Imperfect Competition, Information Heterogeneity, and Financial Contagion

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Abstract

Financial contagion is the propagation of a shock to one security across other fundamentally unrelated securities. In this paper, we examine how heterogeneity of insiders' information about fundamentals may induce excess comovement among asset prices, i.e., beyond the extent justified by the structure of the economy. We develop a model of multi-asset trading, populated by a number of informed strategic speculators facing a trade-off between the maximization of short- versus long-term utility of their wealth, uninformed market-makers, and liquidity traders, in which the liquidation values of the available securities depend on idiosyncratic as well as systematic sources of risk. We show that, even in a setting where such insiders are rational, risk-neutral, and financially unconstrained, financial contagion can be an equilibrium outcome of a semi-strong efficient market, if and only if they receive heterogeneous information about those sources of risk and strategically trade on it. Rational market-makers use the observed aggregate order flow to update their beliefs about the random terminal payoffs of the assets. Imperfectly competitive speculators engage in portfolio rebalancing activity to mask their information advantage. Asymmetric sharing of information among insiders prevents the market-makers from learning about their individual signals and trades with sufficient accuracy. Incorrect cross-inference about fundamentals and contagion then ensue. When used to analyze the transmission of shocks across countries, our model suggests that more adequate regulation of the process of generation and disclosure of information in emerging markets may reduce their vulnerability to international financial contagion.

JEL classification: D82; G14; G15

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1 Introduction

Many recent financial crises, for example the turmoil originating in Mexico at the end of 1994, in East Asia between 1997 and 1998, in Russia during August of 1998, and in Brazil in 1999, eventually involved markets that arguably did not share any significant economic linkage with those countries or regions. More generally, a growing body of empirical evidence seems to suggest that episodes of excess volatility and comovement among asset prices are a pervasive feature of many capital markets during both tranquil and uncertain times. Thus, it should not be surprising that so much effort has been devoted in the financial and economic literature to the search for a satisfactory interpretation of these events. Nevertheless, *financial contagion*, the propagation of a shock to one security or market across other fundamentally unrelated securities or markets, still remains one of the most intriguing and puzzling asset pricing phenomena facing academics, practitioners, and policy-makers.

At the same time, mutual funds have played an increasingly important role as a preferred investment vehicle in both developed and emerging financial markets. For instance, Bhattacharya and Nanda (1999) report that total equity holdings by mutual funds account for more than 16% of the value of all U.S. equities. In emerging markets, the assets held by (mostly foreign) mutual funds represent smaller fractions of the total market capitalization (see Borensztein and Gelos (2000)). However, in the majority of these markets, ownership is usually more concentrated, and consequently turnover is lower than in more mature markets.

While empirical research on portfolio flows has received wide attention in the last decade, and the behavior of hedge funds, pension funds, and mutual funds in those crises has been actively scrutinized (e.g., Brown et al. (1998), Eichengreen and Mathieson (1998), Kaminsky et al. (2000, 2001), Disyatat and Gelos (2001), and Kim and Wei (2002), just to name a few), theoretical analysis of the impact of the actions of institutional investors on asset prices across apparently unrelated markets has only recently gained momentum.

A popular explanation of financial contagion, first introduced by King and Wadhwani (1990), is based on the idea that information asymmetry leads uninformed traders to incorrect updating of beliefs for the terminal payoffs of many assets following idiosyncratic shocks to a single asset. In such circumstances, however, it is routinely assumed that private information is shared symmetrically among a multitude of informed, price-taking traders. Most financial markets are instead characterized by the presence of a discrete number of insiders endowed with diverse, disparate information and strategically competing with each other. This is true, in particular, for the markets of many emerging economies, where the process of generation, acquisition, and disclosure of information is not as standardized and heavily regulated as in more developed economies, and where contagion phenomena have been more frequently observed in the past. Information heterogeneity, defined as significant and persistent differences in the endowments of private information, and imperfect competition among informed market participants represent a richer and more realistic view of a financial market that so far has not been employed to explore the propagation of perturbations across fundamentally unrelated securities.

In this paper, we develop a three-date, two-period model of multi-asset trading, populated by a number of informed speculators not facing any borrowing or short-selling constraints, uninformed market-makers, and liquidity traders, in which the terminal payoffs of the available securities depend on idiosyncratic and systematic sources of risk. Calvo (1999) and Yuan (2000) explore the consequences of insiders being financially constrained in models in which uninformed investors cannot distinguish whether the observed selling activity is due to liquidity or real shocks, hence might misread liquidity-driven, across-the-board sales as signaling bad fundamentals. Financial contagion would then ensue. Alternatively, Kyle and Xiong (2001) describe financial contagion as a wealth effect induced by convergence traders' need to liquidate their positions in all assets even when they are losing money on a single asset. This argument is however not fully satisfactory, as it ignores the fact that market participants hit by a liquidity shock would rather meet their margin calls by selling highly liquid assets, like the ones traded in developed exchanges, and not their holdings in emerging markets.[1]

Our model assumes that the stylized professional money managers are imperfectly competitive, risk-neutral, and care about the interim as well as the terminal value of their holdings. This framework allows us to investigate how strategic portfolio rebalancing by these privately informed speculators, heterogeneity of their informational advantage, and short-term trading affect the likelihood and magnitude of *excess covariance* among asset prices, i.e., covariance beyond what is justified by fundamentals. We show that, even in a setting in which those insiders are rational and financially unconstrained, excess (co)movement can be an equilibrium outcome, if and only if they receive heterogeneous information about the idiosyncratic and systematic factors affecting the liquidation values of the assets and strategically trade

[1] See Kodres and Pritsker (2002). Nonetheless, Schinasi and Smith (1999) observe that specific objective functions for professional money managers and the amount of portfolio leverage may sometimes force liquidation of the most risky assets, instead of the most liquid ones, in proximity of a financial crisis. In Allen and Gale (2000), financial intermediaries withdraw from illiquid investments when they cannot meet an excess demand for liquidity.

on it. In such a case, the magnitude of financial contagion is an increasing function of the number of insiders and the degree of asymmetric sharing of information among them.

This result constitutes the main contribution and empirical implication of the paper. The intuition for it is as follows. Informed trading activity by professional money managers potentially dissipates at least part of their informational advantage. In particular, because the real economy is fundamentally interconnected, the uninformed market-makers may use the observed aggregate demand for one asset to cross-infer any new information about the terminal payoffs of other assets. Therefore, the insiders trade strategically across assets, rather than independently in each security, to minimize not the risk of their holdings but the dispersion of information resulting from their speculative transactions. Nonetheless, the insiders have also an incentive to act noncooperatively, thus to compete more aggressively with each other to exploit their perceived individual informational edge.

When the insiders receive homogeneous information, such competition, in equilibrium, makes the aggregate order flow a sufficient statistic for rational dealers, aware of their motives, to learn about whether the observed demand is due to idiosyncratic or systematic shocks. Heterogeneity of their private signals about one or more securities instead induces those imperfectly competitive speculators to a more cautious, less aggressive, quasi-monopolistic trading behavior, for part of each insider's informational advantage versus the rest of the market is now known exclusively to him. Consequently, in equilibrium, the dealers learn more accurately about the average signal than about any private signal and any individual strategic portfolio diversification choice. The resulting incorrect cross-inference about fundamentals causes excess covariance among asset prices. More heterogeneously informed insiders and/or greater information heterogeneity among them intensify the above effects, thus increasing the magnitude of contagion.

Closely related to our study is a recent paper arguing for the role of portfolio rebalancing as a channel of financial contagion. In Kodres and Pritsker (2002), risk-aversion induces cross-market rebalancing in a classic mean-variance competitive framework with information asymmetry à la Grossman and Stiglitz (1980), consistent with the rationale offered by Fleming et al. (1998) to explain volatility comovements. However, mean-variance portfolio selection may not describe adequately the decision process followed by institutional investors, especially those investing in developing markets. For example, Nanda et al. (2000) and Das and Sundaram (2002) emphasize that compensation schemes and principal-agent considerations are very important to understand observed investment policies of professional money managers. Indeed, Disyatat and Gelos (2001) find that mean-variance optimization fails to explain changes in portfolio weights for more than 600 emerging market mutual funds over the period 1996:1-2000:12, thus casting some doubts on the relevance of Kodres and Pritsker's model in interpreting the more recent contagion episodes in Asia, Eastern Europe, and Latin America. It is because of these considerations, and in order to focus on the implications of imperfect competition and information heterogeneity for financial contagion, that we exclude cross-market hedging as a propagation mechanism by assuming that all market participants are risk-neutral.

In our model, the informed fund managers may also be motivated to move away from the optimal long-term profit-maximization rule in order to increase their short-term welfare. Our analysis nonetheless suggests that such uninformative, short-term oriented behavior by speculators does not exacerbate the magnitude of contagion by real shocks, because more noise trading creates more hiding opportunities for the insiders, eventually bringing forth more informative demand. Despite this fact, shocks to the short-term component of their demand for risky assets as well as uninformative shocks to the order flow (due to errors in the information generation process of a single or few speculators) can still result in financial contagion if those perturbations mislead the uninformed market-makers.

Is financial liberalization at least partially responsible for the spate of contagion events sweeping many emerging countries in the recent past? The increasing financial integration of the world equity markets observed in the last two decades has induced greater participation of professional money managers to trading in securities of emerging economies, where nonetheless imperfect competition and asymmetric information sharing among insiders are more likely to exist. According to our results, these trends may have increased the information content of the aggregate demand for risky assets, hence reducing the extent of excess price comovements due to information noise or uninformative trading shocks, while concurrently raising the vulnerability of those markets characterized by information heterogeneity to financial contagion from shocks to unrelated fundamentals.

The paper is organized as follows. In Section 2 we outline the basic model, derive the equilibrium of our stylized economy, and comment on its properties. In Section 3 we define financial contagion, explore the insiders' strategic trading, and establish the main results of this study. Section 4 focuses on the channels of transmission of informative and uninformative shocks across fundamentally unrelated countries. Section 5 provides the intuition for the above analysis with the help of a numerical example. Finally, in Section 6 we conclude by interpreting the recent wave of international contagion events in light of our findings and by suggesting potential extensions of our work.

2 The model

In this section, we describe our basic model. We extend the K-trader, N-security generalization by Caballé and Krishnan (1994) of the single-trader and single-security model of Kyle (1985) to study the circumstances under which contagion among assets may occur in the presence of imperfectly competitive, heterogeneously informed, risk-neutral mutual fund managers. We first list our assumptions and detail the main features of the model. Then, we introduce the market participants and the relevant information structure. Finally, we discuss the equilibrium notion used in the paper and show that a linear noisy rational expectations equilibrium exists in our setting.

2.1 Structure and notation

The model is a three-date, two-period economy consisting of N risky assets and a riskless asset (the numeraire). Without loss of generality, the riskless rate is taken as zero. Trading occurs only at the end of the first period, at time $t = 1$. At the end of the second period, at time $t = 2$, the payoffs of the N risky assets, represented by a $N \times 1$ multivariate normally distributed (MND) random vector v, with mean $\overline{v}$ and (*nonsingular*) covariance matrix Σ_v, are realized. When the matrix Σ_v is either nondiagonal or block-diagonal (see Definition A1 in Appendix A), either some of the N assets or some assets in any of their subsets (blocks) are fundamentally correlated to each other.

We model such fundamental interaction by assuming that the vector of liquidation values v is characterized by the following linear factor structure:

$$v = u + \beta\vartheta, \tag{1}$$

where u is a $N \times 1$ unobservable random vector of idiosyncratic shocks, ϑ is a $F \times 1$ unobservable random vector of common factors, and β is a $N \times F$ matrix of factor loadings. One can think of u as representing company-, industry-, market-, or country-specific risk factors. The vector ϑ is instead a proxy for systematic sources of risk affecting more than one asset. We assume that u and ϑ are MND with means $\overline{u}$ and $\overline{\vartheta}$ and (diagonal and nonsingular) covariance matrices Σ_u and Σ_ϑ, respectively. Consequently, $\overline{v} = \overline{u} + \beta\overline{\vartheta}$ and $\Sigma_v = \Sigma_u + \beta\Sigma_\vartheta\beta'$, which is nonsingular (but also nondiagonal unless $\beta = O$, where O is a zero matrix).[2]

[2]Indeed, the matrix $\left[\Sigma_u + \beta\Sigma_\vartheta\beta'\right]^{-1}$ always exists for any $N \times F$ matrix β if both Σ_u and Σ_ϑ are nonsingular (e.g., Maddala (1987, p. 446)). Hence, the requirement that Σ_v be nonsingular does not impose any restriction on the factor loadings β.

2.2 Market participants and information

We consider a market with risk-neutral traders: perfectly competitive market-makers (MMs), K privately and heterogeneously informed mutual fund managers (MFs), and liquidity traders. MFs do not observe current prices or current quantities traded by other insiders or by the liquidity traders. MMs do not receive any private information nor do they observe the individual quantities traded by the MFs and the liquidity traders separately. Nevertheless, the MMs do observe the aggregate order flow from all market participants, while the MFs do not. All traders know the structure and parameters of the economy and the decision process leading to order flow and price formation. At time $t = 0$ there is no information asymmetry about v among the traders, and the prices of the risky assets are given by the unconditional means of their terminal payoffs, i.e., $P_0 = \overline{v}$. The vector of liquidation values v is unobservable by all agents. Sometime between $t = 0$ and $t = 1$, however, each MF k receives two sets of private and noisy signals S_{uk} and $S_{\vartheta k}$ of the idiosyncratic and common factors u and ϑ, respectively.

In the spirit of Admati (1985), it is assumed that, for any $k = 1, \ldots, K$, those signals take the form $S_{uk} = u + \varepsilon_{uk}$, with $\varepsilon_{uk} \sim MND\left(\underline{0}, \Sigma_{\varepsilon_{uk}}\right)$ (where $\underline{0}$ is a zero vector), and $S_{\vartheta k} = \vartheta + \varepsilon_{\vartheta k}$, with $\varepsilon_{\vartheta k} \sim MND\left(\underline{0}, \Sigma_{\varepsilon_{\vartheta k}}\right)$.[3] For simplicity, we impose that the random vectors u, ϑ, and all ε_{uk} and $\varepsilon_{\vartheta k}$ are mutually independent, that $\Sigma_{\varepsilon_{uk}} = \Sigma_{\varepsilon_u}$ and $\Sigma_{\varepsilon_{\vartheta k}} = \Sigma_{\varepsilon_\vartheta}$ for any k (i.e., that the precision of each signal is identical across insiders), and that Σ_{ε_u} and $\Sigma_{\varepsilon_\vartheta}$ are diagonal. We can interpret the resulting *information heterogeneity* across the K MFs as arising from the use of diverse, disparate sources to learn about the same underlying variables affecting the payoff vector v. Indeed, significant and persistent differences in private information among traders are an ubiquitous feature of most financial markets, especially the ones in emerging economies, where the process of generation and acquisition of information is not as standardized as in more developed countries.

It then follows (e.g., Greene (1997, pp. 89-90)) that the expectation of v by the k-th MF at $t = 1$, before trading with the MMs, is given by

$$E\left[v|S_{uk}, S_{\vartheta k}\right] = E_1^k\left[v\right] = \overline{v} + \Sigma_u \Sigma_{S_u}^{-1}\left(S_{uk} - \overline{u}\right) + \beta \Sigma_\vartheta \Sigma_{S_\vartheta}^{-1}\left(S_{\vartheta k} - \overline{\vartheta}\right), \quad (2)$$

where $\Sigma_{S_u} = \Sigma_u + \Sigma_{\varepsilon_u}$ and $\Sigma_{S_\vartheta} = \Sigma_\vartheta + \Sigma_{\varepsilon_\vartheta}$. We define the informational advantage of the k-th MF with respect to the uninformed traders in the economy about the terminal values of the risky assets by the random vector $\delta_k = E_1^k\left[v\right] - \overline{v}$. It is clear that $\delta_k \sim MND\left(\underline{0}, \Sigma_\delta\right)$ for all ks, with $\Sigma_\delta =$

[3] In other terms, it is possible that $S_{uk} \neq S_{ui}$ ($S_{\vartheta k} \neq S_{\vartheta i}$) only because of heterogeneous, but identically distributed noise terms $\varepsilon_{uk} \neq \varepsilon_{ui}$ ($\varepsilon_{\vartheta k} \neq \varepsilon_{\vartheta i}$).

$\Sigma_u \Sigma_{S_u}^{-1} \Sigma_u + \beta \Sigma_\vartheta \Sigma_{S_\vartheta}^{-1} \Sigma_\vartheta \beta'$ nonsingular. The above assumptions also imply that, for every pair of MFs k and i, with $i \neq k$, the random vectors δ_k and δ_i have a joint normal distribution and

$$cov\left(\delta_k, \delta_i\right) = \Sigma_c = \Sigma_u \Sigma_{S_u}^{-1} \Sigma_u \Sigma_{S_u}^{-1} \Sigma_u + \beta \Sigma_\vartheta \Sigma_{S_\vartheta}^{-1} \Sigma_\vartheta \Sigma_{S_\vartheta}^{-1} \Sigma_\vartheta \beta', \tag{3}$$

where Σ_c is a *symmetric positive definite* (SPD) matrix.[4] Therefore, $E_1^k\left[\delta_i\right] = \Sigma_c \Sigma_\delta^{-1} \delta_k$ for each $i \neq k$. In general, it will be the case that $\Sigma_c \neq \Sigma_\delta$. Nonetheless, it ensues immediately from Eq. (2) that $cov\left(\delta_k, \delta_i\right)$ is equal to Σ_δ when $\delta_k = \delta$ for each $k, i = 1, \ldots, K$. Σ_c is instead equal to $\rho \Sigma_\delta$ (with $\rho \in (0,1)$) and $E_1^k\left[\delta_i\right] = \rho \delta_k$, for each $i \neq k$, when all sources of fundamental and information noise, besides being uncorrelated across assets, have identical variance and all matrices Σ_u, Σ_{ε_u}, Σ_ϑ, and $\Sigma_{\varepsilon_\vartheta}$ are multiples of the corresponding identity matrix I such that $\Sigma_{S_u}^{-1} \Sigma_u = \rho I$ and $\Sigma_{S_\vartheta}^{-1} \Sigma_\vartheta = \rho I$.

