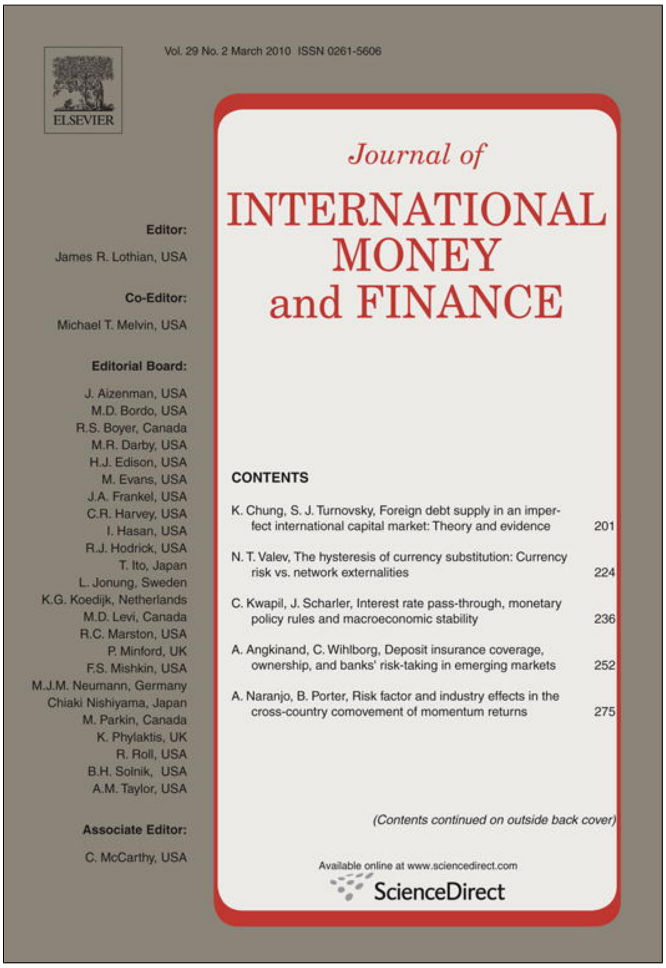
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International order flows: Explaining equity and exchange rate returns

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A B S T R A C T

Macroeconomic models of equity and exchange rate returns perform poorly at high frequencies. The proportion of daily returns that these models explain is essentially zero. Instead of relying on macroeconomic determinants, we model equity price and exchange rate behavior based on a concept from microstructure–order flow. The international order flows are derived from belief changes of different investor groups in a two-country setting. We obtain a structural relationship between equity returns, exchange rate returns and their relationship to home and foreign equity market order flow. To test the model we construct daily aggregate order flow data from 800 million equity trades in the U.S. and France from 1999 to 2003. Almost 60% of the daily returns in the S&P100 index are explained jointly by exchange rate returns and aggregate order flows in both markets. As predicted by the model, daily exchange rate returns and order flow into the French market have significant incremental explanatory power for the daily S&P returns. The model implications are also validated for intraday returns.

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1. Introduction

The aggregate stock market index and the exchange rate are known to have a very low correlation with any other measurable macroeconomic variable except at very low frequencies (Frankel and Rose, 1995; Rogoff, 2001). Financial economists interpret this very lack of predictability as evidence for efficiency, whereby only unpredictable news should move prices. But even gathering proxy variables for news ex-post does not seem to substantially increase the explanatory power of asset pricing models (Roll, 1988). This motivates us to examine a new financial market variable called order flow in its relationship to stock and exchange rate returns. Order flow is the net of buy minus sell *initiated* orders.[3] In the foreign exchange market, daily exchange rate returns and daily order flow show a remarkably high correlation (Evans and Lyons, 2002a,b,c; Killeen et al., 2006) and even permanent changes in the exchange rate appear to be explained by order flow. Unfortunately, most of the microstructure literature features order flow as an exogenous variable in a single market setting. Its very origin remains unexplained and this lack of economic structure constrains the analysis.

In this paper we derive order flow as the result of belief changes by heterogenous investor groups and explore if such a paradigm can structurally explain international equity and exchange rate returns. First, we provide a micro-founded market model in which order flow is the result of belief changes of three different investor groups. This allows for a structural interpretation of order flow regressions. The model features a two-country multi-market setting in which we can explore the relationship between equity, foreign exchange and bond markets. In particular, we obtain testable restrictions which link equity returns to the various order flows. We explicitly model exchange rate determination unlike much of the international investment literature (see Albuquerque et al., 2006). Second, we show that our empirical framework explains up to 60% of the daily return variations in the S&P 100 index. In accordance with the theory, both exchange rate returns and order flow into the overseas market have explanatory power for the domestic stock market returns. Third, our model can account for observable asymmetries in the correlation structure between equity returns and exchange rates. For example, most U.S. equity market appreciations typically come with U.S. dollar appreciations, while European equity market returns correlate negatively with Euro appreciations.

The starting point of our analysis is a coherent interpretation of order flow itself. What motivates trades through market orders as opposed to limit orders? In most microstructure models of limit order markets those market participants with private asset valuations removed from the current midprice tend to pursue market order strategies.[4] The intuition is straightforward. Execution uncertainty related to limit order submission is a multiplicative factor of the expected benefit of a trade. In the absence of risk aversion, the probability of non-execution reduces the expected trade benefit linearly as the difference between current midprice and the private value increases. The cost of market order submission by contrast is an additive cost related to the effective spread. It is unchanged by more extreme private asset valuations. A large change in the asset valuation by a segment of market participants will therefore tend to trigger predominantly market orders. This feature of modern limit order markets makes order flow a suitable proxy for (substantial) investor belief changes. Our simple market model captures this aspect, namely order flow is simply a linear function of belief changes. Hence, order flows can be used to identify heterogeneous belief changes within a segmented investor population. We do not deny that other trade motivations like (urgent) hedging or liquidation needs might also come with a preference for market over limit order implementation of the transaction. These trades are outside the model framework and feature as noise in the empirical analysis. We also highlight that we are agnostic about the source of the belief changes. These could be based on private information or have a behavioral explanation.

[3] Occasionally, order flow is also referred to as order imbalance.

[4] See for example Harris (1998), Parlour (1998), Foucault (1999), Biais et al. (2000). Empirical evidence on the trade-off between execution risk and spread costs is provided by Biais et al. (1995), Grifffiths et al. (2000), Harris and Hasbrouck (1996). See also Hollifield et al. (2004) for a non-parametric test of the hypothesis that order submission strategies depend on the distance of private asset values from the current midprice.

There is a growing literature that considers equity valuation in the context of dispersion of IBES (Institutional Brokers' Estimate System) forecasts. For example, Basak (2000) studies the behavior of security prices in the presence of investors' heterogeneous beliefs regarding the price of risk. In Basak (2005) the basic analysis is generalized to incorporate multiple sources of risk and disagreement about non-fundamentals. Anderson et al. (2005) provide a theoretical treatment of heterogeneous beliefs as well as empirical evidence showing that heterogeneous beliefs matter for asset pricing. A central feature of much of the theoretical literature is a reliance on the combination of behavioral constraints and heterogeneous beliefs. Miller (1977) argues that short-sale constraints could lead to an over-valuation effect because negative views are not acted upon to the same extent as positive ones. An example of the 'investing with constraints' literature is Boehme et al. (2006) where short-selling restrictions combined with dispersion in beliefs are shown to imply Miller's overvaluation effects. This follows similar work such as Diether et al. (2002) who find that raw returns of stocks with higher dispersion of analysts' earnings forecasts earn lower future returns than a control sample.

There are only a few contributions in the literature where belief changes are aggregated to the country level. Kothari et al. (2006) are of interest because they examine earnings announcements at an aggregate level. This is part of an empirical literature that tests whether stock prices move in response to cash-flow news or discount-rate news (Campbell and Shiller, 1988). In contrast with firm-level evidence, Kothari et al. find that aggregate returns and aggregate earnings growth are negatively correlated for the U.S. equity market. They also find that aggregate earnings growth is strongly correlated with discount-rate proxies such as T-bill rates and that cash-flow news is largely idiosyncratic. In other words, positive market-wide earning innovations are associated with increased discounting because of the macroeconomic policy reaction, such that a negative valuation reaction is found. But we also note that Bernard and Thomas (1990) find exceedingly slow and small price reaction to this kind of public news.

A literature which relates more directly to changes in market-wide beliefs, with tenuous links to fundamentals, is the 'investor sentiment' literature. A recent example is due to Kumar and Lee (2006) who examine trades of a very large retail investor sample and find that trading direction has a significant systematic component. A similar finding is expressed in the work of Brown et al. (2003) relating to the investment decisions of mutual funds. These papers relate comovements to commonly held market sentiment which is arguably indistinguishable from belief changes about market-wide fundamentals or about macroeconomic stance. To our knowledge there is no research that relates sentiment changes at the national level to international equity portfolio flows, signed order flows or exchange rate returns.

Previous work on the relationship between asset returns and order flow has typically been focused on a single asset market. The focus of our paper is the market interaction between equity and exchange rate markets in a partially segmented international asset market. Recent empirical and theoretical work have emphasized the limited market integration of the global equity market (Karolyi and Stulz, 2003; Hau and Rey, 2004, 2006, 2008; Stulz, 2005). The microstructure approach used here can be useful in understanding international market interdependence. We show that domestic equity returns should not only be highly correlated with domestic order flow, but exchange rate returns and order flow into the overseas market should have additional explanatory power for domestic equity returns. The additional explanatory power of overseas order flow is a direct consequence of international equity market interdependence. Order flow in the domestic market may originate either in belief changes of domestic investors or alternatively in belief changes of international investors. But these two types of belief changes are likely to have a very different price impact. The domestic order flow is therefore an insufficient statistics to capture this heterogeneity. However, the belief change of the international investor has a simultaneous impact on the exchange rate and the foreign equity market as well as on the order flow in the oversea market. These variables therefore help to identify the nature of the belief shock causing the domestic price change. Hence, oversea order flow has additional explanatory power for domestic equity returns even after accounting for the total domestic order flow. We highlight that the overall explanatory power for daily index returns is astonishing. For the S&P100 we are able to explain around 60% of the daily return variation and for the CAC40 approximately 40%.

International portfolio managers often highlight the asymmetry in the correlation structure of equity and exchange rate returns. Table 1 documents the negative correlation of the U.S. dollar return

Table 1
Asymmetry of exchange rate correlations with stock indices. Reported are correlations of daily bilateral dollar (log) exchange rate returns, R^E, with (1) the US stock index return, R^H, and (2) the foreign country stock index return, R^H (in local currency), for 17 OECD countries for the pre-Euro period 01/01/1992–31/12/1998 (Panel A) and the post-Euro period 01/01/1999–31/06/2006 (Panel B). We report a non-parametric Z-test based on Kendall rank correlations for the null hypothesis that the correlation is zero.

Panel A: pre-Euro period 01/01/1992–31/12/1998				
Foreign country	(1) US stock index		(2) Foreign stock index	
	$\mathrm{Corr}[R^H, R^E]$	Z-test	$\mathrm{Corr}[R^F, R^E]$	Z-test
Australia	0.014	−0.159	0.053	3.523
Austria	−0.127	−6.148	−0.172	−5.701
Belgium–Lux	−0.152	−6.400	−0.191	−7.062
Denmark	−0.155	−6.922	−0.082	−3.486
Finland	−0.111	−5.329	−0.064	−2.250
France	−0.162	−6.898	−0.251	−10.774
Germany	−0.165	−7.044	−0.137	−5.368
Ireland	−0.131	−5.855	−0.167	−4.493
Italy	−0.129	−5.416	−0.014	−0.974
Japan	−0.047	−2.878	0.053	1.816
Netherlands	−0.161	−7.050	−0.245	−10.773
Norway	−0.133	−5.650	−0.115	−4.657
Portugal	−0.122	−6.349	−0.046	−2.035
Spain	−0.129	−5.624	−0.167	−7.100
Sweden	−0.077	−3.000	−0.113	−2.690
Switzerland	−0.170	−7.254	−0.221	−9.165
UK	−0.110	−4.461	−0.184	−7.944
Average	−0.122		−0.121	

Panel B: post-Euro period 01/01/1999–31/06/2006				
Foreign country	(1) US stock index		(1) Foreign stock index	
	$\mathrm{Corr}[R^H, R^E]$	Z-test	$\mathrm{Corr}[R^F, R^E]$	Z-test
Australia	0.067	1.753	0.094	3.074
Austria	−0.190	−7.427	−0.057	−2.576
Belgium–Lux	−0.009	−7.372	0.001	−5.125
Denmark	−0.183	−7.044	−0.052	−3.089
Finland	−0.192	−7.482	−0.119	−5.654
France	−0.192	−7.558	−0.174	−7.474
Germany	−0.191	−7.457	−0.180	−7.455
Ireland	−0.192	−7.502	−0.086	−3.160
Italy	−0.187	−7.458	−0.144	−6.648
Japan	−0.065	−2.531	0.036	2.523
Netherlands	−0.186	−7.340	−0.181	−8.593
Norway	−0.129	−5.570	−0.033	−2.691
Portugal	−0.084	−7.421	−0.038	−3.295
Spain	−0.190	−7.405	−0.127	−5.724
Sweden	−0.033	−1.583	0.006	−1.296
Switzerland	−0.241	−9.247	−0.207	−7.730
UK	−0.126	−5.836	−0.159	−6.808
Average	−0.139		−0.089	

with the U.S. equity market index and the even more negative correlation of all European equity markets with the same exchange rate return. A symmetric setting should imply opposite signs for the respective correlations, hence the notion of asymmetry in the correlation structure. Our model framework can account for this asymmetry. The exchange rate correlation can be negative for both home and foreign country even after controlling for equity order flows. In particular, differences in the

Table 2
Investment opportunities. Represented are the investment opportunities for the four funds $i = e, b, h, f$ in the four markets (Yes/No) and the notation for their respective belief innovation in the equity market.

