirical literature has barely ventured beyond the simple loglinear model, even though theoretical work suggests much richer models. Our ambition is to reduce the gap between theory and empirics by presenting a model whose features are inspired by theory but whose mathematical form is amenable to empirical work.

2 The Regression Models

2.1 A Real-option Model for an Unhedged Ambidextrous Corporation

For generality we consider a firm that has divisions with different exposures. Some of the exposures may be positive, like in exporting or import-substituting activities (subscript x), or zero, like in a domestic division in a sheltered sector (subscript d), or negative, such as in activities that rely on imported inputs or have the option to import instead of buying or producing locally (subscript m). The firm may not be active in more than one of these at all times: the three activities are options that are exercised only when it makes sense. The functional form between the firm's value and the exchange rate should capture the smoothness characteristic suggested by the real options literature and should also allow a tractable transition to a test equation. To that end we approximate the value of each exposed division (or group of divisions) by a piecewise quadratic in S .⁴ Denote the level of the real exchange rate at which the firm decides to abandon its export-like activities by $\underline{S}_{x,t}$, and the alternative value of that division by $\gamma_{x,t}$.⁵ This alternative value may be a liquidation value. More plausibly, the firm also has domestic activities, in which case the best alternative use of the former export-market assets may be to switch them to domestic use; then the alternative value $\gamma_{x,t}$ is a component of the domestic-asset value. A simple model for the positive-exposure or export-like activities, offering both smoothness and tractability, then is

$$V_{x,t} = \gamma_{x,t} + \delta_{x,t}(S_t - \underline{S}_{x,t})_+^2, \quad (6)$$

where $\delta_{x,t}$ is nonnegative and $(S_t - \underline{S}_{x,t})_+^2$ is short for $[\text{Max}(S_t - \underline{S}_{x,t}, 0)]^2$. Like a quadratic spline this is a smoothly changing piecewise function—except that (i) the knot point $\underline{S}_{x,t}$ is estimated rather than pre-set by the researcher, and (ii) we join a linear and a quadratic rather than two quadratics. We label this a semi-spline regression. A similar relation then holds for the negative-exposure or import-like divisions:

$$V_{m,t} = \gamma_{m,t} + \delta_{m,t}(S_t - \underline{S}_{m,t})_-^2, \quad (7)$$

⁴An equivalent approach would be to leave the function unspecified and then take a quadratic approximation for the changes.

⁵Subscripts j for the firm, in V , $\underline{S}_{x,t}$, $\underline{S}_{m,t}$, $\gamma_{x,t}$, $\delta_{x,t}$, $\gamma_{m,t}$ and $\delta_{m,t}$ have been suppressed for ease of reading, but all these numbers are really firm-specific.

Figure 1: The Value of the Firm as a Function of the Real Exchange Rate

Source The option values for the x - and m -divisions upon liquidation are 1.2 and 0.5, respectively, and the divisions decide to suspend at a real rate of 1.25 for the import sections and 0.75 for the export activities. The total value does not include the unexposed ('home') activities, if any.

where $\delta_{m,t}$ is nonnegative⁶ and $(S_t - \underline{S}_{x,t})_-^2$ is short for $[\text{Min}(S_t - \underline{S}_{x,t}, 0)]^2$. Lastly there may be domestic activities, whose value changes we model via the market model, see below.

For the sake of generality, we consider a potentially ambidextrous firm; in what follows, one can always set one of the δ s equal to zero to find the monodextrous case. Summing the two exposed divisions' values, we obtain a total exposed value of

$$V_t = [\gamma_{x,t} + \gamma_{m,t}] + \delta_{x,t}(S_t - \underline{S}_{x,t})_+^2 + \delta_{m,t}(S_t - \underline{S}_{m,t})_-^2. \quad (8)$$

Figure 1 illustrates this. In the example, the liquidation values for the import and export divisions' assets equal 1.2 and 0.5, respectively. Scrapping the export business is optimal when rates fall to 0.75 or lower; for the import-related activities, liquidation is rational for rates equal to or above 1.25. The summed value is a wide U-like shape, here designed to be asymmetric. Obviously, when in a particular period the real exchange rate is mostly high (1.10 or more, in the example), a positive exposure will appear from the tests; but in another subperiod a negative relation may surface, and in the long run there may seem to be no correlation at all,

⁶The local slope is $2\delta_{m,t}(S_t - \underline{S}_{m,t})_-$, with the negative sign coming from $(S_t - \underline{S}_{m,t})_-$ rather than from $\delta_{m,t}$.

unconditionally, between V and S .

We study differences in value to avoid an integrated (unit-root) left-hand side variable, but it remains important to keep the level of the exchange rate in the picture when modeling a dynamically exposed firm. For every division $f \in \{x, m\}$ we identify the change as

$$\Delta(S_t - \underline{S}_f)^2 = 2(S_{t-1} - \underline{S}_f) \dots \Delta S_t + (\Delta S_t)^2. \quad (9)$$

Below, we write the value change of the firm's export-like activities. Adding a similar term for the m divisions, we then obtain the value changes for the exposed units taken together:

$$\begin{aligned} \Delta V_{x,t} &= \Delta \gamma_{x,t} + \delta_{x,t} [2(S_{t-1} - \underline{S}_{x,t}) + \Delta S_t] \mathbf{1}_{S_{t-1} > \underline{S}_{x,t}} \Delta S_t, \\ \Delta V_{m,t} &= \Delta \gamma_{m,t} + \delta_{m,t} [2(S_{t-1} - \underline{S}_{m,t}) + \Delta S_t] \mathbf{1}_{S_{t-1} < \underline{S}_{m,t}} \Delta S_t, \\ \Delta(V_{x,t} + V_{m,t}) &= \Delta \gamma_{x,t} + \Delta \gamma_{m,t} + \delta_{x,t} [2(S_{t-1} - \underline{S}_{x,t}) + \Delta S_t] \mathbf{1}_{S_{t-1} > \underline{S}_{x,t}} \Delta S_t \\ &\quad + \delta_{m,t} [2(S_{t-1} - \underline{S}_{m,t}) + \Delta S_t] \mathbf{1}_{S_{t-1} < \underline{S}_{m,t}} \Delta S_t, \end{aligned} \quad (10)$$

For empirical applications we have to specify how the exposures δ and the alternative values γ behave over time. Two feasible options are to assume them either constant over time or proportional to the lagged total value. We go for constant critical exchange rates $\underline{S}_f$, and proportional parameters for the alternative asset values γ and the exposures δ :

$$\underline{S}_{m,t} = \underline{S}_m; \quad \underline{S}_{x,t} = \underline{S}_x; \quad \gamma_{m,t} + \gamma_{x,t} = \gamma V_{t-1}; \quad \delta_{m,t} = \delta_m V_{t-1}; \quad \delta_{x,t} = \delta_x V_{t-1} \quad (11)$$

Below, we switch to returns:

$$\begin{aligned} r_t &:= \frac{\Delta V_t}{V_{t-1}} = \frac{\Delta V_{d,t}}{V_{t-1}} + \frac{\Delta V_{x,t}}{V_{t-1}} + \frac{\Delta V_{m,t}}{V_{t-1}}, \\ &= \frac{V_{d,t-1}}{V_{t-1}} \frac{V_{d,t} - V_{d,t-1}}{V_{d,t-1}} + \gamma \frac{V_{t-1} - V_{t-2}}{V_{t-1}} + \delta_x [2(S_{t-1} - \underline{S}_x) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} > \underline{S}_x} \\ &\quad + \delta_m [2(S_{t-1} - \underline{S}_m) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} < \underline{S}_m}. \end{aligned} \quad (12)$$