At time $t = 0$ each MF k has an inventory of risky securities, represented by the vector e_k, and holds an amount $NAV_{0k} - e_k' P_0$ of the riskless asset. Clearly, NAV_{0k} represents the initial Net Asset Value (NAV) of the k-th MF's portfolio at $t = 0$ before trading occurs. We assume that the MFs do not face borrowing or short-selling constraints, in order to control for the liquidity channel of contagion described in Section 1, i.e., to eliminate the asymmetric effects of margin calls and budget constraints on their trading decisions. The inventory of risky assets e_k is private information of the MF k. We further assume that, from the perspective of the other market participants, each random endowment vector e_k is MND, with mean $\overline{e}$ and nonsingular covariance matrix Σ_e, and independent from v and any ε_{uk} and $\varepsilon_{\vartheta k}$. We define the informational advantage of the k-th MF with respect to the uninformed traders in the economy about his initial holdings of the risky assets by the random vector $\delta_{ek} = e_k - \overline{e}$. It follows that $\delta_{ek} \sim MND\left(\underline{0}, \Sigma_e\right)$. For simplicity, we impose that Σ_e is diagonal and $cov\left(\delta_{ek}, \delta_{ei}\right) = O$ for all k, so that $E_1^k\left[\delta_{ei}\right] = \underline{0}$ for each $i \neq k$.[5]

2.3 Market participants and trading

At time $t = 1$, both MFs and liquidity traders submit their orders to the MMs, before the price vector P_1 has been set. Hence, the insiders submit market orders X_k based on expected rather than actual prices. Liquidity

[4] See Definition A2 in Appendix A.

[5] This last assumption can be relaxed to allow each MF to use his initial endowment to infer those of the other MFs. This may be realistic if we think of all MFs as being characterized by similar customer bases, management styles, or benchmarks. If we impose that $cov\left(\delta_{ek}, \delta_{ei}\right) = \Sigma_{ee}$ for each $i \neq k$, then $E_1^k\left[\delta_{ei}\right] = \Sigma_{ee} \Sigma_e^{-1} \delta_{ek}$.

traders are assumed to generate a vector of random demands z, which is independent from all δ_k and δ_{ek} and MND with mean $\overline{z}$ and nonsingular covariance matrix Σ_z. Again for simplicity, we assume that Σ_z is also diagonal.

It is a stylized fact about speculative markets (especially emerging markets) that better-informed traders (especially if large enough) use their informational advantage to influence prices, rather than taking them as given. The latter, Grinblatt and Ross (1985) indeed argue, would be "irrational" since prices do respond to their actions. Therefore, we posit that our insiders are imperfectly competitive, hence that, in equilibrium, the MFs correctly anticipate the pricing rule (although not the actual price vector) and incorporate this knowledge in formulating their optimal orders, as in Kyle (1989). To identify these orders, we need to specify an objective function for the insiders. We assume that the k-th MF's optimal demand vector for risky assets, X_k, maximizes the expected value of the following separable utility function U_k of the NAV of his portfolio (i.e., of his wealth) at $t = 1$ and $t = 2$:

$$U_k = \gamma U\left(NAV_{1k}\right) + (1-\gamma)\, U\left(NAV_{2k}\right), \tag{4}$$

where $\gamma \in [0, 1]$. NAV_{1k} is announced at the end of the first period, after the MMs set the market-clearing prices P_1, while NAV_{2k} is announced at the end of the second period, after the payoffs v are realized. As previously mentioned, because in this paper we concentrate on portfolio rebalancing induced by strategic considerations and not (like in Kodres and Pritsker (2002)) by risk-aversion, we assume that the MFs are risk-neutral: $U\left(NAV_{tk}\right) = NAV_{tk}$. Hence, the ratio $\frac{\gamma}{1-\gamma}$ can be interpreted as the MFs' intertemporal marginal rate of substitution (MRS) between short- and long-term NAV. If $\gamma = 0$, each insider reduces to a (long-term) profit-maximizing speculator, as in Kyle (1985) and Caballé and Krishnan (1994). If $\gamma > 0$, the expected utility of the k-th MF at $t = 1$, before trading occurs, $E_1^k\left[U_k\right]$, is given by

$$\begin{aligned} E_1^k\left[U_k\right] \;=\;& NAV_{0k} + \gamma\left\{e_k'\left[E_1^k\left(P_1\right) - P_0\right] + X_k'\left[E_1^k\left(P_1\right) - E_1^k\left(P_1\right)\right]\right\} + \\ &+ (1-\gamma)\left\{e_k'\left[E_1^k\left(v\right) - P_0\right] + X_k'\left[E_1^k\left(v\right) - E_1^k\left(P_1\right)\right]\right\}. \end{aligned} \tag{5}$$

At both dates $t = 1$ and $t = 2$, the change in NAV for the k-th MF with respect to NAV_{0k} depends on two components: the change in value of the existing inventory of the N risky assets (the first term in each bracketed expression in Eq. (5)), and the profits from trading at $t = 1$ (the second term in each bracketed expression in Eq. (5)). Because the MMs set P_1 after having observed the order flow, the value of the net position accumulated at $t = 1$ is equal to zero in NAV_{1k}.

This objective function, introduced by Bhattacharya and Nanda (1999) in a single-security framework, can be motivated by solvency considerations, agency and reputation issues, or by the flow of cash redemptions and injections affecting the interim life of (open-end) mutual funds. A significant portion of compensation for mutual fund managers is usually made of fees expressed as a fixed percentage of the total value of the assets under management, in order to incite performance or induce truthful revelation of managerial skills.[6] Moreover, some of the final investors who own the fund may choose to redeem their claims at $t = 1$ in face of unexpected liquidity shocks or when disappointed by its past performance. We investigate these issues in greater detail in Section 4. Nonetheless, in either case we believe it is reasonable to assume that mutual fund managers would maximize an objective function that weighs positively both the (long-term) liquidation value of the fund at time $t = 2$ and its (short-term) interim value at time $t = 1$.

A popular argument in the financial press, in the wake of major international contagion events, is that short-term oriented behavior by institutional investors helped fuel and spread crises of otherwise limited scale and scope. Excessively long-term oriented behavior is frequently indicated as a culprit as well, for instance in many accounts of the collapse of the hedge fund Long Term Capital Management (LTCM).[7] Whether the short- versus long-term orientation of speculators' trading activity is a crucial factor in determining the likelihood and magnitude of financial contagion is an important question that the setting of Eq. (5) will allow us to address in this paper.

2.4 Equilibrium

In this economy, the risk-neutral, perfectly competitive MMs face a quantity-based signal extraction problem. At time $t = 1$, they in fact observe only the aggregate order flow for all securities $\omega_1 = \sum_{i=1}^{K} X_i + z$ and, with the information extracted from it, establish the vector of trading prices P_1 that clears all markets.[8] We now show that a linear equilibrium for such economy exists. Since $X_k = \arg\max E_1^k [U_k]$ for each MF, we can think of the optimal trading strategies X_k and the market-clearing vector price functional P_1 as functions of the realizations of δ_k and δ_{ek}, $X_k = X_k(\delta_k, \delta_{ek})$, for $k = 1, \ldots, K$, and of ω_1, $P_1 = P_1(\omega_1)$, respectively. Consistently with Kyle (1985), we use the following standard definition of equilibrium.

[6] See Chevalier and Ellison (1997) for a discussion of this topic.

[7] For an analysis of the LTCM debacle, see Edwards (1999).

[8] Calvo and Mendoza (2000) observe that this modeling approach is especially relevant for emerging economies, in view of the short history of prices available for their domestic capital markets under financial integration. Because the MMs do not possess private information and hold their positions until liquidation at $t = 2$, we may also think of them as uninformed long-term speculators, as in Froot et al. (1992).

Definition 1 *A Bayesian Nash equilibrium in the economy is a set of $K+1$ vector functions $X_1(\cdot), \ldots, X_K(\cdot)$, and $P_1(\cdot)$ such that the conditions below hold:*

1. ***Utility maximization:***

$$E_1^k\left[U_k\left(X_k(\delta_k,\delta_{ek}), P_1\left(\sum_{i=1}^K X_i(\delta_i,\delta_{ei})+z\right)\right)\right] \tag{6}$$
$$\geq E_1^k\left[U_k\left(Y_k(\delta_k,\delta_{ek}), P_1\left(Y_k(\delta_k,\delta_{ek})+\sum_{\substack{i=1\\ i\neq k}}^K X_i(\delta_i,\delta_{ei})+z\right)\right)\right]$$

for any alternative trading strategy $Y_k(\cdot)$ and for all $k=1,\ldots,K$;

2. ***Semi-strong market efficiency:***

$$P_1(\omega_1) = E[v|\omega_1]. \tag{7}$$

In Eq. (6), the imperfectly competitive MFs take the pricing rule $P_1(\cdot)$ as given, but exploit their informational advantage by accounting for the impact of their trading decisions on the clearing prices eventually set by the MMs at $t=1$. Hence, Eq. (6) requires that the market order X_k submitted by the k-th MF be optimal, given his information set at the time it is chosen, before the MMs announce P_1. Semi-strong market efficiency (Eq. (7)) is the result of competition among those identical risk-neutral dealers driving to zero their total expected long-term profits in each market, conditional on any set of signals observed by all of them (the order flow vector ω_1), i.e., such that $\omega_1(n)[E(v(n)|\omega_1) - P_1(n)] = 0$ for each $n=1,\ldots,N$.

Caballé and Krishnan (1994) have shown how to explicitly characterize a symmetric linear equilibrium in a multi-security market with information asymmetry and risk-neutrality. The following proposition accomplishes this task for our economy.

Proposition 1 *There always exists a linear equilibrium for the economy given by the price function*

$$P_1 = P_0 + \frac{\sqrt{K}}{2}\Lambda\left[\omega_1 - \overline{z} - \left(\frac{\gamma}{1-\gamma}\right)K\overline{e}\right] = \tag{8}$$
$$= P_0 + H\sum_{i=1}^K \delta_i + \frac{\sqrt{K}}{4}\left(\frac{\gamma}{1-\gamma}\right)\Lambda\sum_{i=1}^K \delta_{ei} + \frac{\sqrt{K}}{2}\Lambda(z-\overline{z}) \tag{9}$$

and by the demand strategy of the k-th MF

$$X_k = \left(\frac{\gamma}{1-\gamma}\right)\overline{e} + C\delta_k + \frac{1}{2}\left(\frac{\gamma}{1-\gamma}\right)\delta_{ek}, \tag{10}$$

for all $k = 1, \ldots, K$*, where* $\Sigma_n = \Sigma_z + \frac{K}{4}\left(\frac{\gamma}{1-\gamma}\right)^2 \Sigma_e$*,* $\Sigma_n^{1/2}$ *and* $\Psi^{1/2}$ *are the unique SPD square roots of* Σ_n *and* $\Psi = \Sigma_n^{1/2}\Gamma\Sigma_n^{1/2}$*, respectively (with the SPD matrix* Γ *defined in Appendix A),* $\Lambda = \Sigma_n^{-1/2}\Psi^{1/2}\Sigma_n^{-1/2}$ *is a SPD matrix,* $H = \left[2I + (K-1)\,\Sigma_c\Sigma_\delta^{-1}\right]^{-1}$*, and* $C = \frac{2}{\sqrt{K}}\Lambda^{-1}H$*.*

Proof. See Appendix A. ■

Remark 1 *The linear equilibrium of Proposition 1 is the unique equilibrium for which* Λ *is symmetric. Moreover, that equilibrium is the unique linear equilibrium if either* $K = 1$ *(there is a single insider) or* $\Sigma_n = \sigma_n^2 I$ *(noise trading has identical variance and is uncorrelated across assets).*

Proof. See Appendix A. It is straightforward to show that if $\Sigma_n = \sigma_n^2 I$, then $\Lambda = \frac{1}{\sigma_n}\Gamma^{1/2}$. ■

2.5 Properties of the equilibrium

The expressions in Eqs. (8) to (10) represent a noisy rational expectations equilibrium. In contrast, in the Gaussian setting with perfect competition of Admati (1985), where prices aggregate information across risk-averse traders, all private information is fully revealed when their risk-aversion wanes. The market-clearing prices in Eq. (8) are not fully revealing because, as we clarify in Section 3, our imperfectly competitive informed MFs do not take the vector P_1 as given and, despite being risk neutral, trade *cautiously* and *strategically* across assets to maximize their objective functions. Hence, portfolio diversification does arise in our model, even if the MFs are neither interested in reducing the variance of their portfolios nor financially constrained, and will play a key role in our analysis of financial contagion.

The optimal trading strategy for each informed MF k, X_k of Eq. (10), depends on the information he receives about v, $C\delta_k$, and on his inventory, $\frac{\gamma}{1-\gamma}\left[\bar{e} + \frac{1}{2}\delta_{ek}\right]$. Because the imperfectly competitive insiders recognize and exploit the impact of the aggregate order flow ω_1 on the price-formation process, the matrix C is equal to $\frac{2}{\sqrt{K}}\Lambda^{-1}H$. For $\gamma = 0$, X_k reduces to the optimal informational demand schedule of Kyle (1985) and Caballé and Krishnan (1994), and its unconditional mean is given by $E\left[C\delta_k\right] = \underline{0}$. For $\gamma > 0$, each MF cares about the interim value of his portfolio, as well as about its terminal NAV. Hence, each trades more than he otherwise would ($E\left[X_k\right] = \frac{\gamma}{1-\gamma}\bar{e}$) in order to distort the asset prices in the direction of his inventory e_k and so increase NAV_{1k}. In equilibrium, these efforts are successful: the unconditional covariance between P_1 and e_k, $cov(P_1, e_k) = \frac{\sqrt{K}}{4}\left(\frac{\gamma}{1-\gamma}\right)\Lambda\Sigma_e$ is SPD, so the unconditional expected change in the value of each inventory, $E[e_k'(P_1 - P_0)] = \frac{\sqrt{K}}{4}\left(\frac{\gamma}{1-\gamma}\right)tr(\Lambda\Sigma_e)$, is positive. However, this has to come at the cost of smaller terminal profits, since $\gamma > 0$ induces the MFs to deviate from their optimal informational strategy $C\delta_k$.

The MMs cannot distinguish the component of the observed order flow due to informative trading by the MFs from the uninformative components due to the activity of liquidity traders and to the MFs' attempts to increase the value of their inventory at $t = 1$ regardless of their signals. Hence, liquidity and short-term trading effectively provide camouflage for the insiders by enabling them to make some long-term profits at the expenses not only of liquidity traders but also of the portion of MFs' short-term trading activity, including their own. Their demand functions in Eq. (10) indeed result from the optimal resolution of this trade-off between short- and long-term profits.

The n-th row (or, equivalently, the n-th column) of $\frac{\sqrt{K}}{2}\Lambda$ in Eq. (8) measures the impact of a unit of trade in asset n on *all* equilibrium prices. Because the matrix Λ is SPD and nondiagonal (unless $\beta = O$), not only the price of each asset $P_1(n)$ is positively related to its corresponding total order flow $\omega_1(n)$ (i.e., $\frac{\sqrt{K}}{2}\Lambda(n,n) > 0$) but also the reaction of each $P_1(n)$ to the total order flow for any other asset j, $\frac{\sqrt{K}}{2}\Lambda(n,j)$, may be different from zero. The matrix $\frac{2}{\sqrt{K}}\Lambda^{-1}$ exists and is SPD, since so is Λ (see Theorem A1 in Appendix A), and, as in Kyle (1985), measures the *depth* of this multi-asset market. Indeed, the element $\frac{2}{\sqrt{K}}\Lambda^{-1}(n,j)$ represents the total order flow for asset j that is necessary for the MMs to move $P_1(n)$ one unit of the numeraire from its unconditional mean $\overline{v}(n)$.

The equilibrium market depth reflects the MMs' attempt to compensate themselves for the losses they anticipate from trading with the insiders, for it affects their profits from liquidity and short-term trading. It follows immediately from the definition of Λ in Proposition 1 that (as expected) $\lim_{K\to\infty}\Lambda = O$ and that the absolute market depth, $\frac{2}{\sqrt{K}}|\Lambda^{-1}|$, is positively related to the number of MFs (K), to their intertemporal MRS ($\frac{\gamma}{1-\gamma}$), and, more generally, to the amount of noise accompanying uninformative trading (the diagonal and nonsingular matrix Σ_n).[9] When K increases, so does the amount of informative trading in ω_1, not only because more insiders submit market orders but also because, as we explain in greater detail in the next section, those insiders tend to compete with each other more aggressively, thus dissipating more of their informational advantage. A higher intertemporal

[9] In this paper, we use the absolute value of a matrix to denote the matrix of the absolute values of its elements.

MRS fosters instead the short-term component of MFs' trading activity, as it raises the relative importance of NAV_{1k} in their utility functions. Similarly, an increase in any $\Sigma_n(n,n)$ makes the portion of expected noise trading in ω_1 more significant. In all such circumstances, the MMs perceive the threat of adverse selection as less serious, and penalize less their counterparts by reducing $|\Lambda|$, i.e., by increasing each market's liquidity.

Consistently with these observations, the equilibrium vector P_1 depends only on the portion of the observed total order flow that the MMs expect to be informative about the liquidation payoffs of the N assets, i.e., ω_1 minus the expected uninformative trading activity. Such term is made of the expected demand from liquidity traders ($\overline{z}$) and of the expected inventory of risky assets held by the K MFs ($K\overline{e}$), adjusted by their intertemporal MRS. Clearly, the greater is γ, the greater are the incentives for the MFs to trade in order to affect the market-clearing price arising at time $t = 1$. Liquidity and short-term trading have no information content regarding the liquidation value of the assets, but simply add noise to the total order flow (via Σ_n).

The existence of noise trading is an important ingredient of the model. As emphasized by Admati (1985), a nonsingular Σ_n provides in fact camouflage for informed trades since it prevents the total order flow ω_1 from being a sufficient statistic for any combination of the private signals of v observed by the MFs, i.e., it prevents the order flow from fully dissipating their informational advantage. Hence, the insiders' concern about interim value of their holdings allows transactions to occur in this economy even in the absence of liquidity traders, as long as there is uncertainty about the original composition of the MFs' portfolios. Remark 2 generalizes Proposition 3 of Bhattacharya and Nanda (1999) to our multi-asset setting, and relates our Proposition 1 to the closed form solution of the noisy rational expectations equilibrium with endowment shocks derived by Diamond and Verrecchia (1981).

Remark 2 *When $\gamma > 0$ and the MFs' inventory vectors e_k of the N risky assets are private information, there is trading in equilibrium even in the absence of liquidity shocks z.*

Proof. Straightforward from Proposition 1.[10] ■

The deviation of the k-th MF from his optimal informational strategy $C\delta_k$ does not depend on the liquidity matrix Λ, although the magnitude of the resulting increase in NAV_{1k} does. This is due to the fact that, in

[10] When $\gamma = 1$, ω_1 does not contain any information about v, hence $\Lambda = O$ and $E[v|\omega_1] = \overline{v}$. The no-profit condition then imposes that $P_1 = P_0$ in equilibrium.

equilibrium, the MMs discount their knowledge of MFs' focus on the intertemporal behavior of their NAVs into the market-clearing prices, while the MFs discount their knowledge of the process by which MMs set prices in their market orders. It should then not be surprising that, although the unconditional variance of X_k, $var\left[X_k\right] = \frac{1}{K}\Sigma_n + \frac{1}{4}\left(\frac{\gamma}{1-\gamma}\right)^2 \Sigma_e$, is a function of γ, Σ_e, and Σ_z, the unconditional variance of P_1, given by the SPD matrix

$$var\left[P_1\right] = H\left[K\Sigma_\delta + K\left(K-1\right)\Sigma_c\right]H' + \frac{K}{4}\Lambda\Sigma_n\Lambda = KH\Sigma_\delta, \tag{11}$$

is not, as in Kyle (1985). In this risk-neutral economy, an increase in the level of noise trading offers more hiding opportunities for insiders, brings forth more aggressive informative trading by the MFs, and eventually does not destabilize prices in equilibrium.