	Fund type							
	International funds				Domestic funds			
	Equity (e)		Bonds (b)		Home (h)		Foreign (f)	
	Invests?	Innov.	Invests?	Innov.	Invests?	Innov.	Invests?	Innov.
Equity markets								
Home country	Yes	μ_e^H	No	–	Yes	μ_h^H	No	–
Foreign country	Yes	μ_e^F	No	–	No	–	Yes	μ_f^F
Bond markets								
Foreign country	No	–	Yes	–	No	–	Yes	–
Home country	No	–	Yes	–	Yes	–	No	–

elasticity of demand faced by the international investor in the home and foreign market should generally result in the observed correlation asymmetry.

Our paper also relates to a recent literature which focuses on the role of order flow in the U.S. equity market. Hasbrouck and Seppi (2001) show that commonality in the order flows of individual stocks explains roughly two-thirds of the commonality in returns. But this paper restricts itself to high frequency intervals. Chordia and Subrahmanyam (2004) study the relationship between order flow and daily returns of individual stocks. Pastor and Stambaugh (2003) find that market-wide liquidity is a state variable important for asset pricing at the daily frequency. Chordia et al. (2002) document for the period 1988–1998 that aggregate order flow in the NYSE is correlated with contemporaneous daily S&P500 returns. But their regressions are not based on any structural model and show much lower explanatory power. To the best of our knowledge, no paper has tried to formally model aggregate equity returns in terms of aggregate equity order flow or related cross country differences in equity order flows to exchange rate movements.

The following section presents the model. Section 3 summarizes and explains the resulting equilibrium relationships. The data is explained in Section 4. The empirical analysis focuses on the two countries for which we were able to construct aggregate daily order flow statistics for an extended time period, namely for the U.S. and France. Section 5.1 discusses the estimation results for aggregate equity daily returns and section 5.2 for intraday returns. Section 6 concludes.

2. The model

The model sketched in this section serves several purposes. First, it is designed to represent a multi-market setting in which different types of fund managers experience exogenous belief changes about the fundamental (or terminal) value of home and foreign equity. Our multi-market setting is a stylized representation of a partially integrated international equity and bond market linked through a common foreign exchange market. Secondly, we wish to capture how belief changes about equity values trigger order flow in each market and lead to simultaneous price changes. Most importantly, it allows for a clear model-based definition of order flow. On the other hand, the model abstracts from bid–ask spreads and the possibility of multiple limit orders submission which both arise naturally in a setting of asymmetric information. Thirdly, we wish to identify a structural relationship between order flow and directly unobservable belief changes. We can then substitute belief changes with order flows and obtain an empirically testable framework relating order flows to market returns.

The multi-market setting features equity and bond markets both at home and at abroad. We assume that there are four different types of agents called 'funds'.[5] These four funds are listed in Table 2. The

[5] To justify competitive price taking behavior, we assume that each investor group is composed of a continuum of atomistic agents. For the price equilibrium only their aggregate risk tolerance matters. Belief heterogeneity within each group represents a less interesting extension as such heterogeneity will "wash out" under aggregation. We therefore focus on heterogeneity across groups.

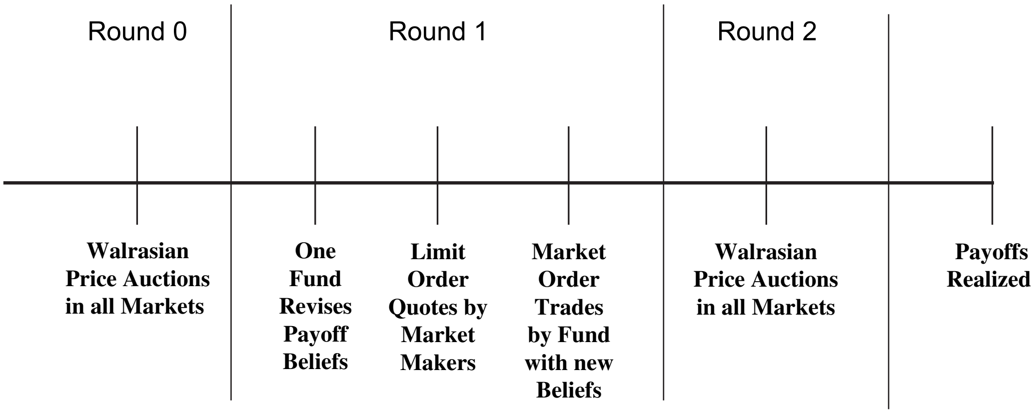

Fig. 1. Market structure.

international equity fund, investing in home and foreign equity; the international bond fund, investing in home and foreign bonds; home country fund, investing in home equity and a home bond; and the foreign fund, investing in foreign equity and a foreign bond.[6] Belief changes about the fundamental value (or liquidation value) of equity we denote by μ. The international equity fund (e) can change its beliefs about both home (H) and foreign (F) equity payoffs μ_e^H and μ_e^F, respectively. The home (h) and foreign (f) funds change beliefs only about their respective domestic market and we denote these belief changes as μ_h^H and μ_f^F, respectively. For simplicity we assume that only one fund type undergoes belief changes over a given trading period. The bond fund (b) is not invested in equity and does not experience any belief changes about equity fundamentals. We highlight that our model features a segmented market in which the exchange rate risk is not diversified. The bonds in both markets are assumed to be in completely price inelastic supply with a constant return in local currency assumed to be r for both home and foreign bonds.[7] The bond prices are normalized to 1 without loss of generality.

Fig. 1 illustrates the market structure for the 3 trading rounds. Round 0 features a Walrasian auction which determines the equilibrium price in each market at the beginning of the trading day. This corresponds to a batch auction at the beginning of the trading day. Market makers as liquidity providers do not participate in round 0. In round 1, either the international equity fund or one of the two domestic funds experience belief changes. Such belief changes about the equity value imply that the fund desires a change in its portfolio allocation. We assume that in round 1 both equity markets and the currency market features competitive risk neutral market makers which accommodate any desire for immediate transactions. The market makers can price discriminate their quotes between the different funds and with respect to size of the transaction. In other words they submit a limit order schedule which depends on which fund experienced a belief change. Such a conditional limit order or quote submission is optimal in both conditioning dimensions. Different fund types have a different equilibrium price impact for the same belief change. Moreover, the size a fund's market order reveals the magnitude of its belief change and therefore indicates the equilibrium price impact.[8] Any asset position acquired by the market makers in round 1 is immediately liquidated in round 2.

The ability of market makers to price discriminate according to the source of a belief change is typically associated with dealership markets in which dealers know their counterparty. But that does not imply that market makers in limit order markets cannot differentiate across different market states.

[6] We fix notation as follows: the four funds are indicated with the subscripts h, f, e and b for home, foreign, international equity and international bond respectively; the superscripts H and F refer to holdings of home and foreign equities respectively and the superscripts B^H and B^F refer to holdings of home and foreign bonds, respectively.

[7] We do not specify what pins down the riskless rate of interest in the model. In addition, there is no distinction between real and nominal returns. The reader may like to think of the riskless rate as being determined by the rate of time preference or a steady state marginal efficiency of capital. Finally, the assumption that the riskless rate is the same in both countries has no bearing on the results.

[8] The market model differs here from the simultaneous trade model (Lyons, 1997; Evans and Lyons, 2002a), in which a price quote is valid for any size of subsequent market order.

We highlight that the belief changes modeled here concern large aggregate investor groups over a daily frequency. It seems more than plausible that market makers can differentiate between a foreign and domestic belief shock and price their liquidity demand accordingly. Transaction volumes in the FX market for example clearly reveal the nature of the belief shock.[9]

The competitive market structure for the market makers implies that the quoted limit order price in round 1 is exactly equal to the expected equilibrium price in trading round 2. This implies that the market makers do not make any trading profits. A fund with a belief change therefore obtains the same transaction price for its market order in round 1 as prevails later in round 2 in a second Walrasian (batch) auction. The trading round 1 therefore only accelerates the price adjustment through market orders. We also note the market order size immediately reveals the new set of payoff beliefs to all market participants. This prevents all other arbitrage trades prior to the final auction in round 2.

Let x_e^H and x_e^F denote the home and foreign equity market investment of the international fund, respectively, and x_h^H and x_f^F the domestic investments of the home and foreign fund. For simplicity, we assume that there are zero net stocks outstanding. The market clearing condition for the equity markets in auction rounds 0 and 2 then takes the form[10]

$$\begin{aligned} x_e^H + x_h^H &= 0 \\ x_e^F + x_f^F &= 0. \end{aligned} \tag{1}$$

Let P^H and P^F denote the prices of home foreign equity, respectively. The foreign exchange market clears for a demand $P^H x_e^H$ of home currency on the part of the international equity market and a home currency demand $x_b^{B^H}$ from the international bond fund. Under zero net balances, we have[11]

$$P^H x_e^H + x_b^{B^H} = 0. \tag{2}$$

We assume that all four funds are fully leveraged and that their net asset position is zero. In combination with the zero net equity supply, this assumption implies that we can neglect risk premia in the analysis. The exchange rate, E, is defined as the ratio of home (U.S.) to foreign currency (Euro), hence an increase in E corresponds to a dollar depreciation.

The investment behavior of the four funds is defined by the following assumption.

Assumption 1. (*Fund objectives*) The four investment funds $i = e, b, h, f$ pursue investment objectives which maximize a CARA objective function given by

$$U_i = \mathcal{E}_i(\Pi_i|I) - \frac{1}{2}\rho_i \mathrm{Var}(\Pi_i|I)$$

where the expected payoffs $\mathcal{E}_i(\Pi_i|I)$ and payoff variance $\mathrm{Var}(\Pi_i|I)$ are conditional on equity prices and the exchange rate ($I = \{P^H, P^F, E\}$) and ρ_i denotes the risk aversion of the fund. The payoff Π_i denotes a fund's stochastic wealth change between the asset position acquired in the Walrasian auction (for periods 0 and 2) or through market order trading (in period 1) and the terminal date when payoffs are realized.

(1) International equity fund (e) chooses optimal home and foreign equity holdings (x_e^H, x_e^F) subject to a budget constraint

$$0 = x_e^H P^H + x_e^F E P^F.$$

[9] Imperfect conditioning on the nature of the belief shock would expose market markers to adverse selection risk. To keep the analysis simple we abstract from the latter.

[10] After the trading in round 1, the market clearing condition has to also account for the temporary positions of market makers and is therefore different.

[11] We could have equivalently expressed the foreign exchange market clearing condition in terms of the demand for foreign currency.

(2) International bond fund (b) chooses optimal home and foreign bond holdings $(x_b^{B^H}, x_b^{B^F})$ subject to a budget constraint

$$0 = x_b^{B^H} + E x_b^{B^F}.$$

(3) Home fund (h) chooses optimal home equity and home bond holdings $(x_h^H, x_h^{B^H})$ subject to the budget constraint

$$0 = x_h^H P^H + x_h^{B^H}.$$

(4) Foreign fund (f) chooses optimal foreign equity and foreign bond holdings $(x_f^F, x_f^{B^F})$ subject to the budget constraint

$$0 = x_f^F P^F + x_f^{B^F}.$$

Each fund participates in the respective asset price auctions in rounds 0 and 2 and chooses optimal market orders in round 1 in consideration of the available liquidity if it experiences a change of payoff beliefs.