Finally, we include a domestic market-model term as a simple way to account for domestic activities and general asset-pricing effects. The domestic market exposure coefficient is allowed to change depending on what happens in the exchange markets affecting the relative importance of the domestic activities in the total firm value ($V_{d,t-1}/V_{t-1}$). For the moment, we denote this time-varying market coefficient as β_t and report the reader to Subsection 2.3 for the exact parametrization of β_t as a function of S_{t-1} .⁷ Including also an intercept, this leads to our

⁷Note that β_t is estimating the market sensitivity of the firm as a whole, not just the home divisions. For instance, the value of the international activities is partly determined by changes in interest rates, which induces a correlation with the domestic market index.

most general model for the firm's currency exposure:

$$\begin{aligned} r_t = & \alpha + \beta_t r_t^M + \gamma \tilde{r}_{t-1} + \delta_x [2(S_{t-1} - \underline{S}_x) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} > \underline{S}_x} \\ & + \delta_m [2(S_{t-1} - \underline{S}_m) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} < \underline{S}_m} + \varepsilon_t, \end{aligned} \quad (13)$$

where $\tilde{r}_{t-1} = (V_{t-1} - V_{t-2})/V_{t-1}$ and ε_t is the error term.

For many firms, as mentioned, one or two of the deltas may have zero values. With two strictly positive δ s, the firm or sector is actually ambidextrous, having sometimes a predominantly export orientation and sometimes a predominantly import-like character. If only one δ is positive and the other zero, in contrast, the firm or sector is either export- or import-oriented, not both. In either case there also is an interest as to at what kind of critical levels $\underline{S}_f$ the international ambitions are abandoned totally. Specifically, the question is where these critical rates are located relative to the feasible range of real-exchange-rate levels and relative to each other. Economically, this depends on whether trade is just an option to the firm or, instead, a *sine qua non* for survival. Statistically, the issue is whether there are three, two or one regime in the dynamic model.

2.2 Three-, two- and one- regime versions of the Dynamic Exposure Model (DEM): economic and statistical interpretation

Suppose, for instance, that next to exports there is viable domestic market for the firm's output. When the foreign exchange rate is sufficiently low, exporters do suspend trade; but since domestic sales are possible, such a decision would not mean the firm has to be liquidated. Thus, trading may be suspended, but that would still not mean that the option to ever trade again at some future point is entirely worthless, in the same way as non-exercising an American-style call option does not mean the option has zero value.⁸ It remains conceivable that, later, the firm might re-enter the export business. Likewise, in some sectors an importing firm can potentially switch to domestic sourcing, given the right exchange rate. If that is the case, the importer may suspend trade, but the option to switch back to imports later is not abandoned once and forever. In either case, trading is not a *sine qua non* for the firm's survival, and the option to (ever) trade again does not really become worthless at any realistic exchange rate. Thus, in many potential or actual export sectors, $\underline{S}_x$ would be so low that this level has not been reached during the sample period and will almost surely never be reached in future: the

⁸The analogy is far from perfect. The option to trade is not just American, but also perpetual and reversible.

export option always remain relevant, for now or for the future. Likewise, in some potential or actual import sectors $\underline{S}_m$ may be so high that it was never reached in the sample and will almost surely never be reached in future: the idea to import never becomes totally irrelevant.

The model, which we label “Dynamic Exposure Model” (DEM) can be tested as a three-, two- or -one-regime model. In the actual estimations we start from three regimes, and reduce the number of regimes whenever the estimates suggest that a less flexible model does not entail a significant loss in explanatory power.

2.2.1 Three-regime model: both options to trade can realistically become worthless

The three-regime model holds when, in Equation (13), both critical rates $\underline{S}_m$ and $\underline{S}_x$ are well inside the range of observed real exchange rates. That is, this three-regime model means that, by our estimates, the option to trade has actually been abandoned irrevocably during the sample period.

Two δ s are estimated and should turn out to be positive. The three regimes are
(i — high exchange rates) the export-side option is valuable, the import one is not
(ii — low exchange rates) the import-side option is valuable, the import one is not;
(iii — elsewhere) either both options have value, or none has, depending on whether $\underline{S}_m$ exceeds $\underline{S}_x$ (like in Figure 1) or not.

(iii.a) In the former case, the firm is ambidextrous in the middle zone, but one (and only one) type of trade may become irrelevant for higher or lower exchange rates.

(iii.b) In the latter case, this is a relatively closed sector where the prospect of trade becomes a speck in the sky only for rather low or high rates, and the two are never relevant simultaneously.

2.2.2 Two-regime models: trade is an option in one direction only

When one of the two critical rates is estimated to be outside the observed range, then in this sample one option to trade never loses value: firms do have domestic alternatives and therefore never have to liquidate (i.e. irrevocably abandon their international options). In the two-regime case this domestic alternative is available at one side only. For instance, if the

option to export is never utterly abandoned we have $\mathbf{1}_{S_{t-1} > \underline{S}_x} = 1, \forall S$, and therefore

$$\begin{aligned}
r_t &= \alpha + \beta_t r_t^M + \gamma \tilde{r}_{t-1} + \delta_x [2(S_{t-1} - \underline{S}_x) + \Delta S_t] \Delta S_t \\
&\quad + \delta_m [2(S_{t-1} - \underline{S}_m) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} < \underline{S}_m} + \epsilon_t. \\
&= \alpha + \gamma \tilde{r}_{t-1} + (\delta_m + \delta_x) [2(S_{t-1} - \underline{S}_a) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} < \underline{S}_m} \\
&\quad + \delta_x [2(S_{t-1} - \underline{S}_x) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} > \underline{S}_m} + \beta r_m + \epsilon_t.
\end{aligned} \tag{14}$$

where $\underline{S}_a := (\delta_m \underline{S}_m + \delta_x \underline{S}_x) / (\delta_m + \delta_x)$, the average critical rate. In contrast, if the option to import is the one that is never utterly abandoned we have $\mathbf{1}_{S_{t-1} < \underline{S}_m} = 1, \forall S$, and therefore

$$\begin{aligned}
r_t &= \alpha + \beta_t r_t^M + \gamma \tilde{r}_{t-1} + \delta_x [2(S_{t-1} - \underline{S}_x) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} > \underline{S}_x} \\
&\quad + \delta_m [2(S_{t-1} - \underline{S}_m) + \Delta S_t] \Delta S_t + \epsilon_t. \\
&= \alpha + \beta_t r_t^M + \gamma \tilde{r}_{t-1} + \delta_m [2(S_{t-1} - \underline{S}_m) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} < \underline{S}_x} \\
&\quad + (\delta_m + \delta_x) [2(S_{t-1} - \underline{S}_a) + \Delta S_t] \Delta S_t \mathbf{1}_{S_{t-1} > \underline{S}_x} + \epsilon_t.
\end{aligned} \tag{15}$$

Both regressions look very similar in that they predict a different value for delta depending on whether S is below or above some critical rate. The tell-tale difference is that in Equation (14) we should observe the higher delta for low exchange rates, while in Equation (15) the higher should occur for high rates. If we cannot reject inequality of the two estimated slopes, then one can accept the hypothesis that one of the deltas is zero (a monodextrous firm).