These considerations suggest that the aggressiveness of the MFs in formulating their orders affects crucially the informativeness of the aggregate order flow and the depth of each of the N markets in equilibrium. In the next section, we reach the core of our analysis by exploring the effect of imperfect competition among heterogeneously informed insiders on such aggressiveness and its implications for the propagation of shocks across assets.

3 Excess covariance

The identification of empirical regularities stemming from episodes of domestic and international financial turmoil is currently at the center of an intense debate in the literature.[11] Nonetheless, a consensus has developed among researchers and practitioners that not only periods of uncertainty but also more tranquil times are generally accompanied by excess volatility and comovement among asset prices within and across both developed and emerging financial markets. We define such *excess covariance* as covariance beyond the degree that is justified by economic fundamentals, and *financial contagion* as the circumstance of its occurrence. In this section we propose an explanation for excess (co)movement that uses two realistic and commonly observed forms of market frictions, imperfect competition among insiders and heterogeneity of their information endowments, in the context of our stylized economy.

[11] A by no means exhaustive list of recent contributions includes Shiller (1989), King and Wadhwani (1990), Pindyck and Rotemberg (1990, 1993), King et al. (1994), Karolyi and Stulz (1996), Baig and Goldfajn (1999), Bekaert and Harvey (2000), Connolly and Wang (2000), Barberis et al. (2002), Boyer et al. (2002), Corsetti et al. (2002), Forbes and Rigobon (2002), Kallberg et al. (2002), and Kallberg and Pasquariello (2002).

3.1 Strategic trading and information

One of the main features of the model of Section 2 is that it allows for imperfectly competitive insiders, albeit risk-neutral, to exploit their heterogeneous private information strategically.

Informed professional money managers use their research to learn about the unobservable liquidation values of all assets, v, and rely on this information in their trading activity. When the matrix Σ_v is either nondiagonal or block-diagonal, uninformed MMs use each order flow to learn about the terminal payoffs of some or all securities. The matrix Λ in Eq. (8) is indeed either nondiagonal or block-diagonal as well. However, the presence of noise in the order flow, in the form of liquidity and short-term trading, induces them to commit errors in their inference for v. These errors lead the MMs to either over-price or under-price the N securities with respect to the expected fundamental values estimated by the money managers using their private information. The MFs compare their beliefs not to the actual prices, but to the prices they expect to receive from the MMs when submitting market orders, and speculate on the expected incorrect inference by the MMs.

Each MF has therefore an incentive not to trade infinite amounts of and not to determine independently his demand for each of the securities, but instead to speculate cautiously and strategically across them. Such trading activity, which we call here *strategic portfolio diversification*, originates from the insiders' need to avoid dissipating all their informational advantage, i.e., to prevent ω_1 from becoming too informative about v and the incorrect inference by the MMs from attenuating. For example, submitting orders just for asset n after having received a signal about $v(n)$ would reduce the insiders' speculative opportunities in that market, as the MMs use the observed total order flow for asset n to learn more about its terminal payoff. If, however, asset n is fundamentally related to asset j, the MFs may trade in such asset as well, to induce the MMs to only a partial or incorrect revision of their beliefs about $v(n)$ and of the equilibrium price $P_1(n)$. The above intuition suggests that the intensity of strategic trading aimed at limiting the informativeness of the order flow plays a key role in explaining the transmission of information shocks across assets in our framework.

For a given amount of noise trading (i.e., for a given Σ_n), the amount of competition among insiders clearly affects their ability to maintain the informativeness of the order flow as low as possible and to make their strategic speculation as profitable as possible in the long-term. Intuitively, the intensity of such competition depends not only on K, the number of MFs, but also on the degree of heterogeneity of their private information, which we measure in our setting by the matrix H (defined in Proposition 1). We say that all insiders share the *same* or receive *similar* (i.e., *not* heterogeneous *enough*) private information if $S_{uk} = S_u$ and $S_{\vartheta k} = S_\vartheta$, so $cov(\delta_k, \delta_i) = \Sigma_\delta$, or if $S_{uk} \neq S_{ui}$ and $S_{\vartheta k} \neq S_{\vartheta i}$ but $cov(\delta_k, \delta_i) = \rho\Sigma_\delta$ (with $\rho \in (0,1)$), respectively, for each $i \neq k$. In particular, when $\Sigma_c = \rho\Sigma_\delta$ each MF k expects the information endowments of all the other insiders to be a fraction of, thus *perfectly correlated* to his own (i.e., $E_1^k[\delta_i] = \rho\delta_k$); moreover, the higher is ρ, the closer is $cov(\delta_k, \delta_i)$ to $var(\delta_k)$ (and $E_1^k[\delta_i]$ to δ_k), hence the greater is the similarity between δ_k and δ_i. In such cases, the matrix H is equal to $\frac{1}{2+\rho(K-1)}I$, with $\rho \in (0,1]$. Conversely, the more Σ_c is distant from $\rho\Sigma_\delta$, the more heterogeneous is the information among the K insiders, and the more H is different from $\frac{1}{2+\rho(K-1)}I$. For the remainder of the paper we refer to the circumstances in which either $\Sigma_c = \Sigma_\delta$ (and $H = \frac{1}{K+1}I$) or, more generally, $\Sigma_c = \rho\Sigma_\delta$ with $\rho \in (0,1]$ (and $H = \frac{1}{2+\rho(K-1)}I$) as *information homogeneity*, and to the circumstances in which $\Sigma_c \neq \rho\Sigma_\delta$ (and $H \neq \frac{1}{2+\rho(K-1)}I$) as (*enough*) *information heterogeneity*, or asymmetric information sharing among insiders. We make more precise the above insights in the context of our multi-asset model by stating the following corollary of Proposition 1.

Corollary 1 *In equilibrium, if there is only one MF ($K = 1$), then $\Lambda_{K=1} = \Sigma_n^{-1/2}\left(\Sigma_n^{1/2}\Sigma_\delta\Sigma_n^{1/2}\right)^{1/2}\Sigma_n^{-1/2}$. If instead there are many ($K > 1$) MFs sharing the same or similar information, then $\Lambda_{K>1} = \frac{2}{2+\rho(K-1)}\Lambda_{K=1}$. This implies that, for each $n = 1, \ldots, N$,*

$$\Lambda(n,n)_{K=1} \geq \Lambda(n,n) \geq \Lambda(n,n)_{K>1}, \tag{12}$$

with a strict inequality holding for at least some n.

Proof. See Appendix A.[12] ■

Multiple homogeneously informed insiders, acting noncooperatively, have an incentive to trade more aggressively than a monopolist MF would in the single insider setting of Kyle (1985). Indeed, $\left|\sum_{i=1}^{K} X_i\right| > |X_{K=1}|$ when $\Sigma_c = \rho\Sigma_\delta$, for it can be shown that, more generally, $|\Lambda_{K=1}| \geq \frac{\sqrt{K}}{2}|\Lambda_{K>1}|$ and $|C_{K=1}| \leq |C_{K>1}|$. This *quasi-competitive* behavior occurs because imperfectly competitive MFs cannot collude to better exploit their informational advantage by using it more parsimoniously. Consequently, they collectively

[12] Similar results and intuition for the case of a single risky asset have been provided by Admati and Pfleiderer (1988) in a one-period framework, by Holden and Subrahmanyam (1992) and Foster and Viswanathan (1996) in a multi-period game, and by Back et al. (2000) in a continuous-time setting.

trade more aggressively in the direction of their private signals, hence dissipating some of their aggregate informational advantage. Because of this less opportunistic, more competitive behavior by the MFs, the resulting information content of the order flow increases, i.e., ω_1 becomes more revealing about v. Thus, MMs fear less adverse selection in trading, and reduce the compensation that they expect to earn from noise trading by increasing each market's liquidity $(\Lambda(n,n)_{K>1} \leq \Lambda(n,n)_{K=1})$.

More diverse, less correlated, heterogeneous information across the K insiders mitigates their incentives to compete aggressively with each other. When information is heterogeneous, each MF has indeed some degree of monopoly on the private signals he observes, because part of them are known exclusively to him. This perception motivates each MF to exploit his informational advantage more carefully by submitting smaller orders, to reveal less of his individual signal. We define the behavior of the imperfectly competitive but heterogeneously informed MFs as *quasi-monopolistic*. The diversity in the observed signals S_{uk} and $S_{\vartheta k}$, and the resulting less aggressive market orders by all the MFs make the total order flow more informative about the average insiders' knowledge of v (since all the noise terms ε_{uk} and $\varepsilon_{\vartheta k}$ are mutually independent and identically distributed), but less informative about each individual signal, i.e., less revealing of each insider's strategic trading activity. This induces the MMs to feel more threatened by adverse selection in trading, hence to reduce each market's depth $(\Lambda(n,n) \geq \Lambda(n,n)_{K>1})$.

The trading activity of a monopolist insider is the least aggressive. Unthreatened by competing money managers, he can indeed exploit fully his private signals by trading cautiously in each of the assets to avoid dispersing his informational advantage. This makes the observed total order flow ω_1 the least informative about the terminal payoffs of the N assets, and the perceived risk of adverse selection the highest for the MMs. The lowest degree of depth in each of the markets ensues $(\Lambda(n,n)_{K=1} \geq \Lambda(n,n))$.

3.2 Information and contagion

We are now ready to address the issue of financial contagion. The results of Section 3.1 suggest that the degree of competition among MFs and the heterogeneity of their information endowments have a significant impact on market liquidity, on the intensity of their strategic portfolio diversification efforts across different securities, hence on the comovement of the resulting equilibrium prices of the traded assets. This is the topic of Proposition 2.

Proposition 2 *In equilibrium, if there is only one MF ($K = 1$), then $var[P_1]_{K=1} = \frac{1}{2}\Sigma_\delta$. If instead there are many ($K > 1$) MFs sharing the* *same or similar information, then* $var\left[P_1\right]_{K>1} = \frac{K}{2+\rho(K-1)}\Sigma_\delta$*. This implies that, for each* $n, j = 1, \ldots, N$*,*

$$\left|var\left[P_1\right](n,j)\right| \geq \left|var\left[P_1\right]_{K>1}(n,j)\right| \geq \left|var\left[P_1\right]_{K=1}(n,j)\right|, \tag{13}$$

with a strict inequality holding for at least one $n = j$*.*

Proof. See Appendix A. ■

In order to understand the implications of Eq. (12) for our analysis, we examine the expression for $var\left[P_1\right]$ in Eq. (11), hence the matrix $KH\Sigma_\delta$. We can think of Σ_δ, previously defined in Section 2.2 as $var\left[\delta_k\right]$, as reflecting the *true* underlying covariance structure of the economy (Σ_u and $\beta\Sigma_\vartheta\beta'$), adjusted for the relative precision of the signals of u and ϑ ($\Sigma_u\Sigma_{S_u}^{-1}$ and $\Sigma_\vartheta\Sigma_{S_\vartheta}^{-1}$). For example, if $\Sigma_v(n,j)$ is equal to zero, then so is $\Sigma_\delta(n,j)$. Therefore, the matrix H, representing the degree of asymmetric information sharing among MFs, also controls for the amount of all private fundamental information about v that is incorporated in P_1, consistent with Eq. (9). When $K = 1$, $H = \frac{1}{2}I$ and the unconditional variance of the equilibrium price vector is given by $\frac{1}{2}\Sigma_\delta$, similarly to Kyle (1985). When there are many ($K > 1$) homogeneously informed insiders, H is instead equal to $\frac{1}{2+\rho(K-1)}I$ and $var\left[P_1\right] = \frac{K}{2+\rho(K-1)}\Sigma_\delta$. In both cases, $var\left[P_1\right]$ is only a fraction of Σ_δ because the order flow is only partially revealing about the insiders' private information.

If the K MFs are heterogeneously informed, $var\left[P_1\right]$ instead departs, in general significantly, from such fundamental variation. More specifically, according to Proposition 2, if $H \neq \frac{1}{2+\rho(K-1)}I$ the insiders' strategic trading activity not only leads to greater volatility of all equilibrium prices than if $\Sigma_c = \rho\Sigma_\delta$, but may also induce equilibrium prices of fundamentally unrelated assets to move together. In other terms, when MFs' private information is homogeneous (and H is diagonal), $var\left[P_1\right]$ mimics the fundamental covariance structure Σ_v embedded in Σ_δ, while, when the insiders receive heterogeneous information about v (and H is nondiagonal), $var\left[P_1\right]$ does not. Indeed, when H is nondiagonal, Eq. (12) implies that $var\left[P_1(n), P_1(j)\right]$ may be different from zero although $\Sigma_v(n,j) = 0$. Hence, excess covariance, which we measure, motivated by the above discussion, by the absolute difference between $var\left[P_1\right]$ and the corresponding $var\left[P_1\right]_{K>1}$, $EC = \left|K\left[H - \frac{1}{2+\rho(K-1)}I\right]\Sigma_\delta\right|$, arises in our economy. The following corollary summarizes these findings.

Corollary 2 *In equilibrium, there is financial contagion across asset prices if and only if* $K > 1$ *and* $H \neq \frac{1}{2+\rho(K-1)}I$*. The intensity of short-term and liquidity trading has no impact on the degree of excess covariance* EC*.*

Proof. See Appendix A. ■

Proposition 2 and Corollary 2 state the main result of this paper. Excess volatility and comovement in asset prices depend crucially on the intensity of competition and the degree of information heterogeneity among MFs. Indeed, even in a setting with risk-neutrality and absence of borrowing and short-selling constraints, financial contagion is an equilibrium outcome if and only if there is enough heterogeneity of private information among strategic insiders. Therefore, in such a setting, information asymmetry is a necessary but not sufficient condition for financial contagion across assets to occur.

The existence of insider and noise trading makes the total order flow observed by the dealers potentially informative (with noise) about the fundamental values of the N securities. In particular, the structure of the economy, represented by the matrix Σ_v, induces the MMs to use the aggregate order flow for each asset, $\omega_1(n)$, to cross-infer new information about the liquidation value of some or all of the other assets. Imperfectly competitive MFs, aware of this learning process, do not use their signals of u and ϑ to trade on each of the securities independently, but decide how much to buy and sell of all of them strategically in order to minimize the amount of information divulged by their submitted market orders and thus exploit their informational advantage δ_k in the most profitable way. Indeed, the matrix C in X_k of Eq. (10) is nondiagonal when so is Σ_v.

The MMs are rational, hence discount the knowledge of the expected strategic portfolio diversification activity by the MFs when they update their priors on v based on the observed total order flow. Their ability to account partially or in full for the strategic trading by the MFs determines whether excess comovement arises in our economy. Corollary 2 suggests that for financial contagion to occur the insiders must receive diverse, disparate information about the terminal payoffs of the N assets. Corollary 2 also tells us that when there is only one MF or when all MFs have the same ($\Sigma_c = \Sigma_\delta$) or similar ($\Sigma_c = \rho\Sigma_\delta$) private information, the signal extraction activity by the dealers is sufficient to eliminate the possibility of such contagion.

What is the intuition behind the important role played by the degree of information heterogeneity in our model? When there is only one MF ($K = 1$) or many ($K > 1$) identically (or similarly) informed MFs, their strategic trading activity is (or is expected to be) perfectly correlated, and correctly anticipated by the MMs, resulting in no excess comovement ($var\left[P_1\right] = \frac{1}{2}\Sigma_\delta$ or $var\left[P_1\right] = \frac{K}{2+\rho(K-1)}\Sigma_\delta$, respectively, and $EC = O$). The presence of only one monopolistic insider limits the sources of uncertainty for the MMs regarding the scope and magnitude of any strategic portfolio diversification activity in ω_1. A larger number of homogeneously (i.e., identically or similarly) informed MFs does not increase this uncertainty. In fact, each of the K insiders knows or infers reasonably well the informational endowments of the others, for those are either identical ($\delta_k = \delta$ for each k) or expected to be perfectly correlated ($E_1^k[\delta_i] = \rho\delta_k$ for each $i \neq k$) to his own. All the MFs, acting noncooperatively, have therefore an incentive to compete aggressively among them to exploit their presumed advantage. In equilibrium, as we previously suggested, they end up divulging more (and not less) information in their trading activity. In these circumstances, the order flow becomes a sufficient statistic for the MMs to avoid incorrect cross-inference in updating their beliefs about the entire vector v.

Enough heterogeneous information ($\Sigma_c \neq \rho\Sigma_\delta$) induces the insiders to less aggressive, more cautious, quasi-monopolistic trading activity, for part of each MF's informational advantage versus the MMs is known exclusively to him. This also implies that each MF has imprecise knowledge of the strategic activity of his competitors, as he now expects their information endowments to be less than perfectly correlated to his own ($E_1^k[\delta_i] \neq \rho\delta_k$ for each $i \neq k$). Thus, the K MFs submit not only less aggressive but also more diverse, less than perfectly correlated market orders to the dealers. Consequently, in equilibrium, the MMs learn more accurately about the average information received by the insiders and their average strategic trading activity, but less accurately about any private signal and any individual strategic portfolio diversification choice from ω_1. The resulting incorrect cross-inference on v causes excess covariance among asset prices ($var[P_1] = KH\Sigma_\delta$ and $EC(n,j) \geq 0$, with a strict inequality holding for at least one $n = j$).[13]

Corollary 2 further tells us that, in equilibrium, the intensity of financial contagion does not depend on the level of liquidity trading (Σ_z) nor on the amount of short-term trading activity by the MFs (γ and Σ_e). Once again, this is due to the fact that more noise in the order flow, by creating more hiding opportunities, brings forth more informative and strategic trading by the MFs, hence leaving the total information content of the observed order flow, and the cross-inference by the MMs, unchanged in equilibrium. This result suggests that short-term trading behavior, although commonly thought to exacerbate the propagation of shocks across assets or markets, does not play any role in explaining excess covariance in our market setting.

Liquidity and short-term trading prevent the total order flow from being a sufficient statistic for the MMs to learn about the signals received by the

[13] Consistently with this interpretation of our findings, Grinblatt and Ross (1985) show that the impact of the actions of an insider behaving like a Stackelberg leader on the noisy rational expectations equilibrium of a two-period economy with one risky security and other perfectly competitive traders is significant only when all agents have less than perfectly correlated private information.

MFs. Hence, we can think of Σ_z, γ, and Σ_e as controlling for the basic degree of information asymmetry in the economy of Section 2. Then, Corollary 2 implies that changes in the intensity of information asymmetry *per se* do not affect the vulnerability of an asset to financial contagion from real shocks unless those changes lead to more asymmetric information sharing among insiders, thus to more incorrect cross-inference by the dealers. When $\Sigma_c \neq \rho\Sigma_\delta$, if we define $\Sigma_c^* = \alpha\Sigma_c + (1-\alpha)\,\rho\Sigma_\delta$, assume that $cov\,(\delta_k, \delta_i) = \Sigma_c^*$ for any $i \neq k$, and consequently substitute Σ_c with Σ_c^* in H, we can interpret the parameter $\alpha \in [0,1]$ as a more general measure of the degree of information heterogeneity among the K MFs. The following remark ensues.