The mean–variance framework allows for a particularly straightforward closed-form solution. Our main interest is not the steady state solution of the price system, but its reaction to perturbations. In particular, we are interested in the price and order flow effects if one fund manager changes his belief about the fundamental value of equity. We assume a single stochastic belief change around the correct expected liquidation values of equity. Formally, we have:

Assumption 2. (*Belief changes*) In round 1 either the international equity fund (e) or the home fund (h) or the foreign fund (f) experience a change in their equity payoff beliefs. Starting from beliefs about the steady state liquidation values $(\overline{V}^H, \overline{V}^F)$ of home and foreign equity, the new conditional beliefs $(I = \{P^H, P^F, E\})$ about the fundamental equity value can be expressed as

$$\begin{aligned}
\mathcal{E}_e\left(V^H \middle| I\right) &= \overline{V}^H + \mu_e^H \\
\mathcal{E}_e\left(V^F \middle| I\right) &= \overline{V}^F + \mu_e^F \\
\mathcal{E}_h\left(V^H \middle| I\right) &= \overline{V}^H + \mu_h^H \\
\mathcal{E}_f\left(V^F \middle| I\right) &= \overline{V}^F + \mu_f^F.
\end{aligned}$$

We assume furthermore that the stochastic belief innovations $\mu_e^H - \mu_e^F$, μ_h^H, μ_f^F have a mean zero and that two of the three terms are zero for the horizon of the model since only one fund experiences belief changes.[12]

Heterogeneous belief changes concern only equity valuation. Relative to bonds with predefined cash flows, equity is notoriously difficult to value and might therefore be more exposed to belief changes. These belief changes only concern the first moment. The funds hold identical and correct beliefs concerning the variances. The liquidation value of both the home and foreign equity has a variance σ^2 and the liquidation value of currency a variance σ_E^2.

The price auctions in round 0 and round 2 provide two equilibrium prices. The equilibrium is defined here in terms of market clearing under optimal asset holdings. The round 2 prices reflect the belief change about the payoffs. This allows us to link the belief innovations to the returns in each

[12] Extending the model to simultaneous belief innovations of multiple funds is possible. However, the inference problem of the market makers then becomes more difficult. Their optimal limit order schedule has to account for the correlation structure of the belief innovations.

market. But we are not only interested in the link between returns and belief innovations. We would also like to tie the belief innovations to the order flows in each market. For this purpose, we introduce round 1 in which risk neutral market makers quote optimal limit order prices conditional on the nature of the belief shock. Following the limit order quotation, the funds submit market orders. These market orders determine the order flow and represent changes in holding levels. The optimal size of the market orders establishes the link between belief changes and the order flow in each market. Assumption 3 states the liquidity demand in round 1.

Assumption 3. (*Competitive risk neutral market makers*) Following the change in fund beliefs, competitive risk neutral market makers provide limit order quotes contingent on the fund type which requested the quote.

Market makers provide liquidity only in round 1 and liquidate their holdings in round 2. Hence they do not change the asset returns between round 0 and round 2. However, the existence of the market makers allows us to characterize the order flow effect of the belief innovations. The risk neutrality of the market makers allows for a relatively simple characterization of the liquidity demand in round 1. The expected price in round 2 is a linear function of a fund's belief changes. Furthermore, a funds' market order size reveals his belief innovation. Hence, it is easy to characterize the competitively quoted limit order price which equals for a given market order size the round 2 equilibrium price. A larger market order implies more price deterioration. The fund managers will still trade since their subjective payoff beliefs will generally deviate from the round 2 asset price. However, they will take the price deterioration due to larger market order into account when they choose the market order size.

3. Equilibrium relationships

The objective function of each fund is defined in terms of mean and variance of the terminal payoff. This allows for simple linear asset demand functions for each fund. Combined with the market clearing condition for the two equity markets and the FX market, we therefore obtain a linear system of three equations which characterizes the equilibrium prices and returns as a function of the belief changes. The three markets in our model are interrelated in the sense that a belief shock in one market affects the equilibrium price in the other two. For example, a positive belief shock for the home fund manager will increase the price of domestic equity. Higher prices in domestic equity induce a substitution effect on the part of the international equity fund, which will increase its demand for foreign equity and reduce its home country equity holdings. This increases the foreign equity price and at the same time increases the demand for foreign exchange balances. The foreign currency will therefore appreciate.

The equilibrium return impact of general belief change on the part of all equity investors is summarized in Proposition 1.

Proposition 1. (*Returns and heterogeneous beliefs*) The equilibrium returns $\mathbf{R} = (R^H, R^F, R^E)$ between period 0 and period 2 for home equity, foreign equity, and the exchange rate, respectively, are linearly related to belief changes $\mu = (\mu_e^H, \mu_e^F, \mu_h^H, \mu_f^F)$ about the home and the foreign equity value according to

$$\mathbf{AR} = \mathbf{B}\boldsymbol{\mu}$$

for matrices **A** and **B** defined as

$$\mathbf{A} = \begin{bmatrix} (1+\lambda_h) & -1 & -1 \\ -1 & \left(1+\lambda_f\right) & 1 \\ -1 & 1 & (1+\lambda_b) \end{bmatrix}, \quad \mathbf{B} = \frac{1}{1+r}\begin{bmatrix} 1 & -1 & \lambda_h & 0 \\ -1 & 1 & 0 & \lambda_f \\ -1 & 1 & 0 & 0 \end{bmatrix}$$

a riskless rate r, parameters defined as

$$\lambda_h = \frac{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}{\rho_h\sigma^2}, \quad \lambda_f = \frac{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}{\rho_f\sigma^2}, \quad \lambda_b = \frac{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}{\rho_b(1+r)^2\sigma_E^2}. \tag{3}$$

Proof. See Appendix.

The return vector **R** is uniquely determined by the belief changes $\boldsymbol{\mu}$ as long as the matrix **A** is non-singular. The three equilibrium equations result directly from the market clearing condition in the home and foreign equity markets and in the foreign exchange market. The belief changes μ_e^H, μ_e^F for the international equity fund always appear symmetrically in the term $\mathbf{B}\boldsymbol{\mu}$ but with opposite sign, hence only the relative belief of the international equity investor change $\mu_e^H - \mu_e^F$ matters for the price determination. The parameters λ_h, λ_f and λ_b denote ratios of asset demand elasticities. For example, λ_h denotes the aggregate demand elasticity of the home equity investors (proportional to $1/\rho_h\sigma^2$) relative to the aggregate demand elasticity of the international equity investors. A lower risk aversion of the home investor or lower home price variance implies a more price inelastic home asset demand and therefore a large parameter λ_h. Belief shocks by the international equity fund then have a more modest home return effect. We also note that the belief changes of the home and foreign fund only enter the first and second equation, respectively, while belief change of the international equity fund affects all three market clearing conditions simultaneously.

Exogenous belief changes are the only source of price change in our model. But such belief changes are not directly observable. But in our stylized trading model, belief changes lead directly to market orders and are therefore revealed through order flow. Generally, belief changes create a motive for each fund to rebalance its portfolio. Theoretically, such rebalancing could occur through a passive limit order submission strategy only. The fund which desires to sell equity would try to maintain the most competitive ask price and reduce its position successively over time as this sell offer is repeatedly executed. In this case the belief shift would not translate into a corresponding (negative) order flow. In practice, however, fund managers typically pursue more active strategies by directly submitting market sell orders. Active order placement tends to accelerate the portfolio rebalancing and avoids front running by other investors. The belief change is then clearly associated with a corresponding (negative) order flow. Recent empirical work on order execution strategies indeed confirm that the likelihood of a market order increases with an investors valuation distance from the spread midpoint (Hollifield et al., 2004). This is captured in our model framework. In round 1 funds react to the belief changes with market orders which result in an aggregate order flow stated in the following proposition.

Proposition 2. (*Equity order flows*) Let the $\boldsymbol{\mu} = (\mu_e^H, \mu_e^F, \mu_h^H, \mu_f^F)$ denotes belief changes about terminal payoffs where the three terms $\mu_e^H - \mu_e^F$, μ_h^H, and μ_f^F have zero mean and two terms are always zero. Under a competitive risk neutral limit order supply, these belief changes trigger in round 1 home and foreign order flow (OF^H, OF^F) given by

$$
\begin{aligned}
OF^H &= k\left[\mu_h^H + \mu_e^H - \mu_e^F\right] \\
OF^F &= k\left[\mu_f^F + \mu_e^F - \mu_e^H\right]
\end{aligned}
$$

where the parameters are defined as

$$
\begin{aligned}
k &= \frac{1}{\Lambda} \times \frac{\lambda_h\lambda_f\lambda_b}{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]} > 0 \\
\Lambda &= \lambda_h\lambda_f\lambda_b + \lambda_h\lambda_f + \lambda_h\lambda_b + \lambda_f\lambda_b.
\end{aligned}
$$

Proof. See Appendix.

Order flow in the home and foreign equity market is proportional to the belief change μ_h^H, μ_f^F of the home and foreign fund, respectively. And in each case order flow depends linearly (with opposite signs) on the relative belief change, $\mu_e^H - \mu_e^F$, of the international equity fund. Hence, as for returns, only the relative belief change is identified though the order flow. It may appear surprising that the belief changes of the international and domestic investor carry equal weights given by k in the measure of total order flow. Intuitively, a less risk averse investor group should submit a larger market order and therefore account for a larger share of the order flow. However, this argument does not account for different price elasticities in the asset demand curve. A less risk averse investor group faces a more price inelastic liquidity demand because of its larger equilibrium price impact. The steeper asset demand curve therefore discourages the more risk neutral investor group from submitting larger market orders and implies equal weights for all belief changes. Differences in risk aversion across investor groups are therefore important for explaining return patterns, but not for the structure of order flows as long as the parameter k is constant.

The international equity fund is also assumed to practice active order placement in the foreign exchange market as a corollary to its rebalancing in the two equity markets. The rebalancing in the two equity markets depends on its own relative belief change $\mu_e^H - \mu_e^F$. The same relative belief change also determines the foreign exchange order flow as stated in Proposition 3.

Proposition 3. (*Foreign exchange order flows*) The international equity fund initiates in round 1 foreign exchange transactions in order to finance overseas equity investments. The foreign exchange order flow OF^E follows as

$$OF^E = k\left[\mu_e^F - \mu_e^H\right].$$

Proof. See Appendix.

The theoretical linkage between order flow in round 1 and the belief changes allow us to restate the structural model in Proposition 1 in terms of observable variables only. In particular, belief changes can be substituted by equity order flows and we obtained a reduced form structure summarized as follows.

Proposition 4. (*Reduced form structure*) The home and foreign equity returns, R^H and R^F, are linearly related to the exchange rate return R^E and the home and foreign equity order flows, OF^H and OF^F, according to:

$$R^H = \frac{1}{3}\left[(1+\lambda_b) + \lambda_b\frac{\left(\lambda_h - 2\lambda_f\right)}{\lambda_h\lambda_f}\right]R^E + \frac{1}{3k(1+r)}\left(2OF^H + OF^F\right) \tag{4}$$

$$R^F = \frac{1}{3}\left[-(1+\lambda_b) + \lambda_b\frac{\left(2\lambda_h - \lambda_f\right)}{\lambda_h\lambda_f}\right]R^E + \frac{1}{3k(1+r)}\left(OF^H + 2OF^F\right) \tag{5}$$

where λ_h, λ_f, $\lambda_b > 0$ and $k > 0$ are the previously defined parameters.

Proof. See Appendix.

The reduced form implies that both home and foreign equity returns can be represented as a linear combination of the exchange rate return and both home and foreign equity market order flows. Moreover, local equity returns are more sensitive to local order flow than the order flow in the overseas equity market. The local order flow has a coefficient twice as large as the overseas order flow. An important advantage of the reduced form is that it can be directly estimated. But before we proceed to estimation, we provide an intuitive explanation for the reduced from structure.

Why does overseas order flow help to explain the local market equity return? The foreign market order flow partly captures belief shifts of the foreign fund. These belief shifts affect the foreign equity price and via the substitution effects of the international equity fund also positively influence the home equity price. On the other hand, these substitution effects occur only in round 2 after the initial price effect in the foreign market is revealed. The substitution effect therefore occurs under public information without any particular order flow implication in the home market. Only the foreign order flow captures the initial price impact of the belief innovations of the foreign fund and the subsequent substitution effect. Hence the additional explanatory power of the foreign order flow for the home return even after controlling for home market order flow. The same applies symmetrically to foreign equity return.