2.2.3 The one-regime models: firms always have an important domestic alternative

The model becomes even simpler if there is no switch at all. This could be true for a monodextrous sector whose option to trade never becomes worthless. The one-regime model also emerges for an ambidextrous firm which never gives up either of its options, or at least not for rates observed in the sample: both $\underline{S}_f$ s are outside the observed range of real exchange rates. In this case all observations are assumed to be inside the middle domain of the general model, and the model simplifies to

$$\begin{aligned}
r_t &= \alpha + \beta_t r_t^M + \gamma \tilde{r}_{t-1} + \delta_x [2(S_{t-1} - \underline{S}_x) + \Delta S_t] \Delta S_t \\
&\quad + \delta_m [2(S_{t-1} - \underline{S}_m) + \Delta S_t] \Delta S_t + \epsilon_t, \\
&= \alpha + \beta_t r_t^M + \gamma \tilde{r}_{t-1} + (\delta_m + \delta_x) [2(S_{t-1} - \underline{S}_a) + \Delta S_t] \Delta S_t + \epsilon_t.
\end{aligned} \tag{16}$$

There is no way to fully disentangle the export and import sides. Since there is no change of regime, we can observe just the sum of the deltas and cannot check whether both deltas are

Table 1: Classification of models on the basis of $\underline{S}_f$, assuming $\delta > 0$.

observation	model's interpretation	label
$S_{min} < \underline{S}_- < \underline{S}_+ < S_{max}$	$S_{min} < \underline{S}_m < \underline{S}_x < S_{max}$	3R MX closed
$S_{min} < \underline{S}_+ < \underline{S}_- < S_{max}$	$S_{min} < \underline{S}_x < \underline{S}_m < S_{max}$	3R MX ambi
$\underline{S}_+ < S_{min} < \underline{S}_- < S_{max}$	$\underline{S}_x < S_{min} < \underline{S}_m < S_{max}$	2R Mswitch
$S_{min} < \underline{S}_+ < S_{max} < \underline{S}_-$	$S_{min} < \underline{S}_x < S_{max} < \underline{S}_m$	2R Xswitch
$\underline{S}_+ < S_{min} < S_{max} < \underline{S}_-$	$\underline{S}_x < S_{min} < S_{max} < \underline{S}_m$	1R

Key In the first column we list the possible positions of the two critical rates or knot points (initially labeled $\underline{S}_+$ and $\underline{S}_-$, referring to the “larger than” and “smaller than” dummies they are associated with) relative to the highest and lowest observed rates S_{min} and S_{max} . Then we show the tentative interpretation of these rates when the δ s are positive, and lastly the model label.

nonzero or not, that is, whether this is an ambidextrous case or not. But if the estimated value of $\underline{S}_a$, the delta-weighted average of the two critical rates, is low (below the lowest observed exchange rate), then the export divisions is likely to be dominant and *vice versa*.

Up to now, we have assumed that the switching behavior in the value of the export and import options are the only sources of threshold effects in the relation between equity returns and the foreign exchange rate. In practice, there may be other reasons for threshold effects, and the results in Section 3 suggest that in our sample this actually is the case quite often. For this reason, in the estimation equations of Section 2 we replace the $\underline{S}_x$ and $\underline{S}_m$ symbols of the model equations (13)-(16) with more neutral versions, $\underline{S}_+$ and $\underline{S}_-$ depending on whether they are associated with the “larger than” or “smaller than” dummies. Also the deltas are re-labeled in this way. When all coefficients have the expected sign, we then associate the estimates $\underline{S}_+$ and $\underline{S}_-$ with $\underline{S}_x$ and $\underline{S}_m$, respectively, and similarly for the deltas.

Table 1 summarizes the taxonomy. In the first column we list the possible positions of $\underline{S}_+$ and $\underline{S}_-$ relative to the highest and lowest observed rates S_{min} and S_{max} . Then we show the interpretation of these rates under our approach, and lastly the model label.

2.3 Flexible Fourier Form modeling of time-varying beta

A final feature of our model is that changes in exchange rates lead to changes in the fraction of total firm value that is generated by the domestic activities ($V_{d,t-1}/V_{t-1}$). The direct impact on the model equation (13) is that the domestic market exposure coefficient β_t depends on the exchange rate and can be time-varying. Our model does not yield any particular specification for this dependence, except that if $\underline{S}_m < S_{t-1} < \underline{S}_x$ it should be a constant. We have

considered several possible specifications for β_t and found the Fourier Flexible Form (FFF) of Gallant (1981) the most elegant. It specifies the unknown function $\beta_t = b(S_{t-1})$ as a Fourier series representation that includes additionally a second-order polynomial in the explanatory variables:

$$\begin{aligned} \beta_t = & \beta_0 + \beta_{x,0}s_{t-1}\mathbf{1}_{S_{t-1} > \underline{S}_x} + \beta_{m,0}s_{t-1}\mathbf{1}_{S_{t-1} < \underline{S}_m} + \beta_{x,1}s_{t-1}^2\mathbf{1}_{S_{t-1} > \underline{S}_x} + \beta_{m,1}s_{t-1}^2\mathbf{1}_{S_{t-1} < \underline{S}_m} \\ & + \sum_{i=1}^p \beta_{x,1+i} \cos(is_{t-1})\mathbf{1}_{S_{t-1} > \underline{S}_x} + \beta_{x,1+2p+i} \sin(is_{t-1})\mathbf{1}_{S_{t-1} > \underline{S}_x} \\ & + \beta_{m,1+i} \cos(is_{t-1})\mathbf{1}_{S_{t-1} < \underline{S}_m} + \beta_{m,1+2p+i} \sin(is_{t-1})\mathbf{1}_{S_{t-1} < \underline{S}_m}, \end{aligned} \quad (17)$$

with s_t a standardized version of S_t , such that s_t is between 0 and 2π , which is needed for the FFF methodology to work. In our application, S_t is the effective exchange rate series of Canada, Germany, Japan, U.K. and U.S over the period 1990-2010. This series is always less than two. Hence we set $s_t = \pi S_t$ in the application. Because of the second order polynomial, fewer trigonometric functions are needed to achieve a given level of accuracy (Gallant, 1981). In the empirical application, we set $p = 2$.⁹ Note that, given $\underline{S}_x$ and $\underline{S}_m$, the model is linear in the regression coefficients, which makes the model still relatively easy to estimate.

3 Empirical procedure

We evaluate the gains in goodness of fit of the dynamic exposure model against the log-linear model of Jorion on two data sets. The first series we investigate is the 1990-2010 monthly returns of industry indices of Canada, Germany, Japan, U.K. and U.S. The stock market index data are downloaded from Bloomberg and are all market weighted. The market index is proxied by the SPTSX, DAX, TOPIX, ASX and S&P 500 for Canada, Germany, Japan, U.K. and U.S., respectively. Under the Bloomberg sector classification, there are 18 sectors for Canada and Germany, 29 for the U.K., 31 for Japan and 58 for the S&P 500. The second return series we study is the 1990-2010 monthly returns of firms belonging to the S&P 500 on July 31, 2010. Excluding the series with missing observations leads to a total of 116 stocks in 9 sectors. The exchange rate is taken as the close price of the IMF's CPI-based real effective exchange rate for the country at the end of month, and the risk-free rate is the IMF's Treasury bill rate in percent *per annum*.

For each series we first estimate the regression specifications corresponding to the models

⁹In case of quasi-multicollinearity one of the strongly correlated regressors is removed from the specification.

in Table 1.¹⁰ The goodness of fit of each of these models is evaluated through a Bayesian type of information criterion, that was designed by Gonzalo and Pitarakis (2002) to select across multiple threshold models. More precisely, when the model has p parameters and T observations resulting in a residual sum of squares RSS_T , the information criterion recommended by Gonzalo and Pitarakis is:

$$BIC = \log RSS_T + p \frac{\log T}{T}. \quad (18)$$

This criterion penalizes large models more than Akaike's criterion for which the penalty is $2p/T$.