Remark 3 *Each positive measure of excess covariance $EC\,(n,j)$ is increasing in K and α. Moreover, $\lim_{K\to\infty} var\,[P_1] = \Sigma_\delta\,(\Sigma_c^*)^{-1}\,\Sigma_\delta$ when $H \neq \frac{1}{2+\rho(K-1)}I$, while $\lim_{K\to\infty} var\,[P_1] = \frac{1}{\rho}\Sigma_\delta$ when $H = \frac{1}{2+\rho(K-1)}I$. Therefore, $\lim_{K\to\infty} EC = \left|\left[\Sigma_\delta\,(\Sigma_c^*)^{-1} - \frac{1}{\rho}I\right]\Sigma_\delta\right|$.*

Proof. See Appendix A. ■

Ceteris paribus, when $H \neq \frac{1}{2+\rho(K-1)}I$ (information heterogeneity) higher K raises the amount of uncorrelated strategic trading in ω_1, so inducing more incorrect cross-inference by the MMs and greater excess (co)movement (toward $\left|\left[\Sigma_\delta\,(\Sigma_c^*)^{-1} - \frac{1}{\rho}I\right]\Sigma_\delta\right|$), although the amount of information embedded in the total order flow, hence in the equilibrium prices P_1, also increases. Higher α raises each security's vulnerability to contagion as well, because it implies greater ex ante dispersion of signals across the insiders, and thus makes it (relatively) more difficult for the MMs to learn about the individual signals from the order flow. When instead $H = \frac{1}{2+\rho(K-1)}I$, the higher is K, the more homogeneously informed MFs are in the market, the more intensely they compete to outplay each other in exploiting the common informational advantage, the more informative ω_1 becomes about v, the smaller is $|\Lambda|$ (toward O), and the closer $var\,[P_1]$ gets to $\frac{1}{\rho}\Sigma_\delta$.

3.3 A no-contagion condition

Information asymmetry among market participants is undoubtedly a necessary (albeit not sufficient) ingredient for excess covariance in our economy, as it allows for inference errors in the signal extraction process by the uninformed dealers, after observing the aggregate order flow. In the previous subsection, we have established a necessary and sufficient condition (information heterogeneity) under which financial contagion may occur in equilibrium. We now conclude this section by stating another necessary (but not sufficient) condition that, if violated, rules out any comovement between fundamentally unrelated assets or blocks of assets, similarly to Kodres and Pritsker (2002).

Proposition 3 *If, as a consequence of the economic structure of Eq. (1), the matrix Σ_v is either diagonal or block-diagonal, then there may be financial contagion across assets within a block, but not among blocks of assets.*

Proof. See Appendix A. ■

Proposition 3 is an important underpinning of the hitherto analysis. When there is no fundamental link across assets, the order flow in one security (or block of securities) cannot reveal any information about the terminal payoffs of other securities (or blocks of securities). In such circumstances, neither cross-inference is possible in the belief updating process by the MMs, nor is strategic portfolio diversification by the MFs effective in limiting the informativeness of the aggregate order flow. Hence, financial contagion cannot occur.

Proposition 3 implies that imperfect competition among insiders and heterogeneity of their private information have no impact on their degree of comovement unless the uninformed MMs are rationally motivated to cross-infer about the terminal payoffs v by a nondiagonal matrix Σ_v. This result suggests that the trend toward a more integrated world economy, by magnifying the significance of global factors in explaining local returns (as shown, for example, in Bekaert, Harvey, and Ng (2002)) and by providing such motivations for cross-inference, might have increased not only the interdependence but also the likelihood of contagion among international financial markets. We examine this issue in greater depth in Section 4.

4 International financial contagion

We have proceeded so far by referring to the structure of the economy in Eq. (1), represented by the random vector v and its nonsingular covariance matrix Σ_v, in a fairly general way. This allowed us to address the implications of the relation between imperfect competition and information heterogeneity for the likelihood and magnitude of excess (co)movement across the broadest possible classes of assets or markets. We now focus on the transmission of shocks across countries, whose recent recurrence, especially among emerging economies, has been puzzling academics and practitioners alike.

Many empirical investigations (e.g., King et al. (1994), Karolyi and Stulz (1996), and, more recently, Connolly and Wang (2000)) indeed find that publicly available macroeconomic variables do not explain the bulk of observed market return comovements, and emphasize instead the importance of unobservable global and local factors. One of the main objectives of this section is to examine how (partially) unobservable real shocks hitting one market may propagate to other economically unrelated markets. To that purpose, we assume that each security in the model represents the entire pool of risky assets of a single country's markets, i.e., that each security n represents country n's all-inclusive market index. We can then interpret the vector S_{uk} as noisy private information about domestic macroeconomic risks (e.g., local fiscal and monetary policies, tax regimes, or political events), and the vector $S_{\vartheta k}$ as private signals of global sources of risk, such as world (or regional) GDP growth and interest rates, commodity prices, or terms of trade.[14]

In Section 3 we have defined financial contagion as the circumstance in which equilibrium asset prices covary more than what one would expect from their underlying fundamentals. The setting of Eq. (1) allows us to investigate in greater detail the channels through which shocks propagate from a country to another. This task can however be accomplished only by specifying an alternative, albeit equivalent, definition of contagion that concentrates on the sources of such shocks. That is what we do next.

4.1 Contagion, not interdependence

Research attempting to explain international contagion phenomena has been particularly rich and intense in the past decade, inspired by a series of financial crises of local origins but global impact, like in the case of East Asia during 1997-1998, Russia in August of 1998, and Brazil in 1999. Nonetheless, there still appears to be disagreement in the financial literature, both theoretical and empirical, about which type of events the term contagion should actually encompass.

In this section, we adopt a definition of contagion suggested by Forbes and Rigobon (2002). We say that *financial contagion* occurs when a shock to one market affects prices of other markets fundamentally unrelated either to that shock or to that market. We find this definition appealing because it allows us to distinguish financial contagion from mere *interdependence*, the propagation of shocks across countries due to real cross-market linkages. The following definition makes the above concepts operational in our framework by means of comparative statics analysis.

[14] There is much anecdotal and empirical evidence of asymmetric information in the markets of developing economies, although a controversy persists on whether domestic or international investors would be the beneficiaries of informational advantages. A partial list of studies on this topic includes Chuhan (1992), Frankel and Schmukler (1996), Brennan and Cao (1997), Claessens et al. (2000), Seasholes (2000), and Froot et al. (2001).

Definition 2 *In equilibrium,* ***financial contagion*** *from country j to country n occurs if any of the following is true:*

$$\frac{\partial P_1(n)}{\partial u(j)} \neq 0 \qquad or \qquad \frac{\partial P_1(n)}{\partial \varepsilon_{uk}(j)} \neq 0, \tag{14}$$

$$\frac{\partial P_1(n)}{\partial \vartheta(f)} \neq 0 \qquad or \qquad \frac{\partial P_1(n)}{\partial \varepsilon_{\vartheta k}(f)} \neq 0 \tag{15}$$

when $\beta(j,f) \neq 0$ but $\beta(n,f) = 0$, or

$$\frac{\partial P_1(n)}{\partial z(j)} \neq 0 \qquad or \qquad \frac{\partial P_1(n)}{\partial e_k(j)} \neq 0. \tag{16}$$

Conversely, ***interdependence*** *between country n and country j occurs if*

$$\frac{\partial P_1(n)}{\partial \vartheta(f)} \neq 0 \qquad or \qquad \frac{\partial P_1(n)}{\partial \varepsilon_{\vartheta k}(f)} \neq 0 \tag{17}$$

when $\beta(j,f) \neq 0$ and $\beta(n,f) \neq 0$.

Given the structure of the economy presented in Eq. (1), a *real shock* to the terminal payoff of index n ($v(n)$) is a shock either to its specific factor ($du(n)$), a real idiosyncratic shock, or to any of the F common factors to which asset values in that country are sensitive ($d\vartheta(f)$), a real systematic shock. *Information noise shocks* are instead shocks to the errors in the signals observed by the MFs about u and ϑ ($d\varepsilon_{uk}(n)$ and $d\varepsilon_{\vartheta k}(n)$, respectively). Finally, *uninformative trading shocks* are shocks to the liquidity trading component of the order flow ($dz(n)$) or to the endowment of any MF k ($de_k(n)$). In the reminder of this section, we analyze the conditions under which each such shock induces contagion (as defined in Eqs. (14) to (16)) in our stylized financial markets in light of the findings of Section 3.

4.2 Real shocks and contagion

According to Definition 2, financial contagion ensues from a real idiosyncratic or systematic shock when $\frac{\partial P_1(n)}{\partial u(j)} \neq 0$ or $\frac{\partial P_1(n)}{\partial \vartheta(f)} \neq 0$ (although $\beta(n,f) = 0$), respectively.[15] Real idiosyncratic and common shocks are observable only by

[15] For example, we could think of the impact of the Russian default of August 1998 on Asia and Latin-America as contagion induced by an apparently idiosyncratic shock. Alternatively, we could interpret the East Asian crisis of 1997 and 1998 spilling over many emerging markets around the world as contagion induced by either a real local or a real regional (i.e., block-common) shock.

the K MFs, and only through the lenses of shocks to the noisy private signal vectors S_{uk} and $S_{\vartheta k}$, hence through shocks to the K individual perceived informational advantage vectors δ_k. Because $S_{uk} = u + \varepsilon_{uk}$ and $S_{\vartheta k} = \vartheta + \varepsilon_{\vartheta k}$, shocks to u and ϑ impact the signals of all K insiders. Proposition 4 provides an explicit characterization of financial contagion induced by real shocks.

Proposition 4 *The impact of real idiosyncratic and systematic shocks on the vector of equilibrium prices P_1 is given by the $N \times N$ matrix*

$$\frac{\partial P_1}{\partial u'} = KH\Sigma_u \Sigma_{S_u}^{-1} \tag{18}$$

and by the $N \times F$ matrix

$$\frac{\partial P_1}{\partial \vartheta'} = KH\beta\Sigma_\vartheta \Sigma_{S_\vartheta}^{-1}, \tag{19}$$

respectively. There is financial contagion from those shocks if and only if $K > 1$ and $H \neq \frac{1}{2+\rho(K-1)} I$, for any $\rho \in (0, 1]$. In this case, both $\left|\frac{\partial P_1(n)}{\partial u(j)}\right|$ and $\left|\frac{\partial P_1(n)}{\partial \vartheta(f)}\right|$ (for $\beta(n, f) = 0$) are increasing in K and α, but are independent from the intensity of noise trading (γ, Σ_e, and Σ_z).

Proof. See Appendix A.[16] ■

The element (n, j) of the matrix $H\Sigma_u \Sigma_{S_u}^{-1}$ measures the change in the equilibrium price of index n induced by an idiosyncratic shock to index j. The element (n, f) of the matrix $H\beta\Sigma_\vartheta \Sigma_{S_\vartheta}^{-1}$ represents instead the change in $P_1(n)$ induced by a shock to the common factor f. Hence, the off-diagonal terms of Eqs. (18) and (19) measure the magnitude of contagion by real shocks. Because H is not symmetric, in general it will be the case that upper and lower-triangular terms in $\frac{\partial P_1}{\partial u'}$ and $\frac{\partial P_1}{\partial \vartheta'}$ are different from each other. But when are those off-diagonal terms different from zero?

The structure of the economy in Eq. (1) allows the dealers to use the aggregate order flow for each country index to cross-infer the terminal payoffs of some or all indices. This (albeit imprecise) learning process by the MMs motivates the MFs to respond less aggressively to their information, and to abstain from formulating their market orders for each security independently,

[16] Additionally, it is easy to show (using the proof of Remark 3 in Appendix A) that $\lim_{K\to\infty} \frac{\partial P_1}{\partial u^0} = \Sigma_\delta (\Sigma_c^*)^{-1} \Sigma_u \Sigma_{S_u}^{-1}$ and $\lim_{K\to\infty} \frac{\partial P_1}{\partial \vartheta^0} = \Sigma_\delta (\Sigma_c^*)^{-1} \beta\Sigma_\vartheta \Sigma_{S_\vartheta}^{-1}$ when $\Sigma_c^* = \alpha\Sigma_c + (1-\alpha)\rho\Sigma_\delta$ but $H \neq \frac{1}{2+\rho(K-1)} I$. When instead $H = \frac{1}{2+\rho(K-1)} I$, it ensues that $\lim_{K\to\infty} \frac{\partial P_1}{\partial u^0} = \frac{1}{\rho}\Sigma_u \Sigma_{S_u}^{-1}$ and $\lim_{K\to\infty} \frac{\partial P_1}{\partial \vartheta^0} = \frac{1}{\rho}\beta\Sigma_\vartheta \Sigma_{S_\vartheta}^{-1}$.

although they observe two separate sets of noisy signals, one for each country-specific factor $u(n)$, and one for each systematic shock $\vartheta(f)$. Rational MMs account for this expected trading activity in setting the equilibrium price $P_1(n)$ in each country's market. When the money managers receive the same or similar signals of u and ϑ, the MMs are able to correctly anticipate the impact of strategic portfolio diversification by the MFs on each observed $d\omega_1(n)$, hence to correctly infer whether that shift is due to idiosyncratic $(du(n))$ or systematic $(d\vartheta(f))$ shocks to $v(n)$.

Indeed, when $K = 1$, or $K > 1$ and $\Sigma_c = \Sigma_\delta$, or $K > 1$ and $\Sigma_c = \rho\Sigma_\delta$, we have that $\frac{\partial P_1}{\partial u'} = \frac{K}{2+\rho(K-1)}\Sigma_u\Sigma_{S_u}^{-1}$ and $\frac{\partial P_1}{\partial \vartheta'} = \frac{K}{2+\rho(K-1)}\beta\Sigma_\vartheta\Sigma_{S_\vartheta}^{-1}$. In the spirit of Kyle (1985), if $\Sigma_c = \Sigma_\delta$ ($\Sigma_c = \rho\Sigma_\delta$) a fraction $\frac{K}{K+1}$ ($\frac{K}{2+\rho(K-1)}$) of the new information available to the insiders about idiosyncratic or systematic factors is revealed to the MMs via the order flow, and by them impounded in the equilibrium prices P_1 to which it pertains, after controlling for its relative precision ($\Sigma_u\Sigma_{S_u}^{-1}$ or $\Sigma_\vartheta\Sigma_{S_\vartheta}^{-1}$), according to (and consistent with) the fundamental structure of the economy (the identity matrix for u or the matrix β for ϑ). Information heterogeneity ($\Sigma_c \neq \rho\Sigma_\delta$) and the resulting quasi-monopolistic trading activity by each insider instead prevent the MMs from accurately anticipating their less than perfectly correlated strategies. Incorrect cross-inference from observing $d\omega_1(n)$ may then ensue. In those circumstances, a real idiosyncratic or systematic shock to the terminal payoff of assets in country n $(v(n))$ would therefore induce a revision not only of $P_1(n)$ but also of the equilibrium prices for some or possibly all of the remaining securities $j \neq n$, hence leading to financial contagion.

Proposition 4 is important because it shows that, in a risk-neutral world, information asymmetry alone does not induce contagion by a real shock, even if all fundamental sources of risk are correlated, unless the order flow is determined *exogenously*, as implicitly assumed in King and Wadhwani (1990). In our model, financial contagion by real shocks is instead an *endogenous* phenomenon, due to strategic portfolio diversification by imperfectly competitive insiders and the resulting incorrect cross-inference by uninformed MMs. Indeed, our setting allows for $\frac{\partial P_1(n)}{\partial v(j)} \neq 0$ even if $\beta(n,f) = 0$ and $\beta(j,f) = 0$, i.e., even if $v(n)$ and $v(j)$ do not share any systematic factor, but only when private information is heterogeneous.

How realistic is this explanation of international financial contagion? Constraints to the availability of detailed data on the portfolio choices of professional investors have limited the scope of many studies of rebalancing activity as a cause of contagion. Nonetheless, the analysis of recent datasets offers supporting evidence of intense strategic hedging around the time of the major international financial crises of the past decade. For example, Kallberg et al. (2002) show that foreign investors' aggregate inflows and outflows from emerging countries were almost simultaneous in 1997 and 1998. At a more detailed level, Borensztein and Gelos (2000) study the investment behavior of more than 400 emerging market funds over the interval 1996:1-1999:3. They find that very frequently those funds not only withdrew money from a country hit by a crisis, but at the same time also invested in other markets that, according to many observers, were experiencing some form of contagion. Extending the same dataset to a longer sample period, Disyatat and Gelos (2001) confirm those results and further suggest that fund managers' holdings in emerging markets contain reliable information regarding future returns in those markets.

Ours is not the first paper to argue for the role of portfolio rebalancing as a major channel of financial contagion across countries. Kodres and Pritsker (2002) extend the intuition of Fleming et al. (1998) by developing a theoretical model of cross-market rebalancing with perfect competition and asymmetric information. In their study, strategic hedging is motivated by risk-aversion in a mean-variance setting, and transmits idiosyncratic shocks across unrelated markets. This implies that the vulnerability of countries to financial contagion should increase in periods in which traders are more risk-averse. However, as emphasized in Sections 1 and 2, many researchers and practitioners consider mean-variance portfolio choice a less than accurate description of the decision process followed by institutional investors, especially those investing in developing markets. This casts some doubts on the relevance of Kodres and Pritsker's model in interpreting the more recent contagion episodes in Asia, Eastern Europe, and Latin America.

Explaining why financial contagion occurs more often, and has been occurring with increasing frequency and magnitude for emerging markets is also on the agenda of the academic and financial communities. Kodres and Pritsker contend that information asymmetry among investors is more likely to arise in the context of less developed economies, and that more information asymmetry within a country's asset market is sufficient to increase the likelihood of that country to experience contagion. It is arguably the case that in emerging markets reliable information is accessible to fewer players and generally more expensive to generate, especially for foreign investors. It is nonetheless difficult to believe that the increased interest of professional money managers in those markets, spurred by a wave of financial integration and liberalization measures in the past two decades (documented by Bekaert et al. (2002), among others), would have led to higher (and not lower) information asymmetry, hence increasing (instead of decreasing) their vulnerability to contagion.

Proposition 4 shows that portfolio rebalancing may still represent a very important channel of contagion among unrelated markets even in a setting in which the insiders are risk-neutral professional money managers, if they receive heterogeneous information about the terminal value of the assets and strategically speculate on it. In our model, insiders' strategic portfolio diversification is indeed motivated by the potential cross-informativeness of the order flow, and not by risk-reduction opportunities. In fact, such trading activity limits the dispersion of the informational advantage the speculators obtain by observing (with noise) the occurrence of real shocks.