Next we explain why the exchange rate has further explanatory power for the equity returns. Consider first the possibility that risk aversion towards equities is the same for the home and foreign fund. This means that $\lambda_h = \lambda_f = \lambda$. In this case, the exchange rate coefficient in the home equation is $\frac{1}{3}[1 + \lambda_b(1 - 1/\lambda)]$ while that in the foreign equation is equal but opposite in sign. Deviations from this symmetry occur when equity demand elasticity (governed by the risk aversion) of the domestic fund differs across the two countries. Note that the sum of the two exchange rate coefficients is $\lambda_b[1/\lambda_f - 1/\lambda_h]$. If risk aversion for the home fund is lower than that of the foreign fund, this sum is positive and vice-versa. For $\lambda_h = \lambda_f = \lambda$, we can then express the sum of the two returns as a linear function of the sum of the two equity order flows only,

$$R^H + R^F = \frac{1}{k(1+r)}\left[OF^H + OF^F\right].$$

Belief changes by the international equity fund creates off-setting negative and positive order flow and return effects which do not affect the sum of order flow and return. However, this pre-supposes that both equity markets have the same asset demand elasticities. Generally, we have

$$R^H + R^F = \lambda_b\left[\frac{1}{\lambda_f} - \frac{1}{\lambda_h}\right]R^E + \frac{1}{k(1+r)}\left[OF^H + OF^F\right].$$

The exchange rate return R^E now enters as an additional term to explain the sum of equity returns. To develop an intuition consider the case of higher risk aversion for the home than foreign fund (or alternatively higher price variance), so that $\lambda_f > \lambda_h$. Belief changes by the international investor have now a larger price effect in the home than in the foreign equity market because of a relatively steeper home asset demand curve. But as pointed out in Propositions 2 and 3, order flows reflect belief changes equally across investor groups of different risk aversion. For a constant parameter k, relative changes in the risk aversion of the home and foreign fund do not alter the order flows. We therefore need the exchange rate return as an additional statistic to fully explain the sum of return changes. Relative optimism of the international investor about the home market, $\mu_e^H - \mu_e^F > 0$, implies a negative exchange rate return (dollar appreciation), $R^E < 0$. Multiplication with a negative coefficient $\lambda_b[1/\lambda_f - 1/\lambda_h]$ implies a positive contribution in explaining the sum of the returns. This sum should be larger for $\mu_e^H - \mu_e^F > 0$ as the positive return effect of the home inflows is exceeding the negative return effect of the foreign outflows due to the relatively steeper asset demand in the home country.

Our model can therefore explain why the exchange rate should have explanatory power for equity index returns even after controlling for the order flows in both markets. Indeed both exchange rate coefficients in equations (3) and (4) can be negative if the asset demand elasticity of the home fund is relatively low. This corresponds to a situation in which home equity investors find it relatively unattractive to substitute between home equity and home bonds. The negative exchange rate coefficients correspond to a negative correlation between index returns and exchange rates conditional on order flows. Whenever the equity order flows are also uncorrelated with the exchange rate (as is actually the case), it follows that the unconditional correlations should also be negative. We can now return to the evidence presented in Table 1. Unconditional correlations between U.S. stock returns and exchange rate returns are negative as shown in column (1). But the correlations for the corresponding foreign stock markets are also negative for the same exchange rate returns (column (3)). This asymmetry with two negative correlations can arise for $\lambda_f > \lambda_h$. The correlations in Table 1 are explained if the substitutability between equity and bonds is lower for U.S. domestic investors compared to the domestic investors in most foreign countries.

For a more intuitive explanation of the exchange rate asymmetry consider two countries, U.S. and France. First, a positive belief change of the French domestic fund generates positive French order flow, increase the French equity price and via a substitution effect from the international fund implies a higher U.S. equity price. At the same time the euro depreciates against the dollar due to the reallocation of the international equity fund. Second, a positive belief change of the international equity fund about French equity fundamentals implies the exact opposite correlation between French equity returns and the exchange rate. We observe again positive French order flow, a French equity appreciation and a euro appreciation. Since both types of belief changes may occur, we need not observe any systematic correlation between the French equity order flow and the exchange rate. But we also note that the magnitude of the second effect for the equity returns can be muted if the demand elasticity of the French fund is very price inelastic. The belief change of the international fund might then have a very small equity price effect on French equity. As a consequence, the positive correlation between a euro appreciation and French equity returns disappears. Then the first effect coming from the belief changes of the French domestic fund dominates and we obtain the strong observed negative correlation between the dollar exchange rate (denominated in dollar per euro) and French equity returns. But for the U.S., a lower price elasticity of demand by the domestic fund implies that the belief change by international equity fund is relatively important for U.S. equity returns. Again the negative correlation (here induced by the international fund) dominates and the observed asymmetry in Table 1 is explained.

4. Data

An empirical test of the above model would ideally involve many country pairs with developed equity markets. While equity return data is available for almost all countries, the information needed to construct order flow data can only be obtained for a small number of countries. The United States and France are the two largest OECD countries for which individual transaction data on a large part of the domestic equity trading volume is publicly available. We therefore take the U.S. to be the home country and France to be the foreign country. The relevant exchange rate is then the Euro–Dollar rate and we assume that the French equity market is representative of the consolidated euro-zone equity market both in terms of order flow characteristics. Our data span the five-year period from January 1999 to December 2003 and therefore start with the creation of the common European currency.

4.1. U.S. equity data

The U.S. order flow data are constructed from the TAQ database with the help of Wharton Research Data Services. We restrict attention to the stocks in the Standard & Poors 100 index and accounted for *all* their trades on AMEX, NASDAQ and NYSE over the five-year period, approximately 600 million trades in total. All trades are signed as buyer- or seller-initiated depending on whether the executed price was higher or lower than the midpoint between the ask and bid quote respectively.[13] Trades executed at the midpoint are not signed. The value of all buy trades in all of the 100 stocks in each day is accumulated to create a single aggregate daily buyer-initiated equity trade series for the U.S. Corresponding series are constructed for the seller-initiated and unsigned trades. The raw aggregate home equity order flow series (ROF^H) is then derived as the buyer-initiated series minus the seller-initiated series. Trading volume (VOL^H) is derived as the sum of the buyer-initiated, seller-initiated and the unsigned trades series. We define the aggregate normalized order flow series as the ratio of order flow to volume ($\mathrm{OF^H}$). The home equity returns series ($\mathrm{R^H}$) is the first difference of the log of the New York closing value for the S&P100. It was obtained from Datastream.

We also examine the model implications for intraday returns.[14] For this purpose we distinguish the $1\frac{1}{2}$ h period of parallel equity trading (subscripted p) in the U.S. and France from the remaining $22\frac{1}{2}$ h for which equity trading occurs sequentially. The intraday return and order flow corresponding to the parallel trading period are denoted by R_p^H and OF_p^H respectively.

[13] The method used by WRDS restricts itself to quotes that have been in effect for at least five seconds when the trade occurs (see Lee and Ready, 1991).

[14] Intraday index values were obtained from Standard & Poors directly.

4.2. French equity data

French order flow and return data is constructed based on transaction and quote data from Euronext (Données de Marché Historiques). The reference universe consists of all stocks in the French CAC40 index. Again, we use the Lee and Ready (1991) algorithm to sign trades. Analogously to the U.S. data, we obtain daily raw aggregate equity order flow series (ROF^F), daily volume series (VOL^F) and the daily normalized order flow (OF^F). French aggregate daily equity returns (R^F) were defined as difference in the log of the Paris closing price for the CAC40. The French data accounts for approximately 200 million transactions.

Naturally, the home order flow is denominated in U.S. Dollars and the foreign order flow in Euros. We note that the scale of the U.S. market exceeds that of France by almost an order of magnitude. The use of normalized order flow addresses both issues simultaneously as normalized order flow is strictly bounded between -1 and 1. Normalized order flow is also without currency denomination. Again, we divided the trading day into a period of parallel trading when the U.S. equity market is open and the remainder of the day. Hence, OF_p^F refers to late afternoon[15] order flow in the French market with a corresponding return of R_p^F.

4.3. Foreign exchange data

Daily foreign exchange order flow was obtained directly from Electronic Broking Services (EBS). There are three types of trades in the forex market: customer-dealer trades, direct inter-dealer trades, and brokered inter-dealer trades. Customers are non-financial firms and non-dealers in financial firms (e.g., corporate treasurers, hedge funds, mutual funds, pension funds, proprietary trading desks, etc.). Dealers are market makers employed in banks worldwide, of which the largest 10 dealing banks account for more than half of the volume in major currencies.

Our data come from the third trade type: brokered inter-dealer trading. There are two main inter-dealer broking systems, EBS and Reuters Dealing 2000-2. Both offer competing central market places through electronic terminals. Estimates by the Bank of England (2004) suggest that electronic trading in London accounts for 55% of total foreign exchange activity, and 67% of inter-dealer spot business. Similarly, the Federal Reserve Bank of New York (2004) estimates the market share of electronic trading systems is increasing though has not yet reached the level prevailing in the UK. Discussions with industry specialists indicate that EBS has a two-thirds market share in the brokered inter-dealer dollar–euro market. Our data set includes the daily value of purchases and sales in the dollar–euro market for first year of our sample, 1999. They are measured in millions of Euros. Unlike the equities data, no algorithm was needed to sign trades (ex-post) since this occurs electronically at the moment of execution. Each trading day (weekday) covers the 24-h period starting at 21.00 GMT. The daily raw foreign exchange order flow series (ROF^E) is calculated as the value of buy trades minus the value of sell trades. The daily volume series (VOL^E) represents the sum of the value of buy and sell trades and the daily normalized order flow (OF^E) is again defined as the ratio of ROF^E to VOL^E. The dollar–euroexchange rate at the New York close was obtained from Datastream. It is defined as the dollar price of euro. The daily foreign exchange return R^E follows as the difference in the log of the exchange rate level. The spot return during the intraday period[16] of parallel trading is denoted as R_p^E.

Table 3 provides descriptive statistics for the variables used in the estimation. Panel A features the daily variables ROF^E, VOL^E, OF^E, ROF^F, VOL^F, OF^F, ROF^H, VOL^H, OF^H and the three daily returns, R^F, R^H, R^E. Panel B details the following variables during the parallel trading period: R_p^F, R_p^H, R_p^E, OF_p^H and OF_p^F . For each variable, the table shows the mean, the standard deviation and the first-order autocorrelation coefficient.

15 Intraday data for France was also obtained from Euronext.

16 Intraday dollar–euro rates were obtained from Olsen & Associates

Table 3

Summary statistics. For the five-year period 01/1999–12/2003 we report for the U.S. (H) and French (F) equity market, as well as dollar/euro foreign exchange market (E) the mean, standard deviation (S.D.), and first-order autocorrelation (AR(1)) of the stock market returns, R^H (S&P100) and R^F (CAC40), the dollar–euro exchange rate return (R^E), the raw daily order flows (ROF), daily trade volume (VOL), and the normalized order flow (OF) defined as the ratio of raw order flow and volume. The daily exchange rate order flow is available only for 12 months from 01/1999 to 12/1999. Panel A reports these summary statistics for a daily sampling frequency and panel B reports the intraday statistics. We identify the $1\frac{1}{2}$ h of parallel trading (p) when both the U.S. and French equity operate simultaneously.

Panel A: daily data									
Daily volume					Raw order flow				
		Mean	S.D.	AR(1)			Mean	S.D.	AR(1)
VOL^H	$ millions	23,206	7591	0.77	ROF^H	$ millions	1412	1075	0.16
VOL^F	€ millions	3153	1101	0.51	ROF^F	€ millions	37	344	0.17
VOL^E	€ millions	37,217	11,527	0.45	ROF^E	€ millions	519	1103	0.26
Daily returns					Daily order flow				
		Mean	S.D.	AR(1)			Mean	S.D.	AR(1)
R^H	%	−0.007	1.40	−0.03	OF^H	%	0.06	0.05	0.15
R^F	%	−0.008	1.66	0.002	OF^F	%	0.01	0.10	0.18
R^E	%	0.005	0.67	−0.07	OF^E	%	0.01	0.03	0.23
Panel B: intraday data									
Intraday returns					Intraday order flows				
		Mean	S.D.	AR(1)			Mean	S.D.	AR(1)
R_p^H	%	−0.007	0.90	0.009	OF_p^H	%	0.06	0.06	0.10
R_p^F	%	−0.033	0.72	−0.012	OF_p^F	%	0.02	0.12	0.10
R_p^E	%	0.009	0.27	−0.03					

5. Estimation results

5.1. The reduced form for daily returns

Unlike the structural form in Proposition 1, the reduced form in Proposition 4 can be directly estimated. The unobservable belief changes $\boldsymbol{\mu} = (\mu_e^H, \mu_e^F, \mu_h^H, \mu_f^F)$ are substituted for order flow variables which proxy for the belief changes. We note, however, that in the system of two equations, the three parameters λ cannot be separately identified. Moreover, the identification rests on the assumption that the funds undergoing belief changes implement their portfolio change through active order placement strategies. Since we aggregate over a large number of daily transactions in many different stocks to obtain daily order flow, the proxy character of order flow for belief changes should still be preserved if a certain proportion of portfolio change is achieved through passive limit order submission.