Chan (1993) and Hansen (2000) establish the super-fast convergence of threshold parameters like our $\underline{S}_x$, $\underline{S}_m$. Under general assumptions, Hansen (2000) even shows that the estimation uncertainty of $\underline{S}_x$ and $\underline{S}_m$ and $\underline{S}$ can be ignored when computing the asymptotic variance of the slope parameters $(\alpha, \beta, \zeta, \gamma, \delta_+, \delta_-)'$ (conditional on knowing the number of regimes). We therefore compute standard errors of the slope estimators using the standard Newey-West estimator of the parameter covariance matrix.

Because of the non-linearity in the regression specification, standard gradient-based procedures to non-linear least squared estimation are likely to be flawed because of local optima. To avoid this, we use a global optimization routine, called differential evolution, in order to obtain the least squares estimates. Note that, given the threshold parameters, the regression becomes a linear function of the parameters. Hence it is possible to concentrate out all other regression parameters from the expression of the residual sum of squares and only optimize over the threshold parameters. This leads to a reliable and computationally convenient estimation procedure.

4 Results

From the description of the models (Section 1) and the estimation procedure (Section 2) the following caveats are in order. First, the diagnostic descriptions in Section 1 of course assume that the piecewise quadratic model is correct. In reality, the estimated critical $\underline{S}_f$ s where the quadratic's slope becomes zero may be way off the true smooth-pasting point, notably

¹⁰To ensure identifiability, we imposed the following parameter space restrictions. A first natural restriction is that $\underline{S}_m, \underline{S}_x > 0$. In the estimation of the 2R Mswitch model, we further impose $\underline{S}_m < 2$. While this value amply exceeds the highest number observed in our real-rate data, the restriction is still needed for identification. Indeed, note that, for large values of $\underline{S}_m$, the variable $2(S_{t-1} - \underline{S}_m) + \Delta S_t \approx \underline{S}_m$ and the coefficient δ_m is no longer unique identified.

if the true functional relation is not well captured by our quadratics, especially at extreme values of the exchange rate, and/or is changing over time. A second sobering thought is that some critical values are quite close to the highest or lowest observed values of S , meaning that some regimes have just a few observations and that some observed terms $(S_t - \underline{S}_+)_+$ or $(S_t - \underline{S}_-)_-$ are almost behaving like dummies for extreme observations. It could be objected that, if we have few observations and/or little variation in the regressors for a certain regime, a significance test would still tell us whether the estimate is to be seriously or not. But the problem with this riposte is that, at this stage, these threshold values are just point estimates without identified confidence intervals.¹¹ Relatedly, the estimated δ s *etc* take the estimated critical $\underline{S}_f$ s and the number of regimes as given. While the references cited above suggest this may be asymptotically correct, the effect still is that the standard errors for the deltas, by ignoring the uncertainties about the estimated critical $\underline{S}_f$ s, might be too narrow in a finite sample like ours. For these reasons, our findings below are to be read as exploratory rather than as hard facts.

These caveats are most relevant if the ambition is to use the regressions to reliably classify each sector into the 3R, 2R-Xswitch or 2R-Mswitch categories. But about the main qualitative findings we feel much more confident: first, there seem to be plenty of non-linear features in the data; and second, disconcertingly few of the non-linear patterns seem to correspond to one of the models proposed here. Below, we flesh out both claims.

The more detailed results are available in Appendix tables 2-6. For the reader's convenience, Tables 2 and 3 summarize some key qualitative features of these results for each sample. In Table 2, which deals with national sector-index data, Panel A documents the occurrence of non-linearities, and provides tallies for each class of models (1-, 2- or 3-regime DEMs, for instance). For the latter purpose we classify the models just on the basis of the position of the knot points relative to the sample range, as in Table 1, ignoring the values of the deltas at this stage.

The results in Panel A show that, among the 145 relations we estimated, not one opts for the standard loglinear regression as statistically attractive, in the BIC sense, compared to a DEM: in all cases, the drop of explanatory power when going from a DEM model to the standard loglinear version is too substantial. The column "1R", next, has zero entries too.

¹¹For the single threshold model, a method to construct confidence bands is proposed by Hansen (2000) based on inverting the likelihood ratio test, but its extension to a multiple threshold model is not obvious.

Table 2: Distribution of models for sector returns, grouped by country.

Panel A: Classification on basis of $\underline{S}_f$							
Country	3R MX closed	3R MX ambi	2R Mswitch	2R Xswitch	1R	log- linear	Nsectors
Canada	9	9	0	0	0	0	18
Germany	8	10	1	0	0	0	19
Japan	6	22	1	1	0	0	30
UK	5	23	0	1	0	0	29
US	17	32	0	0	0	0	49
All	45	96	2	2	0	0	145

Panel B: Classification on basis of $\underline{S}_f$ and sign of δ s								
Country	3R MX closed	3R MX ambi	2R Mswitch	2R Xswitch	1R	log- linear	other	Nsectors
Canada	9	9	0	0	0	0	0	18
Germany	6	10	0	0	0	0	3	19
Japan	3	16	1	1	0	0	9	30
UK	5	20	0	0	0	0	4	29
US	15	28	0	0	0	0	6	49
All	38	83	1	1	0	0	22	145

Key: XMS refers to export-import switch, MS to import switch, XS to export switch, and nR to “ n regimes”. The number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates.

In Panel A, the classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the second panel, we also look at the slopes and classify all equations where at least one delta has the wrong sign as “other”.

That is, the relationship between V and S is not captured by a single quadratic either: we always need some semi-spline feature, with either one single knot point (the 2R models) or two (the 3R cases).

When we look at the types of models that do seem to do well, the following tentative conclusions emerge. First, almost all semi-splines seem to be of the three-regime type, suggesting that the quadratic approximation changes shape at least twice. Within that group, the “ambi” variant dominates two to one (96 to 45, out of 145). That is, there is less evidence of “semi-closed” sectors, exposed only at extreme rates and with a zone of middling exchange rates where the sector seems to be unaffected by forex markets. Rather, the middle zone looks like a domain where two relations overlap. The two-regime semi-spline is a very distant second: in 4 out of 145 cases, there seems to be an exposed stretch, petering out into an unexposed one within the range of observed exchange rates. M- and X-switch versions are equally represented.

When we next bring the signs of the deltas into the picture. In the appendix tables, all series that lead to at least one negative delta (at the 5% significance level) are marked with a “ $\times$ ” sign, and their tallies are summarized in Panel B of Table 2. We see that 20 out of 141 of the 3-regime models actually reject the hypothesis that the deltas are positive, signaling a

Table 3: Distribution of models for S&P 500 stock returns, grouped by sector.