Additionally, our framework allows us to interpret the recurrence and magnitude of contagion events across emerging markets not just in terms of the existence of information asymmetry *per se*. Kodres and Pritsker have maintained that increasing the amount of informed trading in the economy *reduces* an asset's vulnerability to contagion by lowering the existing degree of information asymmetry. The results of this section instead suggest that financial integration, and the consequent growing interest of investors for emerging markets may have *raised* their vulnerability to financial contagion from real idiosyncratic and systematic shocks, if those investors rely on diverse, disparate private information about such markets. Proposition 4 in fact shows that both $\left|\frac{\partial P_1(n)}{\partial u(j)}\right|$ and $\left|\frac{\partial P_1(n)}{\partial \vartheta(f)}\right|$ (for $\beta(n, f) = 0$) are *increasing* functions of the number of insiders K, if $\Sigma_c \neq \rho\Sigma_\delta$. And significant and persistent differences in private information among traders are indeed more likely to be observed in less mature, less heavily supervised financial markets, like the ones of less developed economies, where the process of generation and acquisition of information is still not sufficiently standardized.

Proposition 4 also suggests that policy-makers and international organizations may be able to reduce the vulnerability of the global financial system to contagion by working toward the reduction of α, our proxy for the degree of asymmetric sharing of private information among professional money managers. This could be accomplished, for example, by stimulating or imposing the adoption of uniform, more rigorous, and stringent regulations across emerging financial markets for the generation and disclosure of corporate and macroeconomic information.

4.3 Information noise shocks and contagion

As it is realistic to imagine, the informed MFs do not have exact knowledge of the factors explaining the terminal payoffs of any of the N indices. We have therefore assumed that each of the K insiders receives noisy signals of the underlying idiosyncratic and systematic sources of risk in the economy.

Shocks to the errors in those signals, ε_{uk} and $\varepsilon_{\vartheta k}$, respectively, may also induce contagion, as shown in the following proposition.

Proposition 5 *The impact of shocks to any of the noise terms ε_{uk} and $\varepsilon_{\vartheta k}$ on the vector of equilibrium prices P_1 is given by the $N \times N$ matrix*

$$\frac{\partial P_1}{\partial \varepsilon'_{uk}} = H \Sigma_u \Sigma_{S_u}^{-1} \tag{20}$$

and by the $N \times F$ matrix

$$\frac{\partial P_1}{\partial \varepsilon'_{\vartheta k}} = H \beta \Sigma_\vartheta \Sigma_{S_\vartheta}^{-1}, \tag{21}$$

respectively. There is financial contagion from those shocks if and only if $K > 1$ and $H \neq \frac{1}{2+\rho(K-1)} I$, for any $\rho \in (0,1]$. In such a case, both $\left| \frac{\partial P_1(n)}{\partial \varepsilon_{uk}(j)} \right|$ and $\left| \frac{\partial P_1(n)}{\partial \varepsilon_{\vartheta k}(f)} \right|$ (for $\beta(n,f) = 0$) are independent from the intensity of noise trading (γ, Σ_e, and Σ_z).

Proof. See Appendix A. ■

Clearly, a shock to S_{uk} or $S_{\vartheta k}$ has the same effect on the individual MF's perceived informational advantage δ_k whether it was induced by real shocks to u and ϑ or by a shock to the perturbations ε_{uk} or $\varepsilon_{\vartheta k}$. However, any du or $d\vartheta$ modifies the signals observed by *all* the MFs, not just the k-th, hence has a bigger impact on the equilibrium prices. Shocks to ε_{uk} or $\varepsilon_{\vartheta k}$ lead the k-th insider to the incorrect inference that a fundamental event has occurred in the economy, and induce him to revise his portfolio strategically. MMs discount the expected amount of strategic trading from each MF in their price-setting process. Information asymmetry prevents the dealers from learning about whether the observed $d\omega_1(n)$ is due to news or noise. Information heterogeneity among MFs ($\Sigma_c \neq \rho \Sigma_\delta$) prevents them from learning about whether that shock is due to shocks to information about idiosyncratic ($dS_{uk}(n)$) or systematic ($dS_{\vartheta k}(f)$) factors. Incorrect cross-inference by the MMs and the ensuing contagion effects of Eqs. (20) and (21) may then occur.

Hence, Proposition 5 states that even false and misleading information about the fundamentals of a single country may induce contagion across our stylized financial markets, if one or more players perceive those rumors as being true and trade accordingly. This result suggests that financially integrated markets in which private information is shared asymmetrically may experience excess price comovements as a result not only of real (thus common) shocks to the signals of all market participants but also of shocks to the errors in the information generation process of a single or few speculators.

Such a degree of vulnerability to information noise shocks depends obviously on the many parameters of the economy. The impact of the number of insiders in the economy on the magnitude of financial contagion in Eqs. (20) and (21) deserves particular attention. An increase in the number of privately informed investors has two contrasting effects on $\left|\frac{\partial P_1(n)}{\partial \varepsilon_{uk}(j)}\right|$ and $\left|\frac{\partial P_1(n)}{\partial \varepsilon_{\vartheta k}(f)}\right|$. An increasing number of heterogeneously informed MFs posting their strategically devised but less than perfectly correlated market orders makes it more difficult for the MMs to learn about their individual signals. More incorrect cross-inference on v and greater contagion then ensue from a shock to the information noise of a single MF. However, a bigger K also makes the order flow more informative about the fundamental sources of risk in the economy, and the price-setting process of the MMs less sensitive to a shock to ω_1 coming from a single insider ($|\Lambda|$ smaller). The magnitude of contagion from information noise shocks would then decline.

For a small K, the former effect might dominate the latter, as we show in a numerical example in Section 5. Yet, for a big K, as competition among insiders and the information content of the order flow increase, the incorrect cross-inference resulting from a shock to ε_{uk} or $\varepsilon_{\vartheta k}$ eventually has a negligible impact on the vector of equilibrium prices P_1. Indeed, $\lim_{K\to\infty} H = O$ in Eqs. (20) and (21) regardless of α. Hence, according to our model, rising participation of insiders to multi-market trading (for example, due to the integration of world capital markets) may reduce the vulnerability of all countries to contagion from false or misleading news to a single or few speculators, although it increases the magnitude of contagion from real shocks.

4.4 Uninformative trading shocks and contagion

Liquidity and short-term trading play an important role in our model. Their presence in fact makes the total order flow only partially revealing to the dealers about the signals of v observed by the insiders. We have shown in the previous subsections that the ensuing information asymmetry between MMs and MFs, when accompanied by asymmetric sharing of private information among the professional money managers, may induce incorrect cross-inference, and eventually contagion from real and information noise shocks. Uninformative (or noise) trading also provides additional, more direct channels for financial contagion. In the economic structure of Eq. (1), in which long-term sources of risk are correlated across countries, a shift in the total demand for one security due to uninformative trading may lead to revision of beliefs in many other securities, when ω_1 is not a sufficient statistic for S_{uk} and $S_{\vartheta k}$. The following proposition illustrates such a channel for contagion.

Proposition 6 *The impact of shocks to liquidity trading z and to any endowment e_k on the vector of equilibrium prices P_1 is given by the $N \times N$ SPD matrix*

$$\frac{\partial P_1}{\partial z'} = \frac{\sqrt{K}}{2}\Lambda \tag{22}$$

and by the $N \times N$ SPD matrix

$$\frac{\partial P_1}{\partial e_k'} = \frac{\sqrt{K}}{4}\left(\frac{\gamma}{1-\gamma}\right)\Lambda, \tag{23}$$

respectively. The existence of contagion from those shocks does not depend on the number of insiders (K) or on whether those insiders share information asymmetrically (H).

Proof. See Appendix A. ■

A noise trading shock to asset n affects its corresponding aggregate demand, but not the aggregate demand for any of the remaining $N-1$ assets. This shock in fact does not induce the insiders to revise their cross-hedging strategies in equilibrium, for each MF k is either unaware it occurred ($dz(n)$ or $de_i(n)$ when $i \neq k$) or aware it is uninformative ($de_k(n)$).[17] The MMs instead update their beliefs about v based on the information they assume is contained in the total order flow. Because of the information asymmetry between MMs and MFs, any shock to $\omega_1(n)$, regardless of its informativeness, affects the market-clearing price $P_1(n)$. If fundamental risks are correlated across countries ($\beta \neq O$), this shock is also potentially revealing about other final payoffs $v(j)$, for $j \neq n$. When $d\omega_1(n)$ is due to $dz(n)$ or $de_k(n)$, the MMs' inability to decompose the observed $d\omega_1(n)$ leads them to account for the possibility that such order flow shock may be due to further news-motivated, strategic cross-trading by the MFs in their beliefs, hence to inaccurate and fundamentally unjustified cross-inference about the terminal value of other assets. Eventually, those new, incorrect beliefs affect the price vector P_1 and financial contagion ensues, as shown in Eqs. (22) and (23), for any possible H or K.

[17] In particular, as the MMs fully discount the incentive by the MFs to deviate from long-term profit-maximization in the price vector P_1, in equilibrium,.the short-term component of the optimal individual demand X_k does not depend on Λ and $\frac{\partial X_k(j)}{\partial e_k(n)} = 0$.

That contagion from noise trading shocks may occur despite H being diagonal does not contradict the statement of Corollary 2 that excess covariance is an equilibrium result only when $H \neq \frac{1}{2+\rho(K-1)}I$. Indeed, in equilibrium, both the MFs and the MMs account for the expected impact of z and e_k on ω_1 in their optimal demand and price schedules, respectively. Therefore, $EC = O$ when $H = \frac{1}{2+\rho(K-1)}I$. Nonetheless, any such uninformative perturbation to the order flow may still entail contagion, along the lines of Definition 2, because the resulting $d\omega_1$ (due to dz or $d\delta_{ek}$ in Eq. (10)) is insensitive to the equilibrium market depth $\frac{2}{\sqrt{K}}\Lambda^{-1}$. Accordingly (and contrary to Propositions 4 and 5), the magnitude of these effects (but not EC) depends on the MMs' perceived intensity of adverse selection in trading, for it affects the magnitude of Λ (as argued in Section 2.5) but not $d\omega_1$ (nor its informativeness). For instance, the lower is any of the diagonal terms in Σ_e or Σ_z, the higher are the losses the dealers expect to suffer from transacting with insiders, the higher are the gains that they try to extract from uninformative trading, the smaller is the resulting market depth, hence the greater are $\left|\frac{\partial P_1(n)}{\partial z(j)}\right|$ and $\left|\frac{\partial P_1(n)}{\partial e_k(j)}\right|$. Vice versa, when the number of MFs (K) increases, more informed trading in ω_1 and more aggressive competition among them (dissipating their informational advantage) induce the MMs to make each of the N markets more liquid, thus ultimately reducing the impact of $dz\,(n)$ or $de_k\,(n)$ on all the equilibrium prices. Thus, both the matrices $\frac{\partial P_1}{\partial z'}$ and $\frac{\partial P_1}{\partial e_k'}$ converge to zero for $K \to \infty$, because so does $\sqrt{K}\Lambda$.

As for the case of information noise shocks, an increasing number of heterogeneously informed MFs not only makes easier for the MMs to learn about the shared portion of the MFs' private information from ω_1, but also makes it more difficult for them to infer from it the individual portion of the private signal each insider received. In Section 5 we show that, as a result of these contrasting forces, the absolute magnitude of contagion from noise trading shocks might not fall monotonically toward zero for higher K. Conversely, when the insiders are homogeneously informed, only the second effect prevails and both $\left|\frac{\partial P_1(n)}{\partial z(j)}\right|$ and $\left|\frac{\partial P_1(n)}{\partial e_k(j)}\right|$ decline steadily when K increases. Greater focus by the MFs on their short-term NAVs (higher γ), and the ensuing more intense uninformative trading activity by the insiders also lead the MMs to make each market more liquid, hence decreasing both $|\Lambda|$ and $\left|\frac{\partial P_1}{\partial z'}\right|$, but increasing $\left|\frac{\partial P_1}{\partial e_k'}\right|$.[18]

[18] In fact, only the square root of the intertemporal MRS enters Λ. Intuitively, a greater γ implies that a shock to e_k induces a bigger shift in X_k and ω_1, hence greater false cross-inference by the MMs. Clearly, $\frac{\partial P_1}{\partial z^{\theta}} = \frac{\partial P_1}{\partial e_k^{\theta}} = O$ when $\gamma = 1$, as in such circumstance the aggregate order flow is not informative about v, hence $\Lambda = O$.

The form of contagion described in Proposition 6 depends crucially on the degree of information asymmetry between MFs and MMs and on the strategic behavior of the imperfectly competitive insiders, and finds support in many empirical studies. For example, the already mentioned paper by Connolly and Wang (2000) shows evidence that noise trading from foreign markets may spill over to domestic markets through the imprecise signal extraction process of uninformed traders. Shocks to z can generally be interpreted as arising from supply shocks, shifts to life-cycle motivations, or shocks to any other form of non-speculative, uninformative, liquidity trading activity.

It is possible that not only liquidity traders but also insiders may engage in noise transactions. Calvo (1999) and Yuan (2000) explore this circumstance by analyzing the implications of informed investors' need to liquidate their positions in one or more assets when margin constrained, thus potentially confusing uninformed market participants. The contagion effect represented by Eq. (23) in Proposition 6 moves in a similar direction. Nevertheless, our paper's analysis of financial contagion induced by shocks to the short-term trading activity of privately informed professional money managers is novel to the financial literature on excess price comovements.

How can we interpret such perturbations to the random vector e_k? Uncertainty surrounding each money manager's endowment is uncertainty surrounding the aggregate supply of the risky asset, as for the case of z. Realized liquidity trading activity is however unknown to both MMs and MFs. The supply e_k represents instead private information of the k-th MF, and the path-dependence of his utility function induces him to deviate from the optimal profit-maximizing trading strategy with that information, depending on the intertemporal MRS ($\frac{\gamma}{1-\gamma}$). We have previously argued that such short-term focus may be justified by money managers' need to prop up the interim value of their NAVs in face of potential withdrawals from the final investors. Reputation considerations and size-based compensation schemes may also compel portfolio managers to increase inflows or reduce those withdrawals. Therefore, we could think of the element $e_k' \left[E_1^k (P_1) - P_0\right]$ in $E_1^k [U_k]$ of Eq. (5) as the inflow or outflow of funds that a money manager would anticipate to experience from his investors depending on the expected performance of the N markets in which he invests. The vector e_k could then represent the sensitivity of the k-th MF's customer base to future market conditions, on which it is reasonable to believe the MF holds an informational advantage ($\delta_{ek} = e_k - \overline{e}$) with respect to his competitors and the MMs.

The decision rule embedded in $e_k' \left[E_1^k (P_1) - P_0\right]$ implicitly assumes that final investors display preference for winners, for they pour money in and out of mutual funds at the end of the interim period $t = 1$ (after the MMs have set the equilibrium price vector P_1) based on past stock returns. There is some empirical evidence in support of such behavior and, more generally, on the role played by redemptions and injections of funds during emerging markets crises. For example, Kaminsky et al. (2000, 2001) show that underlying investors in mutual funds systematically engaged in contemporaneous and lagged momentum trading during recent periods of international financial turmoil. This behavior, it is there argued, may have forced many professional money managers to trade regardless of their beliefs about fundamentals.

Consistent with this interpretation, the existence of *positive feedback flows* may be what motivates our stylized professional money managers to move away from the optimal, fundamentals-based profit-maximization rule in order to increase their short-term welfare. Hence, shocks to the sensitivity of a mutual fund's customer base to past performance (due, for instance, to shifts in their tastes or risk-aversion or to changes in the load fees) may affect his trading strategies in each market. The ensuing shock to the observed aggregate order flow, albeit uninformative about u and/or ϑ, may eventually induce incorrect cross-inference on v by the MMs and financial contagion, as in Eq. (23). This result suggests that momentum trading by final investors or any other circumstance inducing greater short-term focus by professional money managers may increase the vulnerability of the global financial system to contagion phenomena, another testable implication of our model.

5 A numerical example

Sections 3 and 4 contain the principal findings of this paper. Information asymmetry and a fundamentally interconnected economy are only necessary but not sufficient conditions for financial contagion from real shocks when speculators and dealers are assumed to be risk-neutral and financially unconstrained. We have in fact shown there that only when insiders share their privileged information asymmetrically does excess (co)movement among securities' prices arise in equilibrium from strategic portfolio diversification by the MFs and incorrect cross-inference about fundamentals by the MMs.

The purpose of this section is to illustrate some of the most interesting implications of these claims in the context of a stylized multi-country example, along the lines of Kodres and Pritsker (2002). We choose a structure similar to the one they suggested (and many of the parameters they selected) not only because it may help us explain the most recent episodes of financial contagion, those observed among emerging and/or developed economies in the past decade, but also because it may facilitate a comparison of our conclusions with theirs. We assume that there are three countries and three idiosyncratic and two systematic factors in the economy. The liquidation values of the indices traded in these markets depend on u and ϑ according to the following expressions:

$$\begin{array}{rcl} v(1) & = & u(1) + \vartheta(1) \\ v(2) & = & u(2) + 0.5\vartheta(1) + 0.5\vartheta(2) \\ v(3) & = & u(3) + \vartheta(2) \end{array} , \tag{24}$$

consistent with Eq. (1). The economies of the two *peripheral* countries, 1 and 3, are fundamentally unrelated ($\beta(1,2) = \beta(3,1) = 0$) but share an exposure to the *core* market 2 via the systematic factors $\vartheta(1)$ and $\vartheta(2)$, respectively ($\beta(1,1) = \beta(3,2) = 1$). Therefore, Eq. (24) violates the no-contagion condition of Proposition 3.

We solve for the equilibrium contagion effects of Propositions 4 to 6 in the above setting using a parsimonious baseline parametrization of the model (reported in Appendix B) and the distributional assumptions described in Sections 2 and 4. In this stylized economy, we can think of country 2, characterized by the lowest fundamental variance ($\Sigma_v(2,2) = 1.25$) and exposure to both systematic factors $\vartheta(1)$ and $\vartheta(2)$ ($\beta(2,1) = \beta(2,2) = 0.5$) as a developed, globalized market, and of countries 1 and 3 as emerging, developing markets. Finally, we impose that $\Sigma_z = \Sigma_e = I$ so that $\Sigma_n = \sigma_n^2 I$, i.e., so that noise trading has identical variance and is uncorrelated across markets. Therefore, according to Remark 1, the resulting linear equilibrium of Eqs. (8) to (10) in Proposition 1 is also *unique*. We start by assuming that the MFs are focused solely on the maximization of the long-term NAVs of their portfolios, i.e., that $\gamma = 0$ in U_k of Eq. (4). Using the results of Section 4, in Figure 1 we plot measures of contagion from real idiosyncratic shocks, $\frac{\partial P_1(3)}{\partial u(1)}$ (Figure 1a), from individual information noise shocks, $\frac{\partial P_1(3)}{\partial \varepsilon_{uk}(1)}$ (Figure 1b), and from liquidity shocks, $\frac{\partial P_1(3)}{\partial z(1)}$ (Figure 1c), with respect to the number of insiders, K, and for different values of α in $\Sigma_c^* = \alpha\Sigma_c + (1-\alpha)\rho\Sigma_\delta$.[19]

The effect of a real shock to the terminal value of index 1 ($du(1)$) on the equilibrium price of index 3 (in Figure 1a) is positive and increasing in K and α, even though countries 1 and 3 (i.e., $v(1)$ and $v(3)$ in Eq. (24)) are ex ante independent. What is the intuition for this result? For example, a negative change in the idiosyncratic component of $v(1)$, hence in the K signals $S_{uk}(1)$, ceteris paribus for any other source of randomness in the model, prompts each

[19]The dynamics of measures of contagion from real systematic shocks (e.g., $\frac{\partial P_1(1)}{\partial \vartheta(2)}$) or information noise shocks (e.g., $\frac{\partial P_1(1)}{\partial \varepsilon_{\vartheta k}(2)}$) are very similar to the ones displayed on Figure 1. Therefore, they are not reported here but are available from the author on request.