Before we estimate the reduced form system, it is instructive to examine how equity returns are affected by own-order flow. Figs. 2 and 3 show scatter diagrams for both the U.S. and France. They show a strong positive correlation. This means that equity index returns are strongly related to aggregate or macroeconomic order flow. But our theory asserts much more. Non-local (or overseas) order flow and the exchange rate return also influence the local equity return. In each equation, the equity return is affected by both home and foreign market order flow. Moreover, local equity returns are more sensitive to local order flow than the order flows into the overseas equity market.

Table 4 displays the estimation results. The upper and lower panels show the results for equations (3) and (4). The first column reports' results using Ordinary Least Squares (OLS). The own-order flow is highly significant in both equations with t-statistics of 27.58 and 16.69 in the home and foreign return equation, respectively. The overseas order flow is also highly significant in both equations with t-statistics of 9.12 and 8.39, respectively. All four order flow coefficients have the correct sign. As predicted by the theory, the magnitude of the coefficient for order flow into the overseas market is less than for own market order flow. The exchange rate return is also significant in both equations. Since

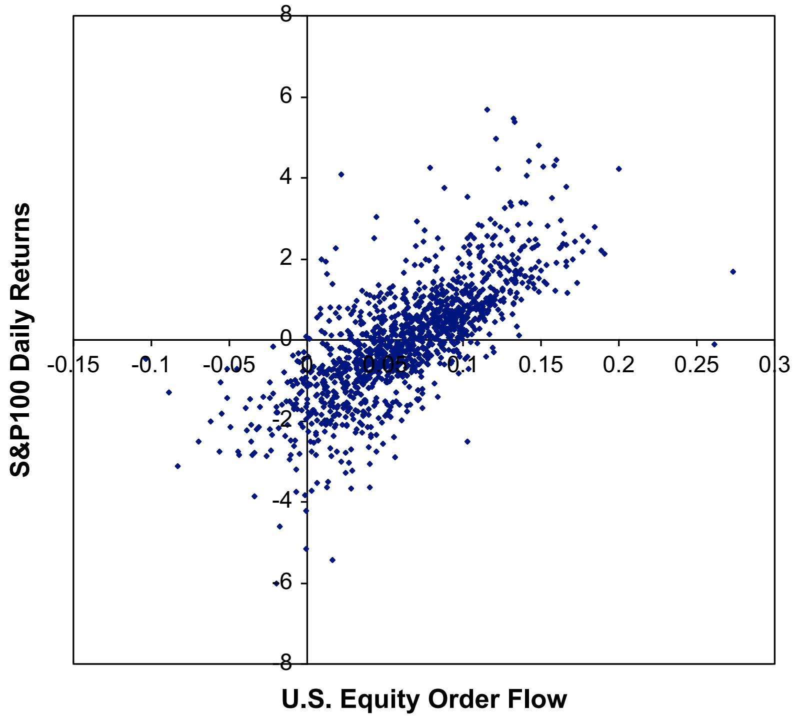

Fig. 2. Plotted are daily returns in the S&P100 index against normalized daily order flow into the U.S. equity market for the five-year period 1999–2003.

both coefficients are negative, we conclude that $\lambda_f > \lambda_h$. Hence, the counterparty asset demand elasticity of domestic relative to international investors is larger for the French than for the U.S. market.[17] We also note that the R^2 in both equations is very high. We succeed in explaining almost 60% of daily aggregate U.S. stock returns. Ljung–Box Q tests for both equations show that there is no evidence of autocorrelation up to 5th order (Fig. 4).

The negative OLS coefficient for the exchange rate in equations (3) and (4) implies a negative correlation between the equity and exchange rate returns conditional on the order flow variables. However, we also find that daily order flows and daily exchange rate returns have a low, but negative correlation. These correlations are -0.18 and -0.16 for home and foreign market order flow, respectively. Omitting the order flow as a control variable creates a negative bias in the unconditional correlation relative to the conditional correlation. Therefore, negative conditional correlations also imply the negative unconditional correlations as reported in Table 1 for a wide cross section of OECD countries.

An obvious criticism against the OLS estimation concerns the endogeneity of exchange rate returns, which implies a simultaneity bias for the coefficients.[18] Finding a suitable instrument for an asset price or its return is generally difficult. However, we know from Evans and Lyons (2002a) that foreign exchange order flow is highly correlated with the exchange rate return. This is confirmed for this particular data set by Hau et al. (2002). We can therefore use foreign exchange order flow as an instrument for the 12 months of 1999.[19] Estimation proceeds by Two-Stage Least Squares (2SLS). Columns 3 and 4 give both the OLS and the 2SLS estimates for the year 1999. Comparing the two sets of estimates for equation (1), it is hard to find any difference between the OLS and 2SLS cases for the first

[17] A narrow interpretation within the two country framework would be that the French domestic investor is less risk averse than the U.S. domestic investor. More generally, differences in the short-run equity demand elasticities my also be influenced by microstructure effects. The centralized limit order book in the French market (Euronext) is reputed for its high degree of liquidity, which could explain a relatively lower price effect of international order flows.

[18] Killeen et al. (2006) show that order flow is weakly exogenous with respect to exchange rate returns. Secondly, they show that order flow is also strongly exogenous with respect to exchange rate returns. Finally, they show strict exogeneity (exchange rate and order flow innovations are orthogonal).

[19] The data on foreign exchange order flow is available only for the first year of the sample.

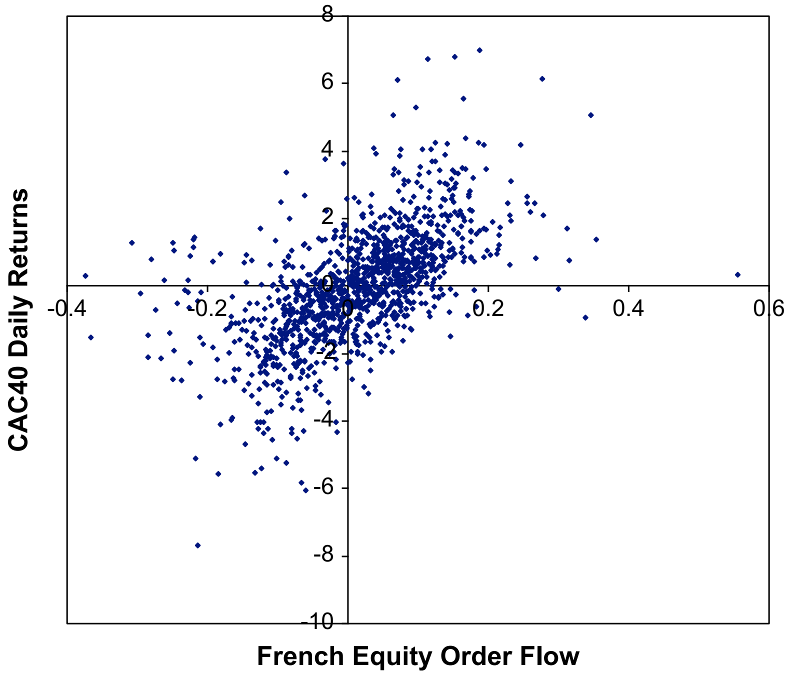

Fig. 3. Plotted are daily returns in the CAC40 index against normalized daily order flow into the French equity market for the five-year period 1999–2003.

year of the sample. This is formally confirmed by the result of the Hausmann specification test in the upper panel. For the foreign returns equation, the only estimate that appears to change is the exchange rate returns coefficient. Nevertheless, it is still negative and significant and again the Hausmann specification test rejects the endogeneity of the exchange rate, at least for this instrument. We conclude that the OLS estimates for the full sample are confirmed by the instrumental variable procedure.[20]

Next, we examine the intertemporal robustness of the return equations. The last line in each of the panels of Table 4 reports the Chow tests on the parameters between 1999 and the rest of the sample. In the upper panel, the estimated coefficients on both the exchange return and foreign order flow appear to be stable. However, the price impact of home equity order flow is smaller for 1999 than for the whole sample. But it is still large, positive and significant. A formal Chow test confirms the absence of intertemporal instability for the U.S. returns equation. For the foreign returns equation, the exchange rate return coefficient is also stable, but both order flow coefficients are smaller in 1999. The upward trend for the order flow coefficients is confirmed by the rejection of the stability assumption underlying the Chow test. Despite this unfavorable statistical result, it is difficult to argue that the 1999 sub-period displays any economically significant difference relative to the whole sample period.

To evaluate the explanatory power of our parsimonious model specification, we confront the data with the exact parameter restrictions. The own-order flow coefficient should be precisely twice the overseas order flow coefficient in both equations. Furthermore, the equivalent coefficients should be the same in both equations. Obviously, the point estimates do not observe these restrictions. A straightforward Wald Test yields a $\chi^2(3)$ test statistic of 397.66. This is a statistically very strong rejection of the parameter restrictions on order flow.[21] But it is natural to ask if model estimation under the exact theoretical parameter restrictions preserves considerable explanatory power for equity returns. In column 2 of Table 4, we show the results of estimating both the home and foreign return equation jointly using Seemingly Unrelated Regressions (SUR). Both the within and cross equation restrictions are now imposed. The explanatory power in the French equation is barely affected by the restrictions, while the R^2 for U.S. return falls to just under 47%. The restricted order flow coefficients

[20] We also estimated the two equations as a system using Seemingly Unrelated Regressions (SUR). It makes almost no difference to neither the estimated coefficients nor the standard errors.

[21] The 1% critical value is 11.345

Table 4
Reduced form estimates for daily data. U.S. and French stock returns, R^H (S&P100) and R^F (CAC40), respectively, are each regressed on the daily dollar–euro exchange rate return R^E as well as daily U.S. (OF^H) and French (OF^F) equity order flow. The equations are estimated using ordinary least squares for the whole sample (OLS, 01/1999–12/2003), ordinary least squares for 1999 only (OLS, 01/1999–12/1999), and two stage least squares for 1999 using foreign exchange order flow as an instrument for exchange rate returns (2SLS, 01/1999–12/1999). We also report a seemingly unrelated regressions (SUR (restricted), 01/1999–12/2003) which imposes the exact parameter restrictions. *T*-tests in parentheses use Newey West robust standard errors.

Panel A: U.S. equity returns

$$R^H = \frac{1}{3}\left[(1+\lambda_b) + \lambda_b \frac{(\lambda_h - 2\lambda_f)}{\lambda_h \lambda_f}\right] R^E + \frac{1}{3k(1+r)}(2OF^H + OF^F)$$

Period	OLS, 01/1999–12/2003		SUR (restricted), 01/1999–12/2003		OLS, 01/1999–12/1999		2SLS, 01/1999–12/1999	
R^E	−0.22	(4.61)	−0.27	(6.04)	−0.22	(2.71)	−0.23	(1.71)
OF^H	21.50	(27.58)	11.58	(40.63)	16.81	(17.75)	16.77	(15.95)
OF^F	2.49	(9.12)	5.79	(40.63)	2.47	(4.21)	2.45	(4.02)
R^2	58.9%		46.5%		63.0%		62.8%	
Q(5)	1.66		1.66		4.30		4.27	
Hausm. test	$\chi^2(4) = 0.05$							
Chow test	$\chi^2(3) = 4.39$							

Panel B: French equity returns

$$R^F = \frac{1}{3}\left[-(1+\lambda_b) + \lambda_b \frac{(2\lambda_h - \lambda_f)}{\lambda_h \lambda_f}\right] R^E + \frac{1}{3k(1+r)}(OF^H + 2OF^F)$$

Period	OLS, 01/1999–12/2003		SUR (restricted), 01/1999–12/2003		OLS, 01/1999–12/1999		2SLS, 01/1999–12/1999	
R^E	−0.17	(2.89)	−0.13	(2.34)	−0.20	(2.12)	−0.38	(2.33)
OF^H	7.32	(8.39)	5.79	(40.63)	3.86	(3.34)	3.08	(2.48)
OF^F	9.19	(16.69)	11.58	(40.63)	6.86	(7.58)	6.61	(7.28)
R^2	40.1%		38.2%		46.4%		44.5%	
Q(5)		3.58		3.58		5.81		4.64
Hausm. test	$\chi^2(2) = 3.79$							
Chow test	$\chi^2(3) = 22.62$							

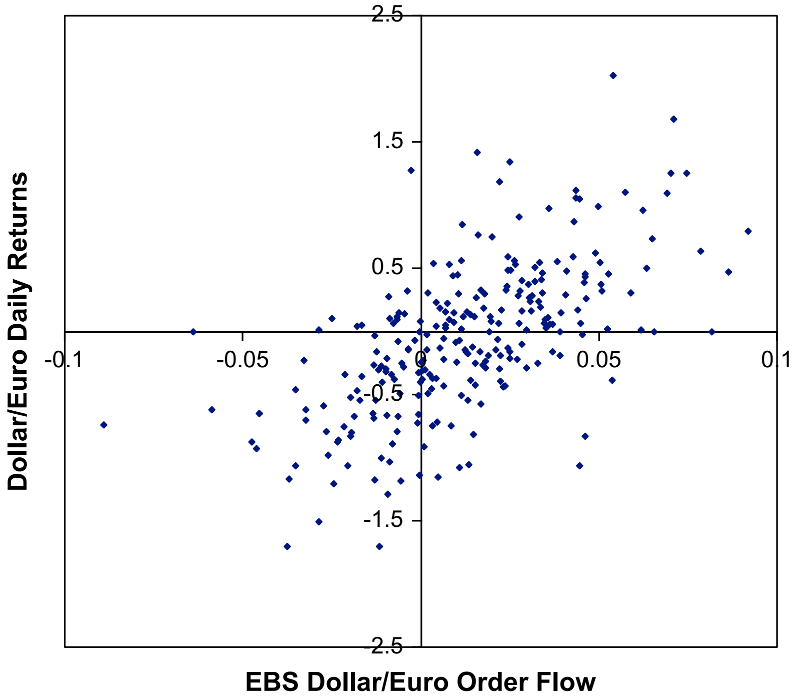

Fig. 4. Plotted are daily returns in the Dollar/Euro exchange rate against normalized daily order flow in the EBS trading system for the year 1999.

have the theoretically correct sign and remain statistically and economically significant. The exchange rate coefficients are also still negative and statistically significant. It is interesting to note that the sum of the exchange rate coefficients is essentially the same under the restricted and unrestricted model estimation. Hence both procedures produce the same implication for the relationship between risk aversions of domestic investors at home and in the foreign country.