Panel A: Classification on basis of $\underline{S}_f$								
Sector	3R MX closed	3R MX ambi	2R Mswitch	2R Xswitch	1R	log- linear	Nfirms	
Consumer Discret.	5	14	0	0	0	0	19	
Consumer Staples	3	9	1	0	0	0	13	
Energy	1	5	0	0	0	0	6	
Financials	3	11	0	0	0	0	14	
Healthcare	4	9	0	1	0	0	14	
Industrials	5	12	0	0	0	0	17	
Information Tech.	3	10	3	0	0	0	16	
Materials	1	5	0	0	0	0	6	
Utilities	3	8	0	0	0	0	11	
All	28	83	4	1	0	0	116	
Panel B: Classification on basis of $\underline{S}_f$ and sign of δs								
Sector	3R MX closed	3R MX ambi	2R Mswitch	2R Xswitch	log- 1R	linear	other	Nfirms
Consumer Discret.	4	7	0	0	0	0	8	19
Consumer Staples	3	9	1	0	0	0	0	13
Energy	1	5	0	0	0	0	0	6
Financials	3	11	0	0	0	0	0	14
Healthcare	3	7	0	0	0	0	4	14
Industrials	5	11	0	0	0	0	1	17
Information Tech	3	8	3	0	0	0	2	16
Materials	1	4	0	0	0	0	1	6
Utilities	2	6	0	0	0	0	3	11
All	25	68	4	0	0	0	19	116

Key: XMS refers to export-import switch, MS to import switch, XS to export switch, and nR to “ n regimes”. The number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates.

In Panel A, the classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the second panel, we also look at the slopes and classify all equations where at least one delta has the wrong sign as “other”.

concave or partly concave relation that does not fit in with our theoretical logic. The failure rate, one out of seven, is about the same in the two subgroups of 3R models. We relegate the economic interpretation to the concluding section; at this point we just note that in a non-trivial minority of cases there is either a serious flaw in our modeling of the options to trade, or an entirely different logic is at work. This problem is absent in Canada, remains rare in the US too, but arises rather strongly in Japan;¹²

While a failure rate of one out of seven is not dramatic, especially for a model that makes

¹²The wayward behavior of the Japanese series is puzzling. One (untested) conjecture is that, for export kings like those two, the market factor actually loads heavily on export companies and picks up a non-trivial part of the exchange-rate effect, non-linearities and all, so that our model for the non-linearities, being imperfect, cannot capture the concavities anymore.

strong assumptions about the stability of the relationship, it still raises the question whether the aggregation implicit in sector-index data might not be one of the causes. Also the predominance of three-regime models may be due to aggregation. But the sample of 116 SP-500 firms does not bring a fundamentally different picture, as the digest in Table 3 shows. Again, three-regime models dominate totally (with 111 out of 116 cases), and within this class, the middle domain appears to be of the overlapping-curve type rather than the no-exposure type (83 against 28). The loglinear or one-regime model is never selected. And when we finally turn to the sign of the deltas, the rejection rate is slightly higher than for the index data, at one out of six rather than one out of seven. Thus, aggregation across firms seems to explain neither the predominance of three-regime models nor the more-than-occasional occurrence of concavity patterns.

5 Discussion and conclusion

The good news, in a sense, is that the semi-spline or DEM model seems to be very successful at unearthing deviations from the loglinear model, hitherto the workhorse in this literature. The bad news, however, is that it is bringing up somewhat too many patterns that are unexpected under the option-to-trade logic. In many cases, the 'other' model suggests a monotone relation, but with a partly convex, partly concave pattern rather than the smoothly convex relations one expects for importers or exporters, respectively.

What could be the reason? Monotone relations could mean the firms are monodextrous with a simple structure, but our regression specification is too flexible; that is, the wobbly-looking relation might be due to overfitting. Another factor that could be obscuring the patterns might be selective hedging. If the firm covers all or part of its currency exposure only under certain circumstances, then in some zones of the observed S s the slope may be much weaker than elsewhere. But why this leads to concave-looking relations is not that obvious. A third avenue could be an equally hard-to-model feature: the relations shift over time because the firm's chosen technology is changing. For instance, the data for low S s may predominantly correspond to a smaller plant size than the data for high S s. In short, it is fair to conclude, we think, that more work is needed here.

A second finding is that, at least in our data, the patterns are not very different between sectoral and individual-firm data. Perhaps that is less surprising firms that stayed in the SP500 for 20 years must be rather big and therefore heterogenous too. A next step then would be to consider a sample of smaller firms.

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Appendix Tables

Table 4: Canada (Over the sample: $0.840 \leq S_t \leq 1.298$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
bank	3R MX ambi	1.194	1.21	4.305	0.112	0.433	0.374	
capitalgoods	3R MX closed	1.251	1.243	11.678	0.657	-0.262	0.565	
consumer.durables.apparel	3R MX closed	1.219	1.107	18.9	0.029	2.415	0.136	
consumer.service	3R MX ambi	0.927	1.244	1.444	0.063	0.037	0.944	
diversified.financial	3R MX ambi	1.199	1.202	6.932	0.213	0.19	0.632	
energy	3R MX closed	1.234	1.233	-2.162	0.85	-0.465	0.276	
food.staples	3R MX ambi	0.936	1.21	1.001	0.039	0.501	0.258	
Food.beverage.tobacco	3R MX closed	1.199	1.124	5.255	0.062	0.232	0.75	
household.personal.products	3R MX closed	1.228	1.107	21.822	0.759	2.879	0.021	
insurance	3R MX ambi	1.159	1.234	-3.776	0.166	-0.448	0.3	
materials	3R MX ambi	1.207	1.297	-5.575	0.198	-0.187	0.589	
media	3R MX closed	1.035	0.928	-0.096	0.907	1.385	0.702	
real.estate	3R MX closed	1.225	1.139	2.524	0.658	0.579	0.511	
retailing	3R MX closed	1.211	1.202	-8.556	0.192	1.044	0.038	
software.services	3R MX ambi	0.914	0.915	-0.251	0.784	0.588	0.978	
telecommunication	3R MX closed	1.212	1.21	2.921	0.732	0.081	0.805	
transportation	3R MX ambi	1.202	1.247	2.85	0.459	-0.442	0.299	
utilities	3R MX ambi	1.072	1.237	0.572	0.492	0.224	0.442	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 5: Germany (Over the sample: $0.821 \leq S_t \leq 1.092$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
auto	3R MX ambi	0.989	0.997	7.463	0.069	0.029	0.971	
bank	2R Mswitch	0	0.979	-0.702	0.011	-7.594	0.002	$\times$
chemicals	3R MX closed	1.022	0.966	6.704	0.364	-1.294	0.018	$\times$
media	3R MX closed	0.984	0.945	-1.366	0.869	0.184	0.939	
basic resources	3R MX ambi	0.99	1.006	-6.233	0.26	0.27	0.768	
food beverage	3R MX ambi	1.011	1.017	-12.59	0.179	1.615	0.012	
technology	3R MX closed	0.979	0.978	-5.68	0.23	0.526	0.253	
insurance	3R MX ambi	1.011	1.011	7.164	0.272	0.156	0.793	
transportation&logistic	3R MX closed	0.996	0.955	4.356	0.253	5.006	0	
machinary	3R MX ambi	0.825	0.961	3.015	0.018	2.466	0.087	
industrial	3R MX ambi	0.993	0.995	3.527	0.268	-1.353	0.18	
construction	3R MX ambi	0.989	1.02	3.507	0.568	-0.379	0.589	
pharm and healthcare	3R MX closed	1.007	1.006	20.768	0	1.483	0.056	
software	3R MX ambi	0.955	0.995	-1.315	0.638	1.733	0.163	
telecommunication	3R MX ambi	1.022	1.04	-17.415	0.262	-0.551	0.705	
financial service	3R MX closed	0.947	0.944	-1.217	0.796	1.845	0.455	
telecommunication	3R MX ambi	1.003	1.04	9.354	0.154	0.81	0.032	
financial service	3R MX closed	0.971	0.97	-3.326	0.448	1.473	0.128	
consumer	3R MX closed	0.998	0.871	1.406	0.746	-9.032	0	$\times$