MF to decrease his optimal demand for that security. The MMs observe the resulting $d\omega_1(1) < 0$ and revise downward their beliefs about $v(1)$, therefore the equilibrium price $P_1(1)$. Indeed, the matrix Λ is SPD, so $\Lambda(1,1) > 0$ for any K and α. To prevent such $dP_1(1) < 0$ from eroding their expected profits from the trade in country 1, the MFs buy more (sell fewer) units of index 2 (e.g., $\frac{\partial X_k(2)}{\partial u(1)} = \left[C\Sigma_u\Sigma_{S_u}^{-1}\right](2,1) = -0.061$ for $K = 15$ and $\alpha = 1$). This trade leads in fact the MMs to the incorrect inference not only that a positive $dv(2)$ may have occurred but also that such $dv(2) > 0$ may be due to a positive shock to $\vartheta(1)$, given the exposure of country 2 to that systematic factor ($\beta(2,1) > 0$). A higher $E[\vartheta(1)|\omega_1]$ by the MMs ensues, thereby attenuating the drop in $P_1(1)$, as $\beta(1,1) > 0$, although at the cost of an increase in $P_1(2)$, so of greater expected losses for the MFs from their trade in index 2. Moreover, the exposure of country 2 to $\vartheta(2)$ ($\beta(2,2) > 0$) ends up mitigating the impact of $dX_k(2) > 0$ on the dealers' beliefs about $\vartheta(1)$. Thus, using the fact that $\beta(3,2) > 0$ as well, the insiders demand country 3's index less aggressively (e.g., $\frac{\partial X_k(3)}{\partial u(1)} = \left[C\Sigma_u\Sigma_{S_u}^{-1}\right](3,1) = 0.027$ for $K = 15$ and $\alpha = 1$) to induce the MMs to adjust downward their beliefs about $\vartheta(2)$ and $v(3)$, hence to set a lower equilibrium price for index 3 and a smaller $dP_1(2) > 0$, and to adjust upward $E[\vartheta(1)|\omega_1]$ and $P_1(1)$.

In short, the (albeit risk-neutral) MFs, aware of the MMs' cross-inference process, trade strategically and with caution across countries ($dX_k(2) > 0$ and $dX_k(3) < 0$) in order to dissipate as little as possible of their initial informational advantage ($dS_{uk}(1) < 0$). At the same time, however, the MMs, aware of the MFs' incentives to engage in such strategic trading activity, account for it in updating their beliefs and clearing the market. Eventually, as a consequence of the MFs' strategic trading activity and the MMs' pricing rule, the perceived possibility that $d\vartheta(1) > 0$ and $d\vartheta(2) < 0$ leads the dealers to select a smaller $dP_1(1) < 0$ (and allows greater profits for the insiders) than if the informed speculators had determined their new demand for each index independently, i.e., traded exclusively in index 1.

Nonetheless, in equilibrium, contagion arises only when the MFs possess diverse and asymmetric pieces of private information, to use the terminology of Admati (1985). Heterogeneity of private information among insiders precludes in fact the MMs from learning from $d\omega_1$ about their individual signals, thus about their individual, less than perfectly correlated, strategic speculation with sufficient accuracy. In the above example, the buying pressure on country 2 and the selling pressure on country 3 result in fundamentally unjustified, hence *excessive*, movements in the equilibrium prices $P_1(2)$ and $P_1(3)$, although both $dv(2) = 0$ and $dv(3) = 0$, only if $\alpha > 0$ (e.g., $dP_1(2) = 0.055$ and $dP_1(3) = -0.149$, respectively, for $K = 15$ and $\alpha = 1$). These excessive movements represent financial contagion, as defined in Section 4.

Accordingly, more asymmetric sharing of private information among speculators (higher α in Figures 1a and 1b) induces a greater impact of $du(1)$ and $d\varepsilon_{uk}(1)$ on the equilibrium price in country 3, for it makes the cross-inference by the MMs more incorrect. There is instead no contagion from real and information noise shocks, but only from liquidity shocks (consistently with Proposition 6) when the MFs receive the same (or similar) sets of signals of u and ϑ, i.e., when $\alpha = 0$. The above example also suggests that contagion phenomena across countries may be accompanied by trading flows of opposite signs, rather than by generalized sales of assets, as already observed in many empirical studies of institutional and foreign investors' behavior during recent financial crises in emerging markets, e.g., Borensztein and Gelos (2000), Kaminsky et al. (2000), and Kallberg et al. (2002).

Increasing the number of insiders makes it more difficult for the MMs to learn accurately about the MFs' individual cross-trading activity; nevertheless, it also makes the aggregate order flow more informative about v, and induces the quasi-monopolistic portfolio managers to trade more aggressively. Thus, higher K raises monotonically the magnitude of contagion from real shocks (in Figure 1a), but at a decreasing rate. However, when $d\omega_1(3)$ is due to information noise shocks or liquidity shocks (in Figures 1b and 1c), this last effect eventually prevails, the MMs' incorrect cross-inference declines, and so do $\frac{\partial P_1(3)}{\partial \varepsilon_{uk}(1)}$ and $\frac{\partial P_1(3)}{\partial z(1)}$ toward zero, as argued in Sections 4.3 and 4.4.[20]

Figure 1d offers another representation of excess covariance due to contagion, consistent with the findings of Section 3. It in fact shows that, when $\alpha = 1$, real shocks to country 1 explain up to 21% of the unconditional variance of the equilibrium price in country 3 due to private information about fundamentals, although countries 1 and 3 do not share any systematic factor and the random variables $u(1)$, $\vartheta(1)$, $u(3)$, and $\vartheta(2)$ are independently distributed. Again, this is due to the MFs' informational advantage and the MMs' incorrect cross-inference from observing the aggregate order flow when insiders receive heterogeneous information and cautiously cross-trade on it.

The simplifying, albeit less realistic, assumption that the insiders' information about idiosyncratic factors in *all* countries, including the developed economy ($u(2)$), is heterogeneous does not affect significantly those results. Indeed, if MFs' private signals about $u(2)$ were homogeneous, in particular if $S_{uk}(2) = S_u(2)$ for each $k = 1, \ldots, K$, implying that $[\Sigma_c](2,2) = \left[\Sigma_u \Sigma_{S_u}^{-1} \Sigma_u\right](2,2) + \left[\beta \Sigma_\vartheta \Sigma_{S_\vartheta}^{-1} \Sigma_\vartheta \Sigma_{S_\vartheta}^{-1} \Sigma_\vartheta \beta'\right](2,2)$, the magnitude of the above

[20]However, when $\alpha = 0$, 0.25, or 0.50, there is no such trade-off for $\frac{\partial P_1(3)}{\partial z(1)}$ (Figure 1c), which therefore merely decreases toward zero, because the resulting information heterogeneity is too low for higher K to induce additional false cross-inference by the MMs.

described contagion effects would not significantly change. For example, when $K = 15$ and $\alpha = 1$, the responses of the equilibrium prices $P_1(2)$ and $P_1(3)$ to a negative marginal shock to $u(1)$ are now given by $dP_1(2) = 0.003$ and $dP_1(3) = -0.113$, respectively. Symmetric sharing of private signals about $u(2)$ attenuates, but does not eliminate the MMs' incorrect cross-inference induced by the strategic trading activity of the MFs. Information about the idiosyncratic shocks $u(1)$ and $u(3)$ and the systematic factors $\vartheta(1)$ and $\vartheta(2)$ remains in fact heterogeneous. Therefore, homogeneous private information about developed economies attenuates, but does not eliminate excess comovement among developing markets.

More generally, allowing for the private signals about only *one* or *few* of the fundamentals to be heterogeneous may help us explain why some countries are, or have been more vulnerable than others to contagion from real shocks. Assume, for instance, that only for country 1 and only for the idiosyncratic factor $u(1)$ do insiders share private information asymmetrically, i.e., that $S_{uk}(1) \neq S_{ui}(1)$ but $S_{uk}(n) = S_{ui}(n)$ and $S_{\vartheta k}(f) = S_{\vartheta i}(f)$ for $n = 2, 3$ and $f = 1, 2$, and for each $i \neq k$. It then follows from Eq. (15) that $\Sigma_c = \Sigma_\delta$ with the exception of $[\Sigma_c](1,1)$ being now equal to $\left[\Sigma_u \Sigma_{S_u}^{-1} \Sigma_u \Sigma_{S_u}^{-1} \Sigma_u\right](1,1) + \left[\beta \Sigma_\vartheta \Sigma_{S_\vartheta}^{-1} \Sigma_\vartheta \beta'\right](1,1)$. In such circumstances, shocks from country 1 do not affect countries 2 and 3, but shocks to $u(3)$ and $\vartheta(2)$ do affect the equilibrium price $P_1(1)$, although both $u(3)$ and $\vartheta(2)$ are uncorrelated to $v(1)$. For $K = 15$ and $\alpha = 1$, the effect of a negative marginal idiosyncratic shock to country 3, $du(3) < 0$, on the price of index 1 is given by $dP_1(1) = -0.085$; however, no equilibrium responses in $P_1(2)$ and $P_1(3)$ ensue from a shock to either $u(1)$ or $\vartheta(1)$. Intuitively, this occurs because, in equilibrium, the MMs learn from the aggregate order flow ω_1 about the MFs' strategic trading activity in securities 2 and 3 with sufficient precision to avoid incorrect cross-inference about countries 2 and 3, but not enough to prevent incorrect cross-inference about country 1. Thus, heterogeneity of private information about local economic and/or political factors affecting assets' liquidation values in a country makes such country more sensitive to fundamentally unrelated shocks from other countries, i.e., increases the likelihood and magnitude of financial contagion.

When $\gamma = 0$, so is $\frac{\partial P_1}{\partial e'_k}$. Additionally, we have demonstrated in Propositions 4 and 5 that the intensity of contagion from real or information noise shocks is not sensitive to the intensity of liquidity and short-term trading. Eqs. (22) and (23) however suggest that the impact of shocks to those uninformative trading activities on P_1, $\frac{\partial P_1}{\partial z'}$ and $\frac{\partial P_1}{\partial e'_k}$, may be considerable. In Figures 2a and 2b we plot $\frac{\partial P_1(3)}{\partial z(1)}$ and $\frac{\partial P_1(3)}{\partial e_k(1)}$ as a function of K, for $\gamma = 0.5$. As argued in Section 4.4, contagion from noise shocks arises from the information asymmetry between MFs and MMs preventing the dealers from correctly accounting for the absence of further strategic portfolio diversification activity by the MFs in their beliefs, regardless of whether they receive the same, similar, or different signals of the vector v. Both $\left|\frac{\partial P_1(3)}{\partial z(1)}\right|$ and $\left|\frac{\partial P_1(3)}{\partial e_k(1)}\right|$ decline toward zero for greater K because more insiders in the economy bring forth more information in the order flow. However, only with information heterogeneity ($\Sigma_c \neq \rho\Sigma_\delta$) may a larger number of MFs in the economy initially also increase the absolute magnitude of contagion, by inducing more incorrect cross-inference by the MMs. Higher γ implies that the MFs give more weight to the short-term NAV of their portfolios in their utility function. Therefore, any shock to e_k causes a bigger shift in the insiders' optimal demand, hence in ω_1, and eventually in P_1, but at a decreasing rate for the aggregate order flow becomes less informative about u and ϑ, as shown in Figure 2d. Higher γ lowers instead $\frac{\partial P_1(3)}{\partial z(1)}$ (Figure 2c) because it reduces the risk of adverse selection for the MMs, hence makes the asset markets more liquid (i.e., each element of the matrix $|\Lambda|$ smaller).

As emphasized in the above discussion and in the analysis of Section 4, the intensity of the incorrect cross-inference by the MMs determines the magnitude of the contagion phenomena reported in Figures 1 and 2. Therefore, the degree of uncertainty surrounding the terminal payoff vector v and the degree of heterogeneity of the private signals obtained by the MFs should play a key role in affecting the precision of such priors' updating process by the dealers, when they observe the aggregate order flow for each security. This is the issue we explore in Figure 3, using the fact that, if $\Sigma_u = \mu I$ and $\Sigma_\vartheta = \mu I$, the scalar μ controls for the variance of the idiosyncratic and systematic factors u and ϑ, respectively. If instead $\Sigma_{\varepsilon_u} = \mu I$ and $\Sigma_{\varepsilon_\vartheta} = \mu I$, the scalar μ controls for the quality of the information received by each MFs, hence for the intensity of the asymmetric sharing of private information among them.

In Figures 3a and 3b, we plot a measure of contagion from real idiosyncratic shocks, $\frac{\partial P_1(3)}{\partial u(1)}$, as a function of the scalar μ and for different values of K. The impact of increasing μ on the magnitude of contagion in equilibrium is the result of the interaction of two effects of opposite sign. If $\Sigma_u = \mu I$ and $\Sigma_\vartheta = \mu I$, the MMs revise their beliefs (and the price vector P_1) more substantially when μ is higher (i.e., when u and ϑ are more volatile), consistently with the empirical evidence of Connolly and Wang (2000), because in these circumstances the relative precision of the MFs' signals of u ($\Sigma_u\Sigma_{S_u}^{-1}$) and ϑ ($\Sigma_\vartheta\Sigma_{S_\vartheta}^{-1}$) is greater, hence the uninformed dealers put more trust in ω_1 to learn about v. However, when the order flow becomes a more reliable source of information, incorrect cross-inference by the MMs becomes less significant. This effect eventually prevails for higher values for μ, and the extent of contagion then declines, as shown in Figure 3a. If instead $\Sigma_{\varepsilon_u} = \mu I$ and $\Sigma_{\varepsilon_\vartheta} = \mu I$, incorrect cross-inference is more significant when μ is higher (i.e., when the signals observed by MFs are more heterogeneous), because it becomes more difficult for the MMs to learn about the individual informational advantage vectors δ_k from ω_1. Nonetheless, Figure 3b suggests that poorer quality of those private signals (i.e., smaller $\Sigma_u \Sigma_{S_u}^{-1}$ and $\Sigma_\vartheta \Sigma_{S_\vartheta}^{-1}$) eventually leads again to less aggressive updating of priors by the MMs, so to smaller shifts in the equilibrium price vector P_1. The analysis of other sources of contagion (e.g., $\frac{\partial P_1(1)}{\partial \vartheta(2)}$, $\frac{\partial P_1(3)}{\partial z(1)}$, or $\frac{\partial P_1(3)}{\partial e_k(1)}$), not reported here, yields similar results.

Higher values of μ attenuate the intensity of the revision of $E[v|\omega_1]$ from shocks to the demand for *all* the markets. Hence, it has non-trivial effects on the decomposition of the fundamental variance of $P_1(3)$, a measure of excess comovement. Figures 3c and 3d display the percentage of such variance of the equilibrium price in country 3 due to real shocks to (the fundamentally unrelated) country 1 as a function of μ. When $\Sigma_u = \mu I$ and $\Sigma_\vartheta = \mu I$, greater volatility of the payoff vector v induces the MMs to consider ω_1 a less reliable source of information, thus to make smaller adjustments to their beliefs after observing $d\omega_1$. Excess comovement of $P_1(3)$ and $v(1)$ then declines (Figure 3c). Vice versa, when $\Sigma_{\varepsilon_u} = \mu I$ and $\Sigma_{\varepsilon_\vartheta} = \mu I$, greater potential dispersion of private signals among the MFs leads to more incorrect cross-inference from $d\omega_1$, thus to more excess comovement of $P_1(3)$ and $v(1)$ (Figure 3d). Therefore, in both circumstances the impact of higher μ on the information content of the order flow is the prevailing one, in a scenario (greater signals' precision) attenuating, and in the other (lower signals' precision) increasing the vulnerability of a country to financial contagion.

6 Conclusions

In this study we concentrated on the impact of the trading decisions of better-informed, imperfectly competitive professional money managers (whose utility functions depend on both short- and long-term NAVs) on the equilibrium prices for a simple multi-asset economy in which the random terminal payoffs of the available securities are affected by idiosyncratic and systematic sources of uncertainty. In this setting, we showed that portfolio rebalancing may induce excess volatility and comovement among asset prices in equilibrium, even when multiple insiders are rational, financially unconstrained, and risk-neutral, if and only if these insiders receive heterogeneous information about those payoffs and strategically speculate on it. Insiders' strategic portfolio diversification is not motivated by risk-reduction, but is functional to limit the informativeness of the aggregate order flow, after they observe their signals and trade on them. Indeed, informed speculators use strategically the potential cross-informativeness of the order flow to minimize the dispersion of their informational advantage in each asset. Information heterogeneity prevents the uninformed market-makers from learning about this activity with sufficient accuracy, eventually leading them to embed the resulting incorrect cross-inference about fundamentals in the equilibrium prices. Financial contagion may then ensue.

The three main features of our model, two realistic market frictions (imperfect competition among insiders and heterogeneity of their information endowments) and short-term trading, allowed us to investigate why financial contagion has been occurring with increasing frequency and magnitude for emerging markets. It is often argued by the financial and academic communities alike that greater price and return comovements (e.g., Bekaert and Harvey (2000)) and the recurrence of crises and contagion events (e.g., Bordo et al. (2000)) should be attributed to the intensification of capital mobility and financial integration across world capital markets, in particular (as in Kodres and Pritsker (2002)) when this process is accompanied by persistent information asymmetries among market participants. It is nonetheless difficult to believe that the increased interest of institutional investors in emerging markets, spurred by the liberalization measures of the recent past, would have led to higher (and not lower) information asymmetry, hence increasing (instead of decreasing) their vulnerability to contagion.

We claimed instead that economic and financial integration, by making the world economy more interconnected and increasing the interest of strategic investors in emerging markets, may have raised such vulnerability to financial contagion from real idiosyncratic and systematic shocks only if those investors produce or obtain diverse, disparate private information about one or more of these markets. Significant differences in private information among imperfectly competitive traders are indeed more likely to exist in the smaller, less mature, less regulated financial markets of many less developed economies, where the process of generation, acquisition, and dissemination of information is still insufficiently standardized and large speculators can still expect to affect market prices. Our investigation also indicated that differences in the degree of information heterogeneity across developing countries could help explain why contagion episodes appear to occur more often, and with greater extent in some of those markets than in others. Hence, the adoption of uniform, more rigorous, and stringent rules for the production and disclosure of corporate and macroeconomic information, by attenuating the degree of asymmetric sharing of private signals among professional money managers and across countries, would reduce the vulnerability of the global financial system to contagion among emerging financial markets.