5.2. Intraday results

Our model is predicated on the idea that all markets are open simultaneously. Though the foreign exchange market is open continuously, the bulk of equity trades are executed during formal opening hours in both France and the U.S. Because of the six-hour time difference, parallel equity trading occurs for only $1\frac{1}{2}$ h of U.S. morning and French afternoon trading. We refer to this interval as parallel trading indexed by p. Defining the intraday periods of parallel trading allows us to estimate equations (3) and (4) again:

$$R_p^H = \frac{1}{3}\left[\left(1+\lambda_b\right) + \lambda_b \frac{\left(2\lambda_h - \lambda_f\right)}{\lambda_h \lambda_f}\right] R_p^E + \frac{1}{3k(1+r)}\left(2OF_p^H + OF_p^F\right) \tag{6}$$

$$R_p^F = \frac{1}{3}\left[-(1+\lambda_b) + \lambda_b \frac{\left(2\lambda_h - \lambda_f\right)}{\lambda_h \lambda_f}\right] R_p^E + \frac{1}{3k(1+r)}\left(OF_{pt}^H + 2OF_p^F\right) \tag{7}$$

Equations (6) and (7) explain intraday U.S. and French equity returns for the period in which both equity markets are open. To this intraday period the model applies most directly.

In Table 5, the estimation results for the equations (6) and (7) are reported. We have placed most credence on the unrestricted OLS estimates of Table 4, and repeat these results here for intraday returns. It is straightforward to summarize the overall result. The general picture conveyed by Table 4 remains unchanged. For both home and foreign equity returns, the exchange rate effect is still negative and even higher in absolute value for the French case. The coefficients are always significant. Own and cross order flows remain positive and highly significant in all cases though the coefficients are somewhat reduced in comparison to the daily equation. The only noticeable deviation from the results of Table 4 is that for French equities, the impact of own-order flow is less than that of overseas order flow (see equation (7)). The regression R^2 is noticeably lower for the U.S. case but is still higher than for France where the explanatory power is essentially unchanged. Again there is no evidence of auto-correlation. Overall, the most striking feature is the robustness of the results.

6. Conclusion

Macroeconomic models account for close to 0% of the international stock and exchange rate returns. This motivates us to explore if simple heterogeneous belief shifts about equity fundamentals provide

Table 5
Intraday results. Equations (6) and (7) explain intraday U.S. and French equity returns for the $1\frac{1}{2}$ h period in which both equity markets are open in parallel (p). The equations are estimated using ordinary least squares (OLS) for the whole sample. *T*-tests in parentheses use Newey West robust standard errors.

Dep. var. period	Equation (6)		Equation (7)	
	R_p^H, 01/1999–12/2003		R_p^F, 01/1999–12/2003	
R_p^E	−0.18	(2.06)	−0.73	(9.02)
OF_p^H	8.23	(13.84)	3.38	(9.33)
OF_p^F	1.84	(9.45)	1.86	(10.36)
R^2	42.2%		38.0%	
Q(5)	3.57		6.03	

a better paradigm for explaining the international return dynamics at a daily frequency. We argue that order flow represents a suitable proxy variable to identify such belief changes. A micro-founded model is developed which matches belief changes both to order flows and asset returns. The multi-market setting provides not only for enough observable prices and order flows to identify heterogeneous investor belief shifts, but it also implies testable restrictions about the international market interdependence. We derived a closed-form solution for equity returns in both equity markets, which relates equity returns to the exchange rate and to order flows in both the local and the overseas market. The model can potentially explain asymmetry across countries in the correlations between domestic equity returns and the exchange rate return conditional on order flows.

We confront the model with 5 years of daily U.S. and French equity data. The respective daily order flows for the S&P100 and the CAC40 index are constructed based on the aggregation of approximately 800 million individual equity transactions. We find that an extraordinarily high percentage of aggregate equity return variation is explained jointly by exchange rate returns and macroeconomic order flows. Our model can explain approximately 60% of the daily variation in the S&P100 return and 40% of the CAC40 return fluctuations. As predicted by theory, both returns are strongly and positively influenced not only by own market order flow, but also by the order flow in the overseas market. The oversea equity order flows capture international equity substitution effects with a very different home equity return impact from those of the aggregate home market order flow. We highlight that our results are essentially unchanged when estimation is limited to the intraday periods of parallel equity trading in France and the U.S.

In summary, heterogeneous belief changes as identified by order flows provide a promising paradigm for future research on equity index movements, exchange rates and international financial market interdependence. More progress in this direction should come from better data structures which not only characterizes aggregate order flow for a particular market (like ours), but identifies order flow for each market by institutional type and location of the counterparties so that the geography of international belief changes can be mapped out more precisely. This would open a new research chapter in international finance.

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Appendix

The four investment funds labelled e, b, h, and f pursue investment objectives which maximize a CARA objective function over a portfolio of just two of the four assets. For normally distributed payoff this simplifies to a utility function in conditional mean and conditional variance of the payoff. In general, for price changes ΔP_g and ΔP_j in two assets g and j corresponding asset holdings x_g and x_j the payoff is given by $\Pi = x_g \Delta P_g + x_i \Delta P_i$. For a budget constraint $x_g P_g + x_j P_j = 0$, we obtain $\Pi = x_g[\Delta P_g - (P_g/P_j)\Delta P_j]$ and the optimal asset demand can be stated as

$$x_g = \frac{\mathcal{E}\left(\Delta P_g - \frac{P_g}{P_j}\Delta P_j \middle| I\right)}{\rho \mathrm{Var}\left(\Delta P_g - \frac{P_g}{P_j}\Delta P_j \middle| I\right)} \tag{A1}$$

where $\varepsilon(.|I)$ denotes conditional expectation, $\mathrm{Var}(.|I)$ the conditional variance and ρ the coefficient of absolute risk aversion.

We solve the model in three different steps by backward induction. First, we consider the price equilibrium of the price auction in round 2. This equilibrium is based on full information about the belief changes. Second, we state the steady state price equilibrium in round 0 prior to the belief changes. Third, we characterize the price equilibrium at the end of round 1 and the corresponding order flows. The latter equilibrium is the result of a competitive limit order supply and the optimal market order demand of the funds after their belief changes.

In what follows, we make the following assumptions without loss of generality. The initial prices of the home and foreign bonds are both normalized to unity and the home and foreign redemption yields are also assumed to be equal. For reasons of symmetry,[22] the expected prices of the home and foreign equities are equal and are normalized to unity. The expected terminal values of the home and foreign equities are also equal. The expected exchange rate and its expected terminal payoff are normalized to unity.

Price equilibrium in round 2

We consider a full information price equilibrium in round 2 in which funds submit demand functions. At this stage, the belief changes of all funds are public information and this allows for a straightforward calculation of the equilibrium price. Let V^H, V^F and V^E denote the liquidation value of the home equity, the foreign equity and the foreign currency respectively. The corresponding equilibrium prices are ${P_2}^H$, ${P_2}^F$ and E_2. The first step is to calculate the demands for each fund.

This is straightforward for the home and foreign fund. The second asset is a bond with an initial price $P_b = 1$ for each of the trading periods and a return $\Delta P_b = r$ if held until liquidation. Hence, their optimal asset demands are given by

$$x_h^H = \frac{\mathcal{E}_h\left[V^H - P_2^H - P_2^H r \middle| I\right]}{\rho_h \mathrm{Var}_h\left(V^H \middle| I\right)} = \frac{\overline{V}^H + \mu_h^H - (1+r)P_2^H}{\rho_h \sigma^2} \tag{A2}$$

$$x_f^F = \frac{\mathcal{E}_f\left[V^F - P_2^F - P_2^F r \middle| I\right]}{\rho_f \mathrm{Var}_f\left(V^F \middle| I\right)} = \frac{\overline{V}^F + \mu_f^F - (1+r)P_2^F}{\rho_f \sigma^2}. \tag{A3}$$

For the international equity fund the first asset is the home equity and the second asset is the foreign equity. The payoff is non-linear and is given by

$$\Pi_e = x_e^H\left[V^H - P_2^H - \frac{P_2^H}{E_2 P_2^F}\left(V^E V^F - E_2 P_2^F\right)\right].$$

For steady state values $\overline{V}^H, \overline{P}_2^H, \overline{V}^E, \overline{E}_2, \overline{V}^F, \overline{P}_2^F,$ we can use Taylor's Theorem to linearize the excess return on home equity as

$$\begin{aligned}
V^H - P_2^H - \frac{P_2^H}{E_2 P_2^F}\left(V^E V^F - E_2 P_2^F\right) &= \left(V^H - \overline{V}^H\right) - \left[1 + \frac{\overline{V}^E \overline{V}^F - \overline{E}_2 \overline{P}_2^F}{\overline{E}_2 \overline{P}_2^F}\right]\left(P_2^H - \overline{P}_2^H\right) \\
&\quad - \frac{\overline{V}^F \overline{P}_2^H}{\overline{E}_2 \overline{P}_2^F}\left(V^E - \overline{V}^E\right) + \frac{\overline{V}^E \overline{V}^F \overline{P}_2^H}{(\overline{E}_2)^2 \overline{P}_2^F}(E_2 - \overline{E}_2) \\
&\quad - \frac{\overline{V}^E \overline{P}_2^H}{\overline{E}_2 \overline{P}_2^F}\left(V^F - \overline{V}^F\right) + \frac{\overline{V}^E \overline{V}^F \overline{P}_2^H}{\overline{E}_2\left(\overline{P}_2^F\right)^2}\left(P_2^F - \overline{P}_2^F\right) \\
&= \left(V^H - \overline{V}^H\right) - \overline{V}^F\left(P_2^H - 1\right) - \overline{V}^F\left(V^E - 1\right) \\
&\quad + \overline{V}^F(E_2 - 1) - \left(V^F - \overline{V}^F\right) + \overline{V}^F\left(P_2^F - 1\right)
\end{aligned}$$

where we used the assumptions $\overline{V}^H = \overline{V}^F$, $\overline{V}^E = \overline{E}_2 = 1$, $\overline{P}_2^H = \overline{P}_2^F = 1$. For the international equity fund the optimal asset demand follows as

[22] There is one asymmetry in the model, namely the choice of currency in which the international fund is denominated. However, this has a second order impact on the model. We abstract from this.

$$x_e^H = \frac{\mathcal{E}_e\left[\left(V^H-\overline{V}^H\right)-\overline{V}^F\left(P_2^H-1\right)-\overline{V}^F\left(V^E-1\right)+\overline{V}^F(E_2-1)-\left(V^F-\overline{V}^F\right)+\overline{V}^F\left(P_2^F-1\right)\Big|I\right]}{\rho_e \mathrm{Var}_e\left(\left(V^H-\overline{V}^H\right)-\overline{V}^F\left(V^E-1\right)-\left(V^F-\overline{V}^F\right)\Big|I\right)}$$
$$= \frac{\mu_e^H-\mu_e^F-\overline{V}^F\left(P_2^H-1\right)+\overline{V}^F\left(P_2^F-1\right)+\overline{V}^F(E_2-1)}{\rho_e\left[2\sigma^2+\left(\overline{V}^F\right)^2\sigma_E^2\right]} \tag{A4}$$

and similarly

$$x_e^F = \frac{-(\mu_e^H-\mu_e^F)+\overline{V}^F\left(P_2^H-1\right)-\overline{V}^F\left(P_2^F-1\right)-\overline{V}^F(E_2-1)}{\rho_e\left[2\sigma^2+\left(\overline{V}^F\right)^2\sigma_E^2\right]}.$$

Note that $x_e^H = -x_e^F$. In fact, each of the four funds possesses this simple leverage relationship.