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 6: Japan (Over the sample: $0.660 \leq S_t \leq 1.249$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
air transportation	3R MX ambi	0.783	0.896	-0.057	0.882	1.199	0.191	
chemical	2R Xswitch	0.78	2	-0.425	0.167	-0.097	0.136	
construction	3R MX ambi	0.751	0.92	-0.531	0.051	-1.109	0.235	
electric appliance	3R MX ambi	0.672	0.778	0.747	0	-0.114	0.95	
electric power&gas	3R MX ambi	0.861	1.028	-0.697	0.298	0.278	0.505	
fishery agri and forestry	3R MX ambi	0.797	1.153	-1.197	0.003	0.018	0.953	×
food	3R MX ambi	0.781	0.802	-0.697	0	-0.295	0.755	×
glass and ceramics	3R MX ambi	0.783	0.788	0.279	0.299	-1.882	0.255	
info&communication	3R MX ambi	0.785	0.857	-1.094	0.009	0.499	0.722	×
insurance	3R MX ambi	0.781	0.789	-0.438	0.205	-0.767	0.586	
iron&steel	3R MX ambi	0.785	1.015	0.553	0.249	-0.218	0.718	
machinary	3R MX ambi	0.94	1.245	-0.68	0.139	-0.286	0.064	
marine transportation	3R MX ambi	0.912	0.971	0.897	0.35	0.151	0.884	
metal prod	3R MX closed	0.785	0.78	-0.161	0.477	-0.757	0.191	
mining	3R MX ambi	0.783	0.789	-0.505	0.298	1.967	0.328	
security and commodity future	3R MX ambi	1.018	1.028	-0.678	0.55	-0.73	0.214	
nonferrous metals	3R MX ambi	0.787	0.857	-0.077	0.822	-1.609	0.122	
oil&coal	3R MX ambi	0.78	1.07	-0.181	0.668	0.745	0.171	
pharmaceutial	3R MX closed	0.994	0.78	-0.77	0.544	-4.022	0.148	
precision instruments	3R MX ambi	0.892	1.02	1.189	0.008	-1.196	0.002	×
real estate	3R MX closed	1.009	0.905	-2.673	0.044	-0.065	0.952	×
land transport	3R MX ambi	0.783	0.97	-0.772	0.003	-0.214	0.593	×
pulp&paper	3R MX ambi	0.783	1.021	-0.052	0.916	0.802	0.252	
retail	3R MX closed	0.787	0.786	-0.536	0.012	-2.849	0.263	×
rubber	3R MX ambi	0.793	0.796	0.574	0.191	-0.703	0.593	
service	3R MX ambi	0.785	0.788	-0.568	0.022	-2.277	0.01	×
textile&apparels	3R MX closed	0.786	0.78	-0.145	0.586	0.607	0.723	
transportation equip	2R Mswitch	0	0.895	0.327	0	0.831	0.424	
warehousing harbor transporation serv	3R MX closed	0.788	0.785	-1.172	0	1.598	0.353	×
wholesale	3R MX ambi	0.789	1.245	-0.509	0.297	-0.379	0.406	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 7: United Kingdom (Over the sample: $0.935 \leq S_t \leq 1.335$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
aerospace.defense	3R MX ambi	1.035	1.047	-0.148	0.768	-5.432	0.236	
automobiles.parts	3R MX closed	1.289	1.166	-3.475	0.826	1.924	0.344	
banks	3R MX ambi	1.082	1.155	-1.838	0.016	0.771	0.353	×
beverages	3R MX ambi	1.035	1.04	0.321	0.332	0.616	0.858	
chemicals	3R MX ambi	1.091	1.166	0.268	0.575	-0.04	0.968	
construction.materials	3R MX ambi	0.944	1.087	0.432	0.163	-2.41	0.308	
electricity	3R MX ambi	1.039	1.279	-0.825	0.119	0.137	0.766	
electronic.equipment	3R MX closed	1.028	1.027	-0.112	0.862	9.589	0.252	
equity.investment.instruments	2R Xswitch	1.024	1.335	0.137	0.511	-0.532	0.021	×
financial.services	3R MX ambi	1.031	1.077	-0.456	0.258	-2.034	0.334	
telecommunications	3R MX ambi	1.035	1.276	-0.145	0.774	1.701	0.01	
food.drug	3R MX ambi	1.046	1.166	0.128	0.779	3.244	0	
food.producers	3R MX ambi	1.011	1.026	0.486	0.054	-0.975	0.885	
forestry.paper	3R MX ambi	1.261	1.319	2.151	0.861	-1.003	0.341	
genera.industrials	3R MX closed	1.004	1.002	0.297	0.318	4.481	0.721	
general.retailers	3R MX ambi	1.024	1.298	-0.047	0.889	0.099	0.826	
health.care	3R MX ambi	0.957	1.176	-0.359	0.331	-1.521	0.111	
engineering	3R MX ambi	1.04	1.154	-0.154	0.608	-2.622	0.024	×
metals.mings	3R MX ambi	1.061	1.061	-1.084	0.386	-8.269	0.338	
transportation	3R MX closed	1.062	0.948	-0.412	0.292	-150.896	0.061	
leisure.goods	3R MX ambi	1.166	1.176	0.431	0.737	-2.523	0.074	
life.insurance	3R MX ambi	1.024	1.092	-0.578	0.132	0.841	0.684	
media	3R MX ambi	1.014	1.016	0.245	0.404	7.903	0.286	
minging	3R MX ambi	1.031	1.064	0.25	0.659	-8.685	0.008	×
oil.gas	3R MX ambi	1.031	1.062	0.74	0.003	-5.219	0.084	
pharmaceuticals	3R MX ambi	1.047	1.049	0.815	0.149	2.536	0.516	
software.computer	3R MX ambi	1.027	1.031	-0.259	0.476	-1.46	0.776	
technology	3R MX ambi	1.025	1.031	-0.493	0.074	2.255	0.683	
tobacco	3R MX closed	1.295	1.276	-21.285	0.39	-0.879	0.167	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 8: United States (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
S5FDSRX	3R MX ambi	0.916	0.922	-0.827	0.145	6.848	0.653	
S5AUTO	3R MX closed	0.983	0.982	0.364	0.83	-1.809	0.783	
S5AUTC	3R MX ambi	0.982	1.06	1.559	0.254	-1.464	0.401	
S5AIRFX	3R MX ambi	0.963	0.963	-3.956	0.02	3.342	0.684	×
S5AIRLX	3R MX ambi	0.965	1.101	2.183	0.113	4.556	0.006	
S5AEROX	3R MX ambi	0.88	0.951	0.83	0.094	0.809	0.929	
S5BEVG	3R MX ambi	0.932	0.965	1.174	0.031	0.419	0.955	
S5BIOTX	3R MX closed	1.045	1.041	4.181	0.361	-7.161	0.113	
S5BUILX	3R MX closed	1.058	1.056	-9.39	0.083	-4.87	0.028	×
S5CHEM	3R MX closed	1.031	0.947	4.003	0.023	-7.189	0.278	
S5CFINX	3R MX closed	1.098	0.986	6.093	0.613	-1.943	0.71	
S5CMPE	3R MX closed	0.965	0.902	4.07	0.006	66.344	0.263	
S5CSTMX	3R MX ambi	1.026	1.039	-14.809	0.047	-0.334	0.904	×
S5CONP	3R MX ambi	0.88	1.101	-0.73	0.26	-0.829	0.592	
S5CBNK	3R MX ambi	1.035	1.115	-4.708	0.079	0.108	0.925	
S5CSTEX	3R MX closed	1.082	0.876	6.126	0.527	620.574	0	
S5COMM	3R MX ambi	0.895	0.969	0.315	0.749	-23.179	0.123	
S5DIVT	3R MX ambi	0.883	0.889	-0.155	0.754	-58.265	0.328	
S5ENRE	3R MX ambi	0.895	0.969	4.052	0	-7.261	0.487	
S5ELEQ	3R MX ambi	0.969	1.021	0.202	0.861	-6.349	0.012	×
S5ELUTX	3R MX closed	0.981	0.936	2.542	0.007	-2.561	0.782	
S5FDPR	3R MX ambi	0.964	1.098	0.965	0.209	-0.199	0.886	
S5GASUX	3R MX ambi	0.864	1.136	2.362	0	1.063	0.407	
S5HODU	3R MX closed	0.981	0.903	-2.392	0.042	32.959	0.238	×
S5HOPRX	3R MX ambi	0.934	0.956	0.579	0.41	2.632	0.705	
S5HOTRX	3R MX ambi	1.026	1.033	1.021	0.59	-2.93	0.09	
S5HCPS	3R MX closed	1.087	1.023	-12.003	0.407	0.292	0.909	
S5HCEQ	3R MX closed	1.068	1.031	-1.552	0.543	-2.053	0.33	
S5INSUX	3R MX closed	1.089	1.06	0.319	0.962	2.219	0.107	
S5INDCX	3R MX ambi	0.859	0.895	0.872	0.041	14.954	0.713	
S5LEIS	3R MX closed	0.926	0.923	1.802	0.013	-10.271	0.427	
S5MRET	3R MX ambi	0.932	0.965	-1.446	0.112	8.004	0.241	
S5MEDAX	3R MX ambi	0.869	0.902	-0.183	0.698	25.319	0.353	
S5MUTIX	3R MX ambi	0.876	0.966	1.047	0.197	-1.682	0.925	
S5MACH	3R MX closed	1.087	0.947	11.604	0.042	-0.489	0.94	
S5METL	3R MX ambi	0.947	1.115	1.092	0.383	-4.924	0.002	×
S5OFFEX	3R MX ambi	0.903	0.917	5.049	0	-41.326	0.254	
S5PHARX	3R MX closed	0.975	0.947	1.048	0.221	5.328	0.55	
S5PERSX	3R MX ambi	0.932	0.96	3.452	0.002	-8.566	0.267	
S5PAFO	3R MX ambi	0.904	0.947	0.884	0.316	-15.885	0.146	
S5REITS	3R MX ambi	0.987	1.024	3.075	0.071	-1.352	0.611	
S5ROAD	3R MX closed	1.092	0.932	18.91	0.001	6.869	0.482	
S5SSEQX	3R MX ambi	0.895	0.927	0.512	0.599	12.318	0.685	
S5SPRE	3R MX closed	0.965	0.902	-2.025	0.153	57.878	0.062	
S5SOFT	3R MX ambi	0.88	0.902	0.56	0.534	116.706	0.077	