Short-term oriented trading behavior by speculators is frequently accused by the financial press of exacerbating the propagation of shocks across markets. Our analysis, however, suggested that short-term trading does not play any role in explaining the magnitude of financial contagion by real shocks in a stylized market setting populated by risk-neutral players, because more noise trading creates more camouflage opportunities for the insiders, therefore bringing forth more of their informative trades. Nonetheless, our stylized money managers may be motivated to move away from the optimal, fundamentals-based long-term profit-maximization rule in order to increase their short-term welfare. Kaminsky et al. (2000, 2001), for example, argue that many investors in mutual funds systematically engaged in contemporaneous and lagged momentum trading during recent financial crises, forcing professional money managers to trade regardless of their beliefs about fundamentals. We showed in this paper that fundamentally uninformative shocks to the sensitivity of a mutual fund's customer base to past performance (due, for instance, to shifts in tastes or risk-aversion) could then affect his short-term trading strategies in each market, mislead the uninformed market-makers, and result in financial contagion.

In our model, financially integrated markets in which private information is shared asymmetrically may experience fundamentally unjustified, i.e., excessive price comovements as a result not only of real shocks to the signals of all informed traders but also of uninformative shocks to the order flow, due to errors in the information generation process of a single or few speculators, or to perturbations to liquidity and short-term trading. Greater participation of insiders to multi-asset or multi-market trading may however reduce the magnitude of financial contagion from information noise or uninformative trading shocks, for it increases the information content of the order flow.

Is globalization at least partially responsible for the contagion events sweeping several developing economies in the recent past? The process of economic and financial integration has taken place only in the last two decades, and is still at an early stage for many of them. Professional money managers investing in emerging capital markets are still relatively less numerous, and the information they produce (or receive) and use for trading is still more discordant than in the more mature markets of most industrialized countries. According to our model, these facts currently justify a high, and even rising vulnerability of the global financial system to contagion events. Nonetheless, the trend for greater participation of institutional investors to developing financial markets and more adequate regulations aimed at levelling the playing field for the acquisition and disclosure of corporate and macroeconomic news will lead to greater competition and less information asymmetry and heterogeneity among traders, hence eventually reduce such vulnerability.

This study offers many avenues for further research. Our claim that information heterogeneity may generate excess covariance among securities or markets is the original contribution of this paper to the financial literature on asset pricing. Supportive evidence is however at this point only anecdotal. The necessity to provide empirical validation of that argument seems nonetheless warranted. In addition, our stylized economy, because inherently static, does not consent to explore the (clearly significant) dynamic implications of sequential updating of beliefs by the uninformed dealers and intertemporal strategic dissipation of private information by the insiders (via their trading activity) on financial contagion. It would also be of interest to assess the impact of relaxing the assumption of perfect dealership competition, hence of semi-strong market efficiency on the contagion effects hitherto discussed. We reserve these investigations for future work.

7 Appendix A

This Appendix contains proofs of all propositions, corollaries, and remarks discussed (but not proved) in the main body of the paper. In few of those proofs, some (tedious) algebraic steps have only been sketched, for economy of space. More details are available from the author on request.

Definition A1. (Greene (1997, p. 32)) *A matrix A is* ***block-diagonal*** *if it can be represented as a partitioned matrix where all the off-diagonal submatrices are null matrices.* ■

Definition A2. (Greene (1997, p. 46)) *If A is a real matrix and the quadratic form $q = x'Ax > 0$ for all real nonzero vectors x, the matrix A is* ***positive definite****. If the matrix A is also symmetric, then A is* ***symmetric positive definite*** *(SPD).* ■

Theorem A1. (Bellman (1970, p. 54 and p. 91)) *A necessary and sufficient condition that the matrix A be* ***positive definite*** *is that all the characteristic roots of A be positive. Therefore, a positive definite matrix A is always* ***nonsingular****. If the matrix A is SPD, so is A^{-1}.* ■

Proof of Proposition 1. The proof is by construction, as in Caballé and Krishnan (1994). We first specify general linear functionals for the pricing rule and insiders' demands, and then show that those functionals indeed represent a rational expectations equilibrium when their parameters are the ones in Eqs. (8) and (10). We start by guessing that the equilibrium price vector (P_1) and market orders submitted by the k-th MF (X_k) are given by

$$P_1 = A_0 + A_1 \omega_1 \tag{A-1}$$

and, for $k = 1, \ldots, K$, by

$$X_k(\delta_k, \delta_{ek}) = B_0 + B_1 \delta_k + B_2 \delta_{ek}, \tag{A-2}$$

respectively, where the matrix A_1 is SPD and the matrix B_1 is nonsingular. The definition of ω_1 and Eqs. (A-1) and (A-2) imply that, from the perspective of each insider k, the expected vector of prices before trading occurs, $E_1^k[P_1]$, is equal to

$$\begin{aligned} E_1^k[P_1] &= A_0 + A_1 \Big[X_k + (K-1) B_0 + B_1 \sum\nolimits_{i \neq k} E_1^k(\delta_i) \\ &\quad + B_2 \sum\nolimits_{i \neq k} E_1^k(\delta_{ei}) + \overline{z} \Big], \end{aligned} \tag{A-3}$$

where $E_1^k(\delta_i) = \Sigma_c \Sigma_\delta^{-1} \delta_k$ and $E_1^k(\delta_{ei}) = \underline{0}$ because of the distributional assumptions made in Sections 2.1 and 2.2 and the properties of multivariate normal random variables (e.g., Greene (1997, pp. 89-90)). From Eq. (A-3), the symmetry of A_1 ($A_1' e_k = A_1 e_k$), and the fact that $E_1^k[v] = \delta_k + \overline{v}$ (by definition of δ_k), we derive the first order condition of the maximization of the objective function $E_1^k[U_k]$ defined in Eq. (5) as

$$\begin{aligned} \underline{0} &= \gamma A_1 e_k + (1-\gamma) \left[\delta_k + \overline{v} - A_0 - (K-1) A_1 B_0 + \right. \\ &\quad \left. - A_1 \overline{z} - (K-1) A_1 B_1 \Sigma_c \Sigma_\delta^{-1} \delta_k - 2 A_1 X_k \right]. \end{aligned} \tag{A-4}$$

The second order condition is satisfied, for the matrix $2(1-\gamma) A_1$ is positive definite. Dividing both sides of Eq. (A-4) by $(1-\gamma)$, replacing X_k with the conjecture of Eq. (A-2), and equating the resulting coefficients, we obtain

$$(K+1) A_1 B_0 = \overline{v} - A_0 - A_1 \left(\overline{z} - \frac{\gamma}{1-\gamma} \overline{e} \right), \tag{A-5}$$

$$2 A_1 B_1 = I - (K-1) A_1 B_1 \Sigma_c \Sigma_\delta^{-1}, \tag{A-6}$$

and

$$2 A_1 B_2 = \frac{\gamma}{1-\gamma} A_1. \tag{A-7}$$

Since A_1 is invertible (see Theorem A1), Eq. (A-7) implies that $B_2 = \frac{1}{2}\left(\frac{\gamma}{1-\gamma}\right)$. Moreover, because the vector ω_1 is MND with mean $E[\omega_1] = K B_0 + \overline{z}$ and variance

$$var[\omega_1] = K B_1 \Sigma_\delta B_1' + \Sigma_n + K(K-1) B_1 \Sigma_c B_1' \tag{A-8}$$

(as $cov\left(\delta_k, \delta_i\right) = \Sigma_c$ and $cov\left(e_k, e_i\right) = O$), and $cov\left[v, \omega_1\right] = K\Sigma_\delta B_1'$, then

$$\begin{aligned} E\left[v|\omega_1\right] &= \overline{v} + K\Sigma_\delta B_1' \left[KB_1\Sigma_\delta B_1' + \Sigma_n + \right. \\ & \left. +K\left(K-1\right)B_1\Sigma_c B_1'\right]^{-1}\left[\omega_1 - KB_0 - \overline{z}\right]. \qquad \text{(A-9)} \end{aligned}$$

According to Definition 1 (Eq. (7)), $P_1\left(\omega_1\right) = E\left[v|\omega_1\right]$ in equilibrium. Therefore, the conjecture of Eq. (A-1) implies that, given the invertibility of B_1,

$$A_1 = \left[B_1 + \left(K-1\right)B_1\Sigma_c\Sigma_\delta^{-1} + \frac{1}{K}\Sigma_n\left(B_1'\right)^{-1}\Sigma_\delta^{-1}\right]^{-1} \qquad \text{(A-10)}$$

and that

$$A_0 = \overline{v} - A_1\overline{z} - KA_1B_0. \qquad \text{(A-11)}$$

The expressions for A_0, A_1, B_0, and B_1 implied by Eq. (8) for P_1 and by Eq. (10) for X_k must solve the system made of Eqs. (A-5), (A-6), (A-10), and (A-11) to represent a linear equilibrium of our economy. Defining A_1B_0 from Eq. (A-5) and substituting it into Eq. (A-11) leads us to

$$A_0 = \overline{v} - A_1\left(\overline{z} + \frac{\gamma}{1-\gamma}K\overline{e}\right). \qquad \text{(A-12)}$$

Plugging Eq. (A-12) into Eq. (A-5), we obtain $B_0 = \frac{\gamma}{1-\gamma}\overline{e}$. We are left with the task of finding A_1 and B_1. Solving Eq. (A-6) for A_1, we get

$$A_1 = \left[2B_1 + \left(K-1\right)B_1\Sigma_c\Sigma_\delta^{-1}\right]^{-1}. \qquad \text{(A-13)}$$

Equating Eq. (A-13) to Eq. (A-10), it follows that $B_1 = \frac{1}{K}\Sigma_n\left(B_1'\right)^{-1}\Sigma_\delta^{-1}$. Substituting this expression for B_1 back into Eq. (A-10) gives us

$$A_1 = \left[\frac{2}{K}\Sigma_n\left(B_1'\right)^{-1}\Sigma_\delta^{-1} + \left(K-1\right)B_1\Sigma_c\Sigma_\delta^{-1}\right]^{-1}. \qquad \text{(A-14)}$$

Using the invertibility of A_1 and Eq. (A-13), it is easy to derive

$$B_1 = A_1^{-1}\left[2I + \left(K-1\right)\Sigma_c\Sigma_\delta^{-1}\right]^{-1} \qquad \text{(A-15)}$$

and

$$\left(B_1'\right)^{-1} = A_1\left[2I + \left(K-1\right)\Sigma_\delta^{-1}\Sigma_c\right]. \qquad \text{(A-16)}$$

We insert Eqs. (A-15) and (A-16) into Eq. (A-14) and rearrange terms to obtain

$$\frac{K}{4}A_1^{-1}\Gamma = \frac{2}{K}\Sigma_n A_1, \qquad \text{(A-17)}$$

where the matrix Γ, defined as

$$\begin{aligned}\Gamma &= \left[\Sigma_\delta^{-1} + \frac{K-1}{2}\Sigma_\delta^{-1}\Sigma_c\Sigma_\delta^{-1}\right]^{-1} + \\ &\quad - \left[2\Sigma_\delta^{-1} + \frac{K-1}{2}\Sigma_\delta^{-1}\Sigma_c\Sigma_\delta^{-1} + \frac{2}{K-1}\Sigma_c^{-1}\right]^{-1}, \qquad \text{(A-18)}\end{aligned}$$

is SPD by the *Rayleigh Principle* (e.g., Bodewig (1959, p. 283)) and Theorem A1, since so is Σ_c. Because we can write Eq. (A-17) as

$$\frac{K}{4}\left(\Sigma_n^{1/2}\Gamma\Sigma_n^{1/2}\right) = \left(\Sigma_n^{1/2}A_1\Sigma_n^{1/2}\right)\left(\Sigma_n^{1/2}A_1\Sigma_n^{1/2}\right) \qquad \text{(A-19)}$$

(where $\Sigma_n^{1/2}$ is the unique SPD square root of Σ_n), and because the left-hand-side of Eq. (A-19) is itself SPD, the matrix $\Sigma_n^{1/2}A_1\Sigma_n^{1/2}$ represents its unique SPD square root (e.g., Bellman (1970, pp. 93-94)). It then ensues that the matrix

$$A_1 = \frac{\sqrt{K}}{2}\left(\Sigma_n^{-1/2}\Psi^{1/2}\Sigma_n^{-1/2}\right) = \frac{\sqrt{K}}{2}\Lambda, \qquad \text{(A-20)}$$

where $\Psi = \Sigma_n^{1/2}\Gamma\Sigma_n^{1/2}$, is clearly the *unique* SPD matrix that solves Eq. (A-19). The matrix B_1 is derived by plugging the above expression for A_1 into Eq. (A-15), and is equal to $\frac{2}{\sqrt{K}}\Lambda^{-1}H$ (i.e., C in Eq. (10)). Because the matrix Λ in Eq. (A-20) is SPD, it is simple to verify that B_1 is invertible, consistently with our initial assumptions, using Theorem A1 and the definition of H in Proposition 1. Finally, it remains to prove that, given any linear pricing rule, the symmetric linear strategies X_k in Eq. (10), for $k = 1, \ldots, K$, represent the *unique* Bayesian Nash equilibrium of the Bayesian game among insiders. This is shown by extending to our setting the *backward reaction mapping* introduced by Novshek (1984) to find n-firm Cournot equilibria. Proposition 1 is in fact equivalent to a symmetric Cournot equilibrium with K MFs. The key to Novshek's argument is to look for the actions of each single fund manager that are consistent with utility maximization and the aggregate demand ω_1, instead of specifying the actions for each MF which are consistent with the choices of the other MFs. Uniqueness then follows from observing that, because the optimal demands X_k depend only on individual attributes δ_k and δ_{ek}, there is only one ω_1 that can be decomposed into the sum of those vectors X_k and liquidity trading, but also that such aggregate order flow ω_1 can be decomposed only in one way into those vectors X_k, given z. ∎

Proof of Remark 1. The equilibrium of Proposition 1 is the unique linear equilibrium for which $\Lambda = \frac{2}{\sqrt{K}}A_1$ is symmetric because, as previously mentioned, the matrix A_1 is the only SPD matrix solving Eq. (A-19). That such linear equilibrium is also unique when $K = 1$ has been shown by Caballé and Krishnan (1990). When instead $\Sigma_n = \sigma_n^2 I$, uniqueness ensues from a straightforward extension of Proposition 3.2 of Caballé and Krishnan (1994) to our setting with $\gamma \in [0, 1]$. ■

Proof of Corollary 1. $\Lambda_{K=1}$ and $\Lambda_{K>1}$ are easily derived using the definitions of Ψ and Λ in Proposition 1, the definition of Γ in Eq. (A-18), and the observation that, when all MFs receive the same or similar set of signals, the matrix Σ_c is equal to Σ_δ or $\rho\Sigma_\delta$, respectively. Inspection then shows that $\Lambda(n,n)_{K=1} \geq \Lambda(n,n) \geq \Lambda(n,n)_{K>1}$ for each $n = 1, \ldots, N$, with a strict inequality holding for at least some n. ■

Proof of Proposition 2. The definition of H in Proposition 1 implies immediately that $H_{K=1} = \frac{1}{2} I$ and $var[P_1]_{K=1} = \frac{1}{2}\Sigma_\delta$, and that $H_{K>1} = \frac{1}{2+\rho(K-1)} I$ and $var[P_1]_{K>1} = \frac{K}{2+\rho(K-1)}\Sigma_\delta$, as Σ_c is equal to Σ_δ or $\rho\Sigma_\delta$ when there is only one insider or the MFs' private information is homogeneous, respectively. Finally, using the fact that $\left|\Sigma_u \Sigma_{S_u}^{-1}(n,j)\right| \leq \rho I(n,j)$ and $\left|\Sigma_\vartheta \Sigma_{S_\vartheta}^{-1}(n,j)\right| \leq \rho I(n,j)$ for any $\rho \in (0,1]$ and for each $n, j = 1, \ldots, N$ (with a strict inequality holding for at least each $n = j$), it can easily be shown that, given the definitions of Σ_δ and Σ_c in Section 2.2, $\left|\Sigma_c \Sigma_\delta^{-1}(n,j)\right| \leq \rho I(n,j)$, hence that $|KH(n,j)| \geq \frac{K}{2+\rho(K-1)} I(n,j) \geq \frac{1}{2} I(n,j)$ for each $n, j = 1, \ldots, N$, with a strict inequality holding for at least one $n = j$ and one $n \neq j$. The inequality in Eq. (13) then follows from Eq. (11). ■

Proof of Corollary 2. That information heterogeneity is a necessary and sufficient condition for financial contagion ensues from Proposition 2 and the definition of excess covariance provided in the text. Indeed, $EC = O$ when $\Sigma_c = \rho\Sigma_\delta$, but $EC(n,j) > 0$ for at least one $n = j$ when $\Sigma_c \neq \rho\Sigma_\delta$. Further, the matrices H and Σ_δ in EC clearly do not depend on the variance of noise trading Σ_n nor on any of its components (γ, Σ_e, and Σ_z). ■

Proof of Remark 3. That each positive element of the matrix $EC = \left|K\left[H - \frac{1}{2+\rho(K-1)} I\right]\Sigma_\delta\right|$ increases for higher K under the conditions of the remark ($\Sigma_c^* \Sigma_\delta^{-1} \neq \rho I$) is evident from rewriting $K\left[H - \frac{1}{2+\rho(K-1)} I\right]$ as $\left(\frac{2}{K} I + \frac{K-1}{K}\Sigma_c^* \Sigma_\delta^{-1}\right)^{-1} - \left(\frac{2}{K} I + \frac{K-1}{K}\rho I\right)^{-1}$ using the definition of H in Proposition 1 and the fact that $\left|\Sigma_c \Sigma_\delta^{-1}\right| \leq \rho I$ for any $\rho \in (0,1]$, as shown in the proof of Proposition 2. Moreover, $\lim_{K\to\infty}\left(\frac{2}{K} I + \frac{K-1}{K}\Sigma_c^* \Sigma_\delta^{-1}\right) = \Sigma_c^* \Sigma_\delta^{-1}$ for any $\alpha \in [0,1]$, as $\lim_{K\to\infty}\frac{1}{K} = 0$ and $\lim_{K\to\infty}\frac{K-1}{K} I = I$, while $\lim_{K\to\infty}\frac{K}{2+\rho(K-1)} I$ is equivalent to $\lim_{K\to\infty}\frac{K}{\rho K} I = \frac{1}{\rho} I$. It then follows that $\lim_{K\to\infty} KH\Sigma_\delta =$