For the international bond fund the first asset is the home bond and the second asset is the foreign bond. The payoff is given by

$$\Pi_b = x_b^H\left[r-\frac{1}{E_2}\left(V^E(1+r)-E_2\right)\right]$$

For steady state values $\overline{V}^E, \overline{E}_2$ we can linearize the excess return to obtain:

$$\Pi_b = x_b^H(1+r)\left(E_2-V^E\right),$$

The optimal demand of the international bond investor follows as

$$x_b^H = \frac{\mathcal{E}_b\left[\left(1+r\right)\left(E_2-V^E\right)\Big|I\right]}{\rho_b \mathrm{Var}_b\left(\left(1+r\right)\left(E_2-V^E\right)\Big|I\right)} = \frac{E_2-1}{\rho_b(1+r)\sigma_E^2}. \tag{A5}$$

Then market clearing conditions in the home and foreign equity markets implies equation (1) which is repeated here for convenience:

$$\begin{aligned} 0 &= x_e^H + x_h^H \\ 0 &= x_e^F + x_f^F, \end{aligned}$$

The steady state occurs when $\mu_e^H = \mu_e^F = \mu_h^H = \mu_f^F = 0$. Using (1) and (A2)–(A4) we obtain:

$$\begin{aligned} 0 &= \frac{\overline{V}^H-(1+r)\overline{P}^H}{\rho_h\sigma^2} \\ 0 &= \frac{\overline{V}^F-(1+r)\overline{P}^F}{\rho_h\sigma^2}. \end{aligned}$$

The two equations solve for $\overline{V}^H = \overline{V}^F = (1+r)$. This also implies that all steady state demands are zero: $\overline{x}_h^H = \overline{x}_e^H = \overline{x}_e^F = \overline{x}_f^F = 0$.

Next we solve for the equilibrium prices $P_2{}^H$, $P_2{}^F$ and E_2 under general belief changes $\mu = (\mu_e^H, \mu_e^F, \mu_h^H, \mu_f^F)$. Market clearing in the two equity markets implies (again using (1) and (A2)–(A4)):

$$\begin{aligned} 0 &= x_e^H + x_h^H = \\ &= \frac{\mu_e^H-\mu_e^F-(1+r)\left(P_2^H-1\right)+(1+r)\left(P_2^F-1\right)+(1+r)(E_2-1)}{\rho_e\left[2\sigma^2+(1+r)^2\sigma_E^2\right]}+\frac{\mu_h^H-(1+r)\left(P_2^H-1\right)}{\rho_h\sigma^2} \\ 0 &= x_e^F + x_f^F = \\ &= -\frac{\mu_e^H-\mu_e^F-(1+r)\left(P_2^H-1\right)+(1+r)\left(P_2^F-1\right)+(1+r)(E_2-1)}{\rho_e\left[2\sigma^2+(1+r)^2\sigma_E^2\right]}+\frac{\mu_f^F-(1+r)\left(P_2^F-1\right)}{\rho_f\sigma^2}. \end{aligned}$$

Market clearing in the currency market occurs between the two international funds and yields. Linearizing the market clearing condition $0 = P^H x_e^H + x_b^{B^H}$ around steady state values $\overline{P}^H = 1$ and $\overline{x}_e^H = 0$, we obtain (using (2), (A4) and (A5))

$$0 = x_e^H + x_b^{B^H} = \frac{\mu_e^H - \mu_e^F - (1+r)\left(P_2^H - 1\right) + (1+r)P_2^F - 1 + (1+r)(E_2 - 1)}{\rho_e\left\{2\sigma^2 + (1+r)^2\sigma_E^2\right\}} + \frac{E_2 - 1}{\rho_b(1+r)\sigma_E^2}.$$

The last three equations can be summarized in the following system of equations

$$\mathbf{P}_2 = \begin{bmatrix} P_2^H \\ P_2^F \\ E_2 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} + \mathbf{A}^{-1}\mathbf{B}\begin{bmatrix} \mu_e^H \\ \mu_e^F \\ \mu_h^H \\ \mu_f^F \end{bmatrix} \tag{A6}$$

with the matrices **A** and **B** defined in Proposition 1. The price vector $\mathbf{P}_2$ characterizes the equilibrium in round 2.

Price equilibrium in round 0.

With the above result it is straightforward describe the initial price equilibrium prior to the belief changes. We just have to assume $\mu_e^H = \mu_e^F = \mu_h^H = \mu_f^F = 0$, and the initial price equilibrium follows as the vector

$$\mathbf{P}_0 = \begin{bmatrix} P_0^H \\ P_0^F \\ E_0 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}. \tag{A7}$$

Price equilibrium in round 1.

Between the two price equilibria $\mathbf{P}_0$ and $\mathbf{P}_2$, we assume that the competitive risk neutral market makers quote a counterpart specific limit order schedules consisting of prices dependent on the size of the market order. The funds chose the optimal market order size given their belief change about the equity fundamentals. This stage allows us to infer the order flows induced by the belief changes. The liquidity supply by the market makers is rational in the sense that it anticipates the price effect of the belief change of each fund type. The size of the market order reveals the exact magnitude of a funds belief change. Rational liquidity supply can anticipate that contingent on belief innovations $\boldsymbol{\mu}$ the equilibrium prices in round 2 are given by the system of equations in (A6)

$$P_2^H - 1 = \frac{\lambda_f\lambda_b}{(1+r)\Lambda}\left(\mu_e^H - \mu_e^F\right) + \frac{\lambda_h\left\{\left(1+\lambda_f\right)(1+\lambda_b) - 1\right\}}{(1+r)\Lambda}\mu_h^H + \frac{\lambda_b\lambda_f}{(1+r)\Lambda}\mu_f^F \tag{A8}$$

$$P_2^F - 1 = \frac{-\lambda_h\lambda_b}{(1+r)\Lambda}\left(\mu_e^H - \mu_e^F\right) + \frac{\lambda_b\lambda_h}{(1+r)\Lambda}\mu_h^H + \frac{\lambda_f\{(1+\lambda_b)(1+\lambda_h) - 1\}}{(1+r)\Lambda}\mu_f^F \tag{A9}$$

$$E_2 - 1 = \frac{-\lambda_f\lambda_h}{(1+r)\Lambda}\left(\mu_e^H - \mu_e^F\right) + \frac{\lambda_h\lambda_f}{(1+r)\Lambda}\left(\mu_h^H - \mu_f^F\right). \tag{A10}$$

where we define

$$\Lambda = \lambda_h\lambda_f\lambda_b + \lambda_h\lambda_f + \lambda_h\lambda_b + \lambda_f\lambda_b$$

and

$$\lambda_h = \frac{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}{\rho_h\sigma^2}, \quad \lambda_f = \frac{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}{\rho_f\sigma^2}, \quad \lambda_b = \frac{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}{\rho_b(1+r)^2\sigma_E^2}.$$

Given these prices in round 2, we can next derive the optimal liquidity supply schedule of the market makers. Competitive risk neutral liquidity provision amounts to a 'no profit condition' where the quoted round 1 price equals the market maker's expected round 2 price for each of the three possible types of belief shocks. Consider first the belief change by the home fund (h). For a belief innovation μ_h^H on the part of the home investor, the quoted price should be equal to the market maker's expected price in round 2 under the 'no profit condition', hence

$$\begin{aligned} P_1^H\langle\mu_h^H\rangle - 1 &= \mathcal{E}\left[P_2^H\langle\mu_h^H\rangle - 1 \middle| \mu_h^H\right] \\ &= \frac{\lambda_h\left\{\left(1+\lambda_f\right)(1+\lambda_b) - 1\right\}}{(1+r)\Lambda}\mu_h^H, \end{aligned} \tag{A11}$$

where ε denotes the market makers' expectation.

Let $OF_h^H\langle\mu_h^H\rangle$ denotes the size of the market order (or order flow) of the home investor as a function of his belief innovation μ_h^H. Then the market maker's competitive (zero expected profit) limit order quote to the home fund follows as

$$\begin{aligned} P_1^H - 1 &= \frac{\lambda_h\left\{\left(1+\lambda_f\right)(1+\lambda_b) - 1\right\}}{(1+r)\Lambda}\mu_h^H \\ &= \left[\frac{\lambda_h\left\{\left(1+\lambda_f\right)(1+\lambda_b) - 1\right\}}{(1+r)\Lambda}\right]\left(OF_h^H\right)^{-1} \end{aligned}$$

where $\mu_h^H = (OF_h^H)^{-1}$ denotes the inverse of the order flow function. The optimal size of the market order (or order flow) by the home fund corresponds to the change in his asset demand. It follows from the asset demand equation (A2) as

$$OF_h^H = \frac{\mu_h^H - (1+r)\left(P_1^H\langle\mu_h^H\rangle - 1\right)}{\rho_h\sigma^2}. \tag{A12}$$

In the presence of fully price elastic demand, the size of the optimal market order by the home fund would be given by $\mu_h^H/\rho_h\sigma^2$. However, the liquidity demanding market makers increase the price to $P_1^H\langle\mu_h^H\rangle - 1$ for a quantity OF_h^H which reveals the belief innovation to be μ_h^H. Substitution of equation (A11) into equation (A12) implies for the size of the market order

$$\begin{aligned} OF_h^H &= \frac{\mu_h^H - (1+r)\left(P_1^H\langle\mu_h^H\rangle - 1\right)}{\rho_h\sigma^2} \\ &= \frac{1}{\rho_h\sigma^2}\left[1 - \frac{\lambda_h\left\{\left(1+\lambda_f\right)(1+\lambda_b) - 1\right\}}{\Lambda}\right]\mu_h^H \\ &= \frac{1}{\rho_h\sigma^2}\frac{\lambda_f\lambda_b}{\Lambda}\mu_h^H = k\mu_h^H \end{aligned}$$

where we have defined

$$k = \frac{\lambda_f\lambda_b}{\rho_h\sigma^2\Lambda} \tag{A13}$$

and we use

$$\Lambda - \lambda_h\left\{\left(1+\lambda_f\right)(1+\lambda_b)-1\right\} = \lambda_h\lambda_f\lambda_b + \lambda_h\lambda_f + \lambda_h\lambda_b + \lambda_f\lambda_b - \lambda_h\left\{\lambda_f\lambda_b + \lambda_b + \lambda_f\right\} = \lambda_f\lambda_b.$$

Our market model assumes that execution occurs at one (uniform) price which is given by

$$P_{1h}^H = 1 + \frac{\lambda_h\left\{\left(1+\lambda_f\right)(1+\lambda_b)-1\right\}}{(1+r)\Lambda}\mu_h^H.$$

Symmetric algebraic expression apply to the case of a belief shock by the foreign fund.