S5TEXA	3R MX ambi	0.895	1.101	0.228	0.798	-1.296	0.439	
S5TOBAX	3R MX ambi	0.893	0.923	0.614	0.411	26.69	0.203	
S5INSSX	3R MX ambi	0.864	0.902	2.723	0.087	252.604	0.109	
S5INCR	3R MX ambi	1	1.084	7.797	0.033	0.752	0.867	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 9: Consumer Discretionary (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
HRB	3R MX closed	1.099	1.012	38.534	0.071	-3.751	0.481	
CCL	3R MX closed	1.086	0.899	-8.837	0.534	24.435	0.429	
F	3R MX ambi	1.088	1.144	-55.916	0.004	-6.386	0.082	×
GPS	3R MX ambi	0.869	0.932	0.725	0.729	-13.544	0.93	
GT	3R MX ambi	0.982	1.136	-0.415	0.913	-9.72	0.009	×
HD	3R MX closed	0.965	0.963	-1.491	0.443	13.104	0.408	
IGT	3R MX ambi	0.974	1.13	1.7	0.651	-6.153	0.017	×
IPG	3R MX ambi	0.982	0.982	4.49	0.215	-20.658	0.043	×
LEG	3R MX ambi	0.968	1.097	-1.003	0.639	-4.253	0.066	
LEN	3R MX ambi	1.084	1.088	-42.5	0.009	-4.322	0.246	×
LOW	3R MX ambi	1.086	1.098	-21.667	0.153	2.769	0.218	
MCD	3R MX ambi	0.891	1.081	0.526	0.503	-6.041	0.011	×
MHP	3R MX ambi	0.964	1.118	2.231	0.218	-3.14	0.071	
MDP	3R MX closed	1.086	0.988	-54.931	0	7.902	0.217	×
JWN	3R MX ambi	0.953	1.088	-2.907	0.225	-4.991	0.177	
RSH	3R MX ambi	0.879	0.965	2.423	0.216	-3.98	0.739	
TGT	3R MX closed	1.031	0.936	-2.119	0.56	22.591	0.709	
DIS	3R MX ambi	0.963	1.1	0.771	0.552	-7.183	0.001	×
WHR	3R MX ambi	0.982	0.983	-0.091	0.981	-1.762	0.793	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 10: Consumer Staples (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
CLX	3R MX ambi	0.932	0.953	-0.704	0.316	26.43	0.054	
KO	3R MX ambi	0.917	0.954	2.836	0.001	-11.727	0.448	
CCE	3R MX closed	0.936	0.934	3.16	0.203	4.435	0.857	
COST	3R MX ambi	0.944	1.034	-0.587	0.727	-5.029	0.25	
K	3R MX ambi	0.943	0.965	2.223	0.076	-8.741	0.228	
KR	3R MX ambi	1.062	1.104	-8.765	0.16	0.079	0.962	
MKC	3R MX ambi	0.901	1.028	0.425	0.691	4.695	0.098	
TAP	2R Mswitch	0	1.021	0.579	0.011	5.311	0.263	
PG	3R MX ambi	0.952	0.953	0.788	0.394	-1.363	0.876	
SYT	3R MX closed	1.065	0.936	-0.43	0.946	9.741	0.438	
HSY	3R MX ambi	0.925	0.931	-0.628	0.4	-14.587	0.422	
WMT	3R MX ambi	0.933	1.082	0.435	0.706	1.988	0.36	
WAG	3R MX closed	1.088	0.952	-13.343	0.233	12.871	0.252	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 11: Energy (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
CVX	3R MX ambi	0.891	1.1	0.356	0.535	-1.593	0.179	
COP	3R MX ambi	0.891	1.083	2.089	0.053	0.966	0.549	
EOG	3R MX ambi	0.958	1.083	1.081	0.488	1.987	0.345	
XOM	3R MX closed	1.024	1.023	4.235	0.053	-0.523	0.827	
SLB	3R MX ambi	0.953	0.982	5.442	0.001	-4.926	0.566	
SUN	3R MX ambi	0.921	0.99	-0.737	0.639	-4.243	0.409	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 12: Financials (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
AIG	3R MX ambi	1.062	1.062	15.304	0.524	5.18	0.01	
AON	3R MX closed	0.963	0.953	-0.865	0.463	8.408	0.592	
BAC	3R MX closed	0.989	0.987	-2.025	0.475	7.33	0.27	
SCHW	3R MX ambi	0.966	1.046	-2.237	0.292	-8.547	0.159	
C	3R MX ambi	0.988	0.989	2.964	0.246	2.709	0.656	
HCP	3R MX ambi	0.964	1.011	2.088	0.164	-0.61	0.841	
JPM	3R MX ambi	0.902	0.926	-0.869	0.536	-7.233	0.799	
LM	3R MX ambi	1.009	1.09	-0.536	0.874	-1.693	0.511	
MMC	3R MX ambi	0.952	0.981	-2.324	0.055	9.795	0.082	
RF	3R MX ambi	0.984	1.033	-4.96	0.077	1.277	0.652	
SLM	3R MX closed	1.046	1.045	7.886	0.402	3.449	0.34	
USB	3R MX ambi	1.031	1.053	0.247	0.935	2.156	0.522	
VNO	3R MX ambi	1.009	1.018	0.763	0.772	-3.343	0.085	
WFC	3R MX ambi	1.016	1.116	-1.878	0.473	-2.263	0.23	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 13: Healthcare (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
AET	3R MX ambi	1.004	1.09	-4.187	0.262	-6.815	0.01	×
AMGN	3R MX ambi	1.041	1.104	-6.942	0.286	-4.343	0.058	
BAX	3R MX ambi	0.887	0.908	0.651	0.382	-28.668	0.574	
BMJ	3R MX ambi	0.863	1.009	-0.041	0.936	-3.596	0.447	
CAH	3R MX ambi	0.932	1.058	1.674	0.344	1.717	0.539	
CERN	3R MX ambi	0.908	0.915	-0.717	0.75	-38.152	0.532	
FRX	3R MX closed	0.952	0.951	0.32	0.908	-8.376	0.535	
HUM	2R Xswitch	0.936	2	-9.53	0.1	-1.883	0.007	×
JNJ	3R MX closed	0.969	0.967	2.438	0.086	5.761	0.475	
LLY	3R MX ambi	0.92	0.932	1.646	0.265	-8.572	0.65	
MRK	3R MX closed	1.115	1.058	-124.062	0	2.61	0.379	×
MYL	3R MX ambi	0.921	1.027	1.351	0.552	-7.628	0.141	
PFE	2R Xswitch	1.017	2	-6.039	0.067	-0.555	0.01	×
STJ	3R MX closed	1.022	0.952	-3.805	0.242	-15.54	0.061	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 14: Industrials (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
AVY	3R MX ambi	0.917	1.035	0.621	0.644	-0.459	0.887	
BA	3R MX ambi	0.87	0.883	2.251	0.008	187.664	0.026	
CAT	3R MX ambi	0.981	1.06	6.219	0.034	2.717	0.324	
CSX	3R MX closed	1.067	0.936	14.752	0.053	22.106	0.076	
CMI	3R MX ambi	0.921	1.144	0.396	0.885	-2.268	0.445	
DOV	3R MX ambi	0.916	1.142	1.799	0.237	-1.496	0.447	
FAST	3R MX ambi	0.92	0.963	0.374	0.817	1.574	0.877	
GE	3R MX ambi	0.963	1.021	1.607	0.363	-2.322	0.519	
HON	3R MX ambi	0.917	0.926	2.713	0.051	-34.657	0.209	
LMT	3R MX closed	0.996	0.966	1.297	0.585	6.696	0.458	
MAS	3R MX ambi	0.991	1.058	0.168	0.965	-7.13	0.071	
PCAR	3R MX closed	1.01	0.982	2.793	0.33	10.466	0.252	
PBI	3R MX ambi	0.917	0.963	-0.314	0.828	1.093	0.897	
LUV	3R MX closed	1.035	0.937	11.09	0.066	31.835	0.04	
TYC	3R MX ambi	0.861	0.879	0.786	0.563	-1239.187	0	×
UNP	3R MX closed	1.025	1.024	2.13	0.459	1.628	0.588	
UTX	3R MX ambi	0.937	1.117	1.489	0.077	-3.02	0.059	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 15: Information Technology (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
ALTR	3R MX ambi	0.902	1.052	-0.553	0.838	-10.61	0.107	
AAPL	2R Mswitch	0	0.932	0.778	0.008	49.189	0.094	
AMAT	3R MX closed	1.058	0.947	14.653	0.024	10.86	0.594	
CSCO	3R MX ambi	0.868	0.951	1.501	0.312	-52.24	0.024	×
DELL	2R Mswitch	0.857	1.064	3.336	0.059	-0.573	0.886	
HPQ	3R MX ambi	0.902	1.089	-1.676	0.252	-9.945	0.001	×
INTC	3R MX ambi	0.932	0.952	3.77	0.028	0.265	0.99	
IBM	2R Mswitch	0.163	1.064	0.809	0	0.771	0.801	
MU	3R MX ambi	0.931	0.972	0.4	0.893	-4.87	0.816	
MSFT	3R MX ambi	0.947	0.972	5.673	0	11.147	0.31	
MSI	3R MX ambi	0.947	1.097	3.126	0.113	-4.846	0.102	
NSM	3R MX ambi	0.951	0.952	4.21	0.111	-42.099	0.077	
ORCL	3R MX closed	0.901	0.894	4.657	0.002	350.994	0	
SYMC	3R MX closed	1.119	0.88	308.165	0.024	143.494	0.532	
TER	3R MX ambi	0.085	0.934	1.117	0.001	37.558	0.221	
XRX	3R MX ambi	0.902	0.917	5.788	0.001	-43.043	0.434	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 16: Materials (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
AA	3R MX ambi	0.947	1.091	1.196	0.418	-5.243	0.064	
BLL	3R MX ambi	0.936	0.968	1.177	0.347	13.467	0.126	
DD	3R MX ambi	1.044	1.059	4.479	0.136	0.35	0.873	
NUE	3R MX ambi	0.916	1.052	-0.307	0.843	-13.423	0	×
SIAL	3R MX ambi	0.969	1.053	5.375	0.002	0.692	0.818	
VMC	3R MX closed	1.079	1.012	-23.808	0.204	-3.923	0.33	