$\left(\Sigma_c^*\Sigma_\delta^{-1}\right)^{-1}\Sigma_\delta = \Sigma_\delta\left(\Sigma_c^*\right)^{-1}\Sigma_\delta$, $\lim_{K\to\infty}\frac{K}{2+\rho(K-1)}I = \frac{1}{\rho}\Sigma_\delta$, and consequently $\lim_{K\to\infty} EC = \left|\left[\Sigma_\delta\left(\Sigma_c^*\right)^{-1} - \frac{1}{\rho}I\right]\Sigma_\delta\right|$. Finally, each positive element of the matrix EC also decreases for lower α, as $\lim_{\alpha\to 0}\Sigma_c^* = \Sigma_\delta$, $\lim_{\alpha\to 0} H = \frac{1}{2+\rho(K-1)}I$, and $\lim_{\alpha\to 0} K\left[H - \frac{1}{2+\rho(K-1)}I\right]\Sigma_\delta = O$. ■

Proof of Proposition 3. In Sections 2.1 and 2.2 we assumed that all liquidity, information noise, and endowment shocks are independent across assets, i.e., that the matrices Σ_z, Σ_{ε_u}, $\Sigma_{\varepsilon_\vartheta}$, and Σ_e are diagonal. Hence, if the matrix Σ_v is either diagonal or block-diagonal, it is easy to see that the matrices Σ_δ and Σ_c are either diagonal or block-diagonal as well. All their sums, products, and inverses are therefore either diagonal or block-diagonal, and so are the matrices Λ, C, and H. The no-contagion result then ensues from inspection of the expression for $var\left[P_1\right]$ in Eq. (11). Note however that, when $H \neq \frac{1}{2+\rho(K-1)}I$, $EC\left(n,n\right) > 0$ even if $\beta = O$, because a multiplicity of diverse signals for u and ϑ increases the information content of the order flow, thus driving $KH\Sigma_\delta$ toward Σ_v. ■

Proof of Proposition 4. Eqs. (18) and (19) ensue straightforwardly from Proposition 1, given the definitions of S_{uk} and $S_{\vartheta k}$ and the fact that δ_k is equal to $\Sigma_u\Sigma_{S_u}^{-1}\left(S_{uk} - \overline{u}\right) + \beta\Sigma_\vartheta\Sigma_{S_\vartheta}^{-1}\left(S_{\vartheta k} - \overline{\vartheta}\right)$ for all $k = 1,\ldots,K$. When $H = \frac{1}{2+\rho(K-1)}I$, inspection of $KH\Sigma_u\Sigma_{S_u}^{-1}$ and $KH\beta\Sigma_\vartheta\Sigma_{S_\vartheta}^{-1}$ immediately reveals that $\frac{\partial P_1(n)}{\partial u(j)} = 0$ and $\frac{\partial P_1(n)}{\partial\vartheta(f)} = 0$ (for $\beta\left(n,f\right) = 0$) for any $n, j = 1,\ldots,N$, $n \neq j$, and for any $f = 1,\ldots,F$. When instead $K > 1$ but $\Sigma_c \neq \rho\Sigma_\delta$ (i.e., when $H \neq \frac{1}{2+\rho(K-1)}I$), the matrix H is nondiagonal, hence so are $KH\Sigma_u\Sigma_{S_u}^{-1}$ and $KH\beta\Sigma_\vartheta\Sigma_{S_\vartheta}^{-1}$. In this case, the absolute magnitude of contagion, as measured by $\left|\frac{\partial P_1(n)}{\partial u(j)}\right|$ and $\left|\frac{\partial P_1(n)}{\partial\vartheta(f)}\right|$, is increasing in K and α because so is each positive element of the matrix $\left|KH\right| = \left|\left(\frac{2}{K}I + \frac{K-1}{K}\Sigma_c^*\Sigma_\delta^{-1}\right)^{-1}\right|$, as $\left|\Sigma_c\Sigma_\delta^{-1}\left(n,j\right)\right| \leq \rho I\left(n,j\right)$ for any $\rho \in (0,1]$ (see the proof of Proposition 2), $\frac{\partial\frac{1}{K}}{\partial K} = -\frac{1}{K^2} < 0$, and $\frac{\partial\frac{K-1}{K}}{\partial K} = \frac{1}{K^2} > 0$. Finally, both Eqs. (18) and (19) clearly do not depend on the intensity of liquidity or short-term trading, for the matrices H, Σ_u, Σ_{s_u}, Σ_ϑ, Σ_{s_ϑ}, and β do not depend on Σ_z, Σ_e, or γ. ■

Proof of Proposition 5. The statement of the proposition follows straightforwardly from Proposition 1, the proof of Proposition 4 in Appendix A, and the definitions of S_{uk}, $S_{\vartheta k}$, δ_k, and H, which also imply that both $\frac{\partial P_1}{\partial u'} = \frac{\partial P_1}{\partial\varepsilon_{uk}'}$ and $\frac{\partial P_1}{\partial\vartheta'} = \frac{\partial P_1}{\partial\varepsilon_{\vartheta k}'}$ when $K = 1$. ■

Proof of Proposition 6. Eqs. (22) and (23) follow straightforwardly from Eq. (9) in Proposition 1. Corollary 1 and the fact that Λ is nondiagonal (unless $\beta = O$) then ensure that the existence of contagion induced by shocks to z and e_k does not depend on K or H. ■

8 Appendix B

This Appendix reports the baseline parametrization of our model, i.e., of the matrices Σ_u, Σ_{ε_u}, Σ_ϑ, and $\Sigma_{\varepsilon_\vartheta}$, used in the numerical example of Section 5.

$$\Sigma_u = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.25 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \qquad \Sigma_{\varepsilon_u} = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 2 \end{bmatrix}, \tag{B-1}$$

$$\Sigma_\vartheta = \begin{bmatrix} 3 & 0 \\ 0 & 1 \end{bmatrix}, \qquad \Sigma_{\varepsilon_\vartheta} = \begin{bmatrix} 0.25 & 0 \\ 0 & 0.25 \end{bmatrix}. \tag{B-2}$$

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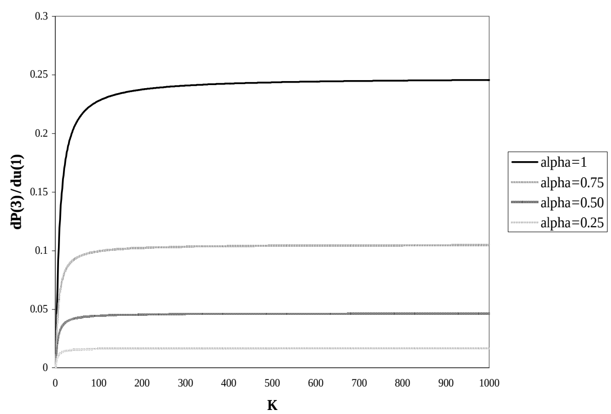
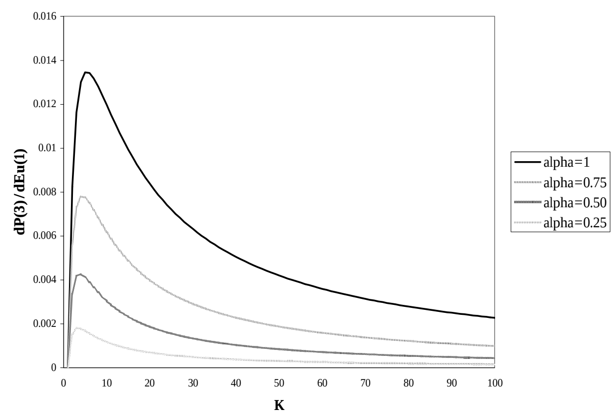
Figure 1. Measures of contagion when $\gamma = 0$

Figures 1a to 1c plot measures of contagion from *real* shocks ($\frac{\partial P_1(3)}{\partial u(1)}$ in Proposition 4), from individual *information noise* shocks ($\frac{\partial P_1(3)}{\partial \varepsilon_{uk}(1)}$ in Proposition 5), and from *liquidity* shocks ($\frac{\partial P_1(3)}{\partial z(1)}$ in Proposition 6) with respect to the number of better-informed MFs (K) in the three-country economy described in Section 5, given the parametrization reported in Appendix B. We compute these effects for different values of α in $\Sigma_c^* = \alpha\Sigma_c + (1-\alpha)\rho\Sigma_\delta$ with $\rho = 1$, i.e., for different degrees of information heterogeneity. Finally, in Figure 1d we plot the percentage of the unconditional variance of $P_1(3)$ due to fundamental information δ_k that is explained by shocks to the liquidation value of index j, for $j = 1, 2, 3$, $var\left[\frac{\sqrt{K}}{2}\sum_{i=1}^{K}(\Lambda C)(3,j)\,\delta_i(j)\right]$, as a function of K and for $\alpha = 1$.

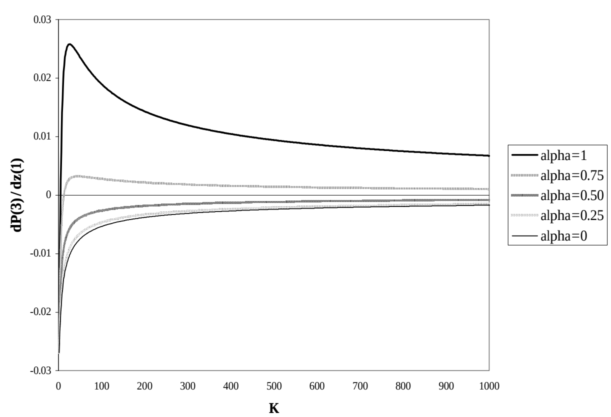
a) $\frac{\partial P_1(3)}{\partial u(1)}$



b) $\frac{\partial P_1(3)}{\partial \varepsilon_{uk}(1)}$



c) $\frac{\partial P_1(3)}{\partial z(1)}$



d) Variance decomposition

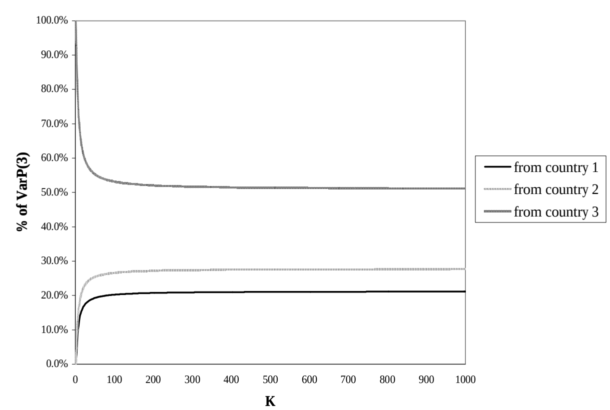
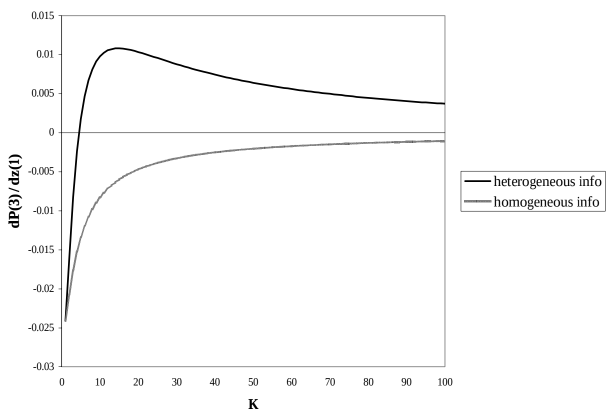


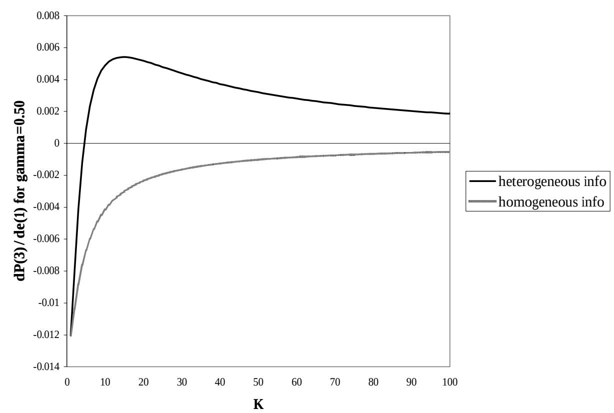
Figure 2. Contagion from uninformative trading when $\gamma > 0$

Figures 2a and 2b plot measures of contagion from shocks to *liquidity* trading ($\frac{\partial P_1(3)}{\partial z(1)}$) and from shocks to the *short-term* trading activity by the insiders ($\frac{\partial P_1(3)}{\partial e_k(1)}$), defined in Proposition 6, as a function of the number of better-informed MFs (K) when $\gamma = 0.5$ and the informational advantage enjoyed by the insiders is either heterogeneous ($\Sigma_c \neq \rho\Sigma_\delta$) or homogeneous ($\Sigma_c = \rho\Sigma_\delta$, with $\rho = 1$ because of the parameters in Eqs. (B-1) and (B-2)). Figures 2c and 2d instead display $\frac{\partial P_1(3)}{\partial e_k(1)}$ and $\frac{\partial P_1(3)}{\partial z(1)}$ as a function of γ, for different values of K, when the MFs are heterogeneously informed.

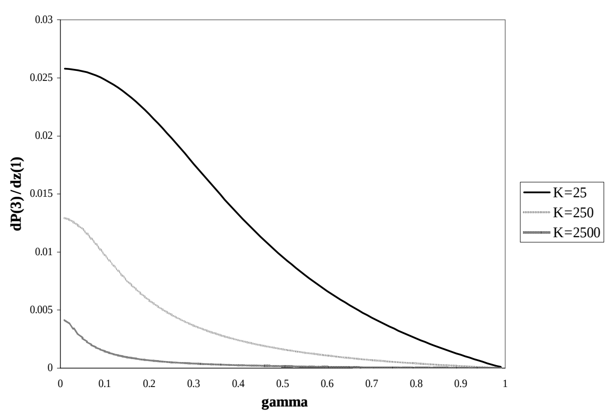
a) $\frac{\partial P_1(3)}{\partial z(1)}$



b) $\frac{\partial P_1(3)}{\partial e_k(1)}$



c) $\frac{\partial P_1(3)}{\partial z(1)}$ versus γ



d) $\frac{\partial P_1(3)}{\partial e_k(1)}$ versus γ

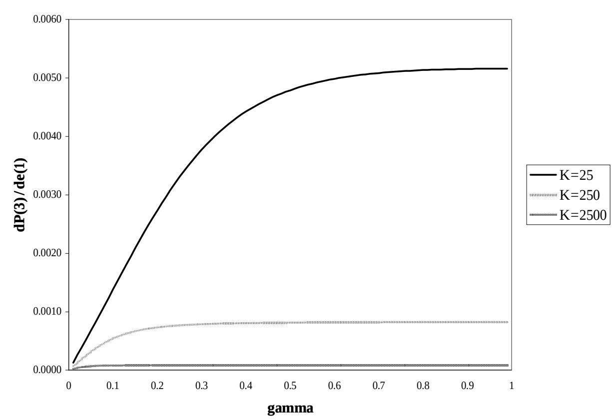
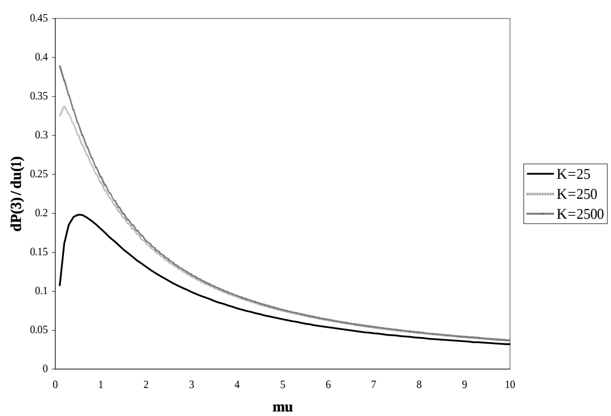


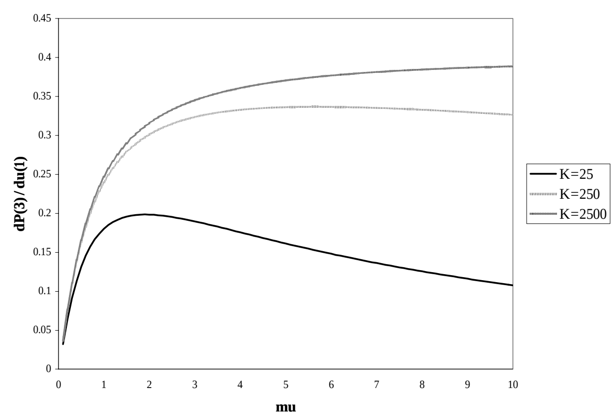
Figure 3. Contagion versus fundamental and information noise

Figures 3a and 3b plot measures of contagion from *real* shocks, $\frac{\partial P_1(3)}{\partial u(1)}$ in Proposition 4, as a function of μ (nu), a proxy for the uncertainty surrounding u and ϑ, when $\Sigma_u = \mu I$ and $\Sigma_\vartheta = \mu I$, or surrounding the individual error terms ε_{uk} and $\varepsilon_{\vartheta k}$, when $\Sigma_{\varepsilon_u} = \mu I$ and $\Sigma_{\varepsilon_\vartheta} = \mu I$, for different values of K (and $\alpha = 1$). In Figures 3c and 3d we instead plot the percentage of the variance of the equilibrium price of index 3 due to fundamental information δ_k that is explained by shocks to $v(1)$, $var\left[\frac{\sqrt{K}}{2}\sum_{i=1}^{K}(\Lambda C)(3,1)\,\delta_i(1)\right]$, as a function of μ, when $\Sigma_u = \mu I$ and $\Sigma_\vartheta = \mu I$, or when $\Sigma_{\varepsilon_u} = \mu I$ and $\Sigma_{\varepsilon_\vartheta} = \mu I$, respectively.

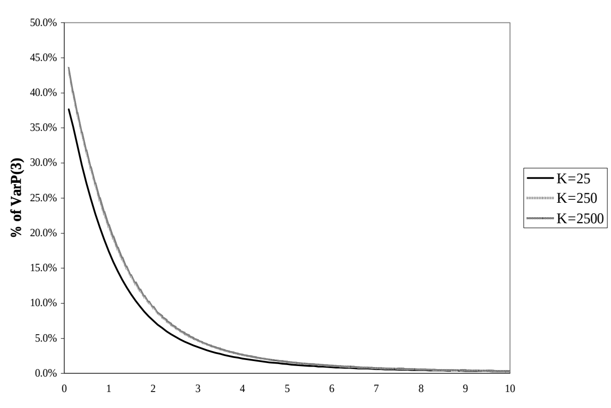
a) $\frac{\partial P_1(3)}{\partial u(1)} : \Sigma_u = \mu I$ & $\Sigma_\vartheta = \mu I$



b) $\frac{\partial P_1(3)}{\partial u(1)} : \Sigma_{\varepsilon_u} = \mu I$ & $\Sigma_{\varepsilon_\vartheta} = \mu I$



c) Variance decomposition from market 1 : $\Sigma_u = \mu I$ & $\Sigma_\vartheta = \mu I$



d) Variance decomposition from market 1 : $\Sigma_{\varepsilon_u} = \mu I$ & $\Sigma_{\varepsilon_\vartheta} = \mu I$