Next we derive the competitive liquidity demand for a belief change of the international equity fund (e). For a belief innovation $\mu_e^H - \mu_e^F$ of the international equity fund, the competitive (zero profit) liquidity demand requires a price change given by

$$P_1^H\langle\mu_e^H - \mu_e^F\rangle - 1 = \mathcal{E}\left[P_2^H\langle\mu_e^H - \mu_e^F\rangle - 1\middle|\mu_e^H - \mu_e^F\right] = \left[\frac{\lambda_f\lambda_b}{(1+r)\Lambda}\right]\left(\mu_e^H - \mu_e^F\right). \tag{A14}$$

Market makers quote the two other asset prices according to

$$\begin{aligned} P_1^F\langle\mu_e^H - \mu_e^F\rangle - 1 &= \mathcal{E}\left[P_2^F\langle\mu_e^H - \mu_e^F\rangle - 1\middle|\mu_e^H - \mu_e^F\right] = \left[\tfrac{-\lambda_h\lambda_b}{(1+r)\Lambda}\right](\mu_e^H - \mu_e^F) \\ E_1\langle\mu_e^H - \mu_e^F\rangle - 1 &= \mathcal{E}\left[E_2\langle\mu_e^H - \mu_e^F\rangle - 1|\mu_e^H - \mu_e^F\right] = \left[\tfrac{-\lambda_f\lambda_h}{(1+r)\Lambda}\right](\mu_e^H - \mu_e^F). \end{aligned} \tag{A15}$$

The market order OF_e^H by the international equity fund is given by

$$OF_e^H = \frac{\mu_e^H - \mu_e^F - (1+r)\left(P_1^H\langle\mu_e^H - \mu_e^F\rangle - 1\right) + (1+r)\left(P_1^F\langle\mu_e^H - \mu_e^F\rangle - 1\right) + (1+r)\left(E_1\langle\mu_e^H - \mu_e^F\rangle - 1\right)}{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}, \tag{A16}$$

which follows from (A4). Again, the belief innovation μ_e^H minus; μ_e^F of the international equity fund can be inferred from the size of the market order OF_e^H. Substitution of equations (A14) and (A15) into equation (A16) implies the order flow of the international equity fund in the home market given by

$$\begin{aligned} OF_e^H &= \frac{1}{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}\left[1 - \frac{\lambda_f\lambda_b}{\Lambda} - \frac{\lambda_h\lambda_b}{\Lambda} - \frac{\lambda_f\lambda_h}{\Lambda}\right]\left(\mu_e^H - \mu_e^F\right) \\ &= \frac{\frac{1}{\Lambda}}{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}\left[\lambda_h\lambda_f\lambda_b\right]\left(\mu_e^H - \mu_e^F\right) = k\left(\mu_e^H - \mu_e^F\right) \end{aligned}$$

The last equality is obtained using (A13) and (3) to get

$$k = \frac{\lambda_h\lambda_f\lambda_b}{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]\Lambda} \times \frac{\frac{\rho_e\left[2\sigma^2 + (1+r)^2\sigma_E^2\right]}{\rho_h\sigma^2}}{\lambda_h} = \frac{\lambda_f\lambda_b}{\rho_h\sigma^2\Lambda}.$$

The execution price for the international equity fund is therefore

$$P_{1e}^H = 1 + \frac{\lambda_f\lambda_b}{(1+r)\Lambda}\left(\mu_e^H - \mu_e^F\right).$$

The market orders for home equity of the home and international investors are therefore executed at two different prices ${P_{1h}}^H$ and ${P_{1e}}^H$.[23] An analogous derivation for the foreign market shows that the order flows are

[23] Given that we assume that only one fund experiences a belief change only one of the two transaction prices should occur over the horizon of the model.

$$\begin{aligned} OF_f^F &= \tfrac{\lambda_h \lambda_b}{\rho_f \sigma^2 \Lambda} \mu_f^F = k\mu_f^F \\ OF_e^F &= \tfrac{-\lambda_h \lambda_f \lambda_b}{\rho_e \left[2\sigma^2 + (1+r)^2 \sigma_E^2\right] \Lambda} \left(\mu_e^H - \mu_e^F\right) = -k\left(\mu_e^H - \mu_e^F\right) \end{aligned}$$

for the foreign fund and international fund, respectively. To obtain the last equality in the equation for foreign equity order flow, we used (A13) and (3) to rewrite

$$k = \frac{\lambda_h \lambda_b}{\rho_f \sigma^2 \Lambda} \times \frac{\lambda_f}{\frac{\rho_e\left[2\sigma^2 + (1+r)^2 \sigma_E^2\right]}{\rho_f \sigma^2}} = \frac{\lambda_h \lambda_f \lambda_b}{\rho_e \left[2\sigma^2 + (1+r)^2 \sigma_E^2\right] \Lambda}.$$

The foreign equity prices at which the round 1 market orders are executed are

$$\begin{aligned} P_{1f}^F &= 1 + \tfrac{\lambda_f\{(1+\lambda_h)(1+\lambda_b) - 1\}}{(1+r)\Lambda} \mu_f^F \\ P_{1e}^F &= 1 - \tfrac{\lambda_h \lambda_b}{(1+r)\Lambda} \left(\mu_e^H - \mu_e^F\right). \end{aligned}$$

depending on whether a belief change μ_f^F or alternatively $\mu_e^H - \mu_e^F$ occurs.

Proposition 1. (*Returns and heterogeneous beliefs*) For asset returns $R^H = P^H - 1$, $R^F = P^F - 1$ and $R^E = E - 1$ defined as the price change from the initial price vector $\mathbf{P}_0$ in round 0 to the full information price equilibrium $\mathbf{P}_2$ in round 2, we obtain (using (A7) and (A6)) a linear system of three equations is given by

$$\begin{bmatrix} (1+\lambda_h) & -1 & -1 \\ -1 & \left(1+\lambda_f\right) & 1 \\ -1 & 1 & (1+\lambda_b) \end{bmatrix} \begin{bmatrix} R^H \\ R^F \\ R^E \end{bmatrix} = \frac{1}{1+r} \begin{bmatrix} \mu_e^H - \mu_e^F + \mu_h^H \lambda_h \\ \mu_e^F - \mu_e^H + \mu_f^F \lambda_f \\ \mu_e^F - \mu_e^H \end{bmatrix}.$$

The return vector $\mathbf{R}^{\mathrm{T}} = (R^H, R^F, R^E)$ can then be expressed linearly in terms of belief changes $\boldsymbol{\mu}^{\mathrm{T}} = (\mu_e^H, \mu_e^F, \mu_h^H, \mu_f^F)$ as $\mathbf{R} = \mathbf{A}^{-1}\mathbf{B}\boldsymbol{\mu}$. This proves proposition 1. The derivation does not assume any particular distributional assumption about the belief changes.

Proposition 2. (*Equity order flow*) At the end of round 1, the fund with the belief change places market orders to acquire a position in accordance with its belief change. The competitive liquidity demand of their counterparty is price elastic and takes into account the equilibrium price effect of these demand changes. The liquidity demand elasticity in turn conditions the optimal size of the fund's market order. Order flow will come from either the international fund, the home fund or the foreign fund. The combined order flow in the home equity market is defined as sum of the order flow by the home and international fund and similarly as the sum of the foreign and international fund in the foreign market. We obtain

$$\begin{aligned} OF^H &= OF_h^H + OF_e^H = k\left(\mu_h^H + \mu_e^H - \mu_e^F\right) \\ OF^F &= OF_f^F + OF_e^F = k\left(\mu_f^F + \mu_e^F - \mu_e^H\right) \end{aligned}$$

where we define the parameter k in (A13). Proposition 2 is valid only if market makers can condition their liquidity demand on the fund type and if the belief changes of different funds are non-simultaneous.[24]

Proposition 3. (*FX order flow*) The risk neutral liquidity demand in the FX market in period 1 (as a function of the order flow) is given by

[24] The proposition also hold for simultaneous belief changes which are independent. This implies of cause that different transaction prices in round 1 occur simultaneously for different funds.

$$\begin{aligned} E_1\langle\mu_e^H-\mu_e^F\rangle-1 &= \mathcal{E}\Big[E_2\langle\mu_e^H-\mu_e^F\rangle-1\Big|\mu_e^H-\mu_e^F\Big] \\ &= \frac{-\lambda_h\lambda_f}{(1+r)\Lambda}\Big(\mu_e^H-\mu_e^F\Big) \\ &= \frac{-\lambda_h\lambda_f}{(1+r)\Lambda}\Big(OF_e^E\Big)^{-1} \end{aligned}$$

and the order flow in the FX market is determined only by the demand of the of the international equity fund. Hence

$$OF^E = OF_e^E = k\Big[\Big(\mu_e^F-\mu_e^H\Big)\Big].$$

Proposition 4. (*Reduced form structure*) The system of equations in proposition 1 can be rewritten as

$$\begin{bmatrix} \big(1+\lambda_h\big)\lambda_f & -\lambda_f & -\lambda_f \\ -\lambda_h & \big(1+\lambda_f\big)\lambda_h & \lambda_h \\ -1 & 1 & (1+\lambda_b) \end{bmatrix}\begin{bmatrix} R^H \\ R^F \\ R^E \end{bmatrix} = \frac{1}{1+r}\begin{bmatrix} \big(\mu_e^H-\mu_e^F\big)\lambda_f+\mu_h^H\lambda_h\lambda_f \\ \big(\mu_e^F-\mu_e^H\big)\lambda_h+\mu_f^F\lambda_f\lambda_h \\ \mu_e^F-\mu_e^H \end{bmatrix}.$$

Adding the first two equations yields

$$\begin{bmatrix} \big(1+\lambda_h\big)\lambda_f-\lambda_h & \big(1+\lambda_f\big)\lambda_h-\lambda_f & \lambda_h-\lambda_f \\ -1 & 1 & (1+\lambda_b) \end{bmatrix}\begin{bmatrix} R^H \\ R^F \\ R^E \end{bmatrix}$$
$$= \frac{1}{1+r}\begin{bmatrix} (\mu_e^H-\mu_e^F)\big(\lambda_f-\lambda_h\big)+\big(\mu_h^H+\mu_f^F\big)\lambda_h\lambda_f \\ \mu_e^F-\mu_e^H \end{bmatrix}$$

and adding (λ_f–λ_h) times the last equation gives

$$\begin{bmatrix} \lambda_h\lambda_f & \lambda_f\lambda_h & \big(\lambda_f-\lambda_h\big)\lambda_b \\ -1 & 1 & (1+\lambda_b) \end{bmatrix}\begin{bmatrix} R^H \\ R^F \\ R^E \end{bmatrix} = \frac{1}{1+r}\begin{bmatrix} \big(\mu_h^H+\mu_f^F\big)\lambda_h\lambda_f \\ \mu_e^F-\mu_e^H \end{bmatrix}.$$

Finally, dividing the first equation by $\lambda_h\lambda_f$, we obtain

$$\begin{bmatrix} 1 & 1 & \frac{(\lambda_f-\lambda_h)\lambda_b}{\lambda_h\lambda_f} \\ 1 & -1 & -(1+\lambda_b) \end{bmatrix}\begin{bmatrix} R^H \\ R^F \\ R^E \end{bmatrix} = \frac{1}{1+r}\begin{bmatrix} \mu_h^H+\mu_f^F \\ \mu_e^H-\mu_e^F \end{bmatrix}$$

The order flow definitions allow us to rewrite

$$\begin{aligned} OF^H+OF^F &= k\Big[\mu_h^H+\mu_f^F\Big] \\ OF^H-OF^F &= k\Big[\Big(\mu_h^H-\mu_f^F\Big)+2\big(\mu_e^H-\mu_e^F\big)\Big]. \end{aligned}$$

Note that the exchange rate return can be expressed as

$$R^E = \frac{-\lambda_f\lambda_h}{(1+r)\Lambda}\Big(\mu_e^H-\mu_e^F\Big)+\frac{\lambda_h\lambda_f}{(1+r)\Lambda}\Big(\mu_h^H-\mu_f^F\Big)$$

or

$$\begin{aligned} \frac{1}{\rho_b(1+r)\sigma_E^2}R^E &= -k\Big(\mu_e^H-\mu_e^F\Big)+k\Big(\mu_h^H-\mu_f^F\Big) \\ &= -3k\Big(\mu_e^H-\mu_e^F\Big)+\Big(OF^H-OF^F\Big) = 3OF^E+\Big(OF^H-OF^F\Big) \end{aligned}$$

or

$$\mu_e^H - \mu_e^F = \frac{1}{3k}\left(OF^H - OF^F\right) - \frac{1}{3k(1+r)\rho_b\sigma_E^2}R^E.$$

Substitution then implies

$$\begin{bmatrix} 1 & 1 & \lambda_e\frac{(\lambda_f-\lambda_h)}{\lambda_h\lambda_f} \\ 1 & -1 & -(1+\lambda_b) \end{bmatrix}\begin{bmatrix} R^H \\ R^F \\ R^E \end{bmatrix} = \begin{bmatrix} \frac{1}{k(1+r)}\left(OF^H + OF^F\right) \\ \frac{1}{3k(1+r)}\left(OF^H - OF^F\right) - \frac{1}{3k\rho_b(1+r)^2\sigma_E^2}R^E \end{bmatrix}$$

Adding the two equations implies the following expression for home returns

$$R^H = \frac{1}{3}\left[\left(1+\lambda_b\right) + \lambda_b\frac{\left(\lambda_h - 2\lambda_f\right)}{\lambda_h\lambda_f}\right]R^E + \frac{1}{3k(1+r)}\left(2OF^H + OF^F\right)$$

and subtracting gives

$$R^F = \frac{1}{3}\left[-(1+\lambda_b) + \lambda_b\frac{\left(2\lambda_h - \lambda_f\right)}{\lambda_h\lambda_f}\right]R^E + \frac{1}{3k(1+r)}\left(OF^H + 2OF^F\right)$$

where we used

$$\begin{aligned}\left(1+\lambda_b\right) - \frac{1}{3k\rho_b(1+r)^2\sigma_E^2} &= (1+\lambda_b) - \frac{1}{3}\frac{\Lambda}{\lambda_h\lambda_f} \\ &= (1+\lambda_b) - \frac{1}{3}\left[\left(1+\lambda_e\right) + \lambda_e\frac{\left(\lambda_h+\lambda_f\right)}{\lambda_h\lambda_f}\right] \\ &= \frac{2}{3}(1+\lambda_b) - \frac{1}{3}\lambda_e\frac{\left(\lambda_h+\lambda_f\right)}{\lambda_h\lambda_f}.\end{aligned}$$

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