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.

Table 17: Utilities (S&P 500) (Over the sample: $0.857 \leq S_t \leq 1.149$).

	selectedmodels	Sx	Sm	$\delta_x/\delta/\zeta$	pvalue	δ_m/η	pvalue	other
CEG	3R MX ambi	1.111	1.144	-224.222	0	-1.798	0.227	×
DUK	3R MX ambi	0.906	0.916	1.642	0	38.389	0.339	
EIX	3R MX ambi	0.916	0.965	2.672	0.001	15.263	0.38	
EXC	3R MX closed	0.96	0.959	2.81	0.074	8.557	0.159	
TEG	3R MX ambi	1.017	1.018	2.739	0.05	1.479	0.634	
NEE	3R MX ambi	0.926	0.953	2.669	0.001	4.072	0.578	
POM	3R MX ambi	0.963	0.989	2.821	0.044	-2.429	0.688	
PPL	3R MX ambi	0.86	0.933	0.434	0.654	2.082	0.905	
PGN	3R MX closed	1.031	0.932	1.508	0.345	5.335	0.677	
SCG	3R MX closed	1.089	0.916	-21.721	0.009	7.996	0.447	×
TE	3R MX ambi	0.965	1.149	2.376	0.264	-1.962	0.047	×

Key: nR means there seem to be “ n regimes”. The estimated number of regimes is unity plus the number of estimated critical rates $\underline{S}_f$ that fall in the observed range of exchange rates. The classification of r -regimes models into export- and import-switch is based on whether the out-of-sample estimated $\underline{S}_f$ is below or above the observed range. In the last column, a “ $\times$ ” signals a significantly negative delta (at $\alpha = 0.05$), which is incompatible with the model’s logic.