Strategic Investors and Exchange Rate Dynamics

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Abstract

The huge trading volumes in the foreign exchange rate markets are highly concentrated among few financial players. Differently from standard models of exchange rate determination, we reject the assumption of perfectly competitive financial markets and assume traders to be imperfect competitors. We develop an international portfolio choice model with noise shocks and traders' heterogeneity in market power. Large non-competitive traders internalize the impact of their portfolio decisions on the determination of prices. We show that the presence of strategic investors leads to the amplification (dampening) of the impact of non-fundamentals (fundamental) trade on the exchange rate, reducing its informativeness. The implications of the models are that the presence of strategic investors: i) increases exchange rate volatility; ii) reduces the role of fundamentals in explaining exchange rate movements (exchange rate disconnect); and iii) increases foreign asset excess return and makes it more predictable. Our theoretical predictions are empirically confirmed using trading volume concentration data from the NY Fed FXC Reports for 18 currencies from 2005 to 2019. Welfare analysis suggests that the consolidation in the financial sector in the last three decades increased investors' welfare by 30%.

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1 Introduction

In June 2013, Bloomberg News trilled that "*traders at some of the world's biggest banks colluded to manipulate the benchmark foreign-exchange rates used to set the value of trillions of dollars of investments in Pensions Funds and money managers globally*". After extensive investigations, banks pleaded guilty and paid more than $10 billion in fines.[1]

We develope an international portfolio choice model with noise shocks and impefectly competitive markets. In our model, exchange rate dynamics are deeply influenced by the presence of traders that internalize the impact of their portfolio decisions on the determination of prices. The underlying institutional setting is a first role determinant of exchange rate and helps rationalize the presence of several puzzle in international finance and their cross-currency heterogeneity. Despite extensive evidence that foreign exchange rate markets are highly concentrated and perfect competition is hardly realistic, the literature has ignored this feature of the underlying market structure when studying the dynamics of exchange rate.

The huge trading volume in the currency markets is highly concentrated among the market-making desks of few banks and other large financial institutions, which can exert enormous pressure on the markets.[2] Moreover, it is common today to model (large, generally more informed) investors as strategic agents since Kyle (1989) and subsiquent literature defined "unsatisfactory" the property that traders take the equilibrium price as given when deciding their trading even though they influence that price when they trade. The price-taking assumption is also in contrast with the collusive misconducts unveiled in 2013, which suggest that large players do not behave competitively, but internalize the effects of their tradings on the determination of the equilibrium exchange rate.[3] Moreover, the opaque over-the-counter structure of the FX markets favors specialization and concentration as extensively reported in the literature, casting doubt upon the assumption of perfectly competitive

[1] Investigations later revealed that traders were exchanging information about the type and volume of client orders in private chatrooms called 'The Cartel" or "The Mafia" in order to manipulate the WMR/Reuter fix for their own financial gain.

[2] In 2019, the average daily global volume the foreign exchange market was about $6.6 trillion. 80% of all transactions took place in the six major markets, UK, USA, Japan, Singapore, Switzerland and Hong Kong. Within each market, 75% of tradings is concentrated in the hand of few financial players, e.g. 4 in the US. Source: BIS Triennial Survey of Foreign Exchange Markets, 2019; NY Fed FX report, 2019.

[3] Despite significant institutional reforms in 2015, market manipulation might not have ceased (see Cochrane (2015) or Osler et al. (2016)).

markets.[4]

Our model captures this element of reality by taking seriously the competitive dynamics and the underlying market organization. We augment a standard monetary model of exchange rate determination in the spirit of Mussa (1982) and Bacchetta and Van Wincoop (2006) with imperfectly competitive financial markets. We depart from the standard assumption of perfectly competitive agents assuming the presence of a continuum of investors that differ in their degree of market of power. A fraction of traders acts competitively, taking prices as given. The complementary fraction is populated by a finite number of investors acting oligopolistically, internalizing the effects of their trading decision on equilibrium prices. Our theory of exchange rate determination with imperfectly competitive markets makes market structure a key determinant of exchange rate dynamics. The exchange rate is determined as a weighted average of fundamental (interest rate differential) and non-fundamental (noise) components. The weight on the fundamental component, which represents the information loading factor of the exchange rate, ultimately depends on the degree of competition in the financial markets: in less competitive markets, overall investors' position is lower and less elastic, reducing exchange rate informativeness.

We show that the presence of strategic investors leads to the amplification (dampening) of the impact of non-fundamentals (fundamental) trade on the exchange rate, reducing its informativeness. The mani implication of the amplification of non-fundamental shocks rationalizes the weak explanatory power of macroeconomics variables in predicting exchange rates, known as exchange rate disconnect puzzle (Meese and Rogoff (1983)). Since exchange rate price informativeness is decreasing in market power, the information content of exchange rate about fundamentals shrinks, explaining the disconnection between the two. Consequently, given the same volatility in fundamentals, a less noisy process of non-fundamental trading is required to match the volatility of the exchange rate. This complements the common belief that exchange rate fluctuations are mostly driven by noise, shifting the focus on the role of the underlying market structure and its interaction with non-fundamental trading.

Based on standard parametrizations, the unconditional volatility of the exchange rate monotonically increases when markets are less competitive. As inverstors' market power increases, exchange rate price informativeness falls and the noise component becomes more relevant in the dynamics of exchange rate. Since the process of fundamentals is less volatile

[4] The finance and market microstructure literature stress that the OTC structure can give rise to strategic behaviors among market makers due to, for instance, search frictions (see Duffie et al. (2005), Lester et al. (2018), Allen et al. (2019)). Pieces of empirical evidence have been provided also for the foreign exchange market, as in Lyons (1995).

than the noise process, the variance of exchange rate increases.

We also study the implications that non-competitive financial markets have for another major puzzle in the exchange rate literature, the Fama puzzle (Fama (1984)). The presence of strategic investors interacts with the amount of risk absorbed in the economy and, thus, with foreign asset excess return and its predictability. The model accounts for UIP failures because the presence of non-competitive traders reduces the risk appetite of market. This raises the required risk premium associated to foreign assets in order to clear the market. Our model predicts that currencies towards which traders have more market power tend to be more predictable. Notice that our model does not deliver a novel explanations for UIP deviations. Our model predicts excess return predictability also in the limiting case of perfectly competitive markets. Non competitive financial markets interact with the degree of predictability and deliver a possible explanation for cross-currency differencies in UIP deviations.

Based on this framework, we derive a set of theoretical predictions. We test our model using data on FX turnover concentration from the NY Fed FXC Reports for 18 currencies from 2005 to 2019. Results validate all the qualitative predictions derived through the lens of the model, corroborating the relevance of institutional features in the determination of exchange rate dynamics.

The BIS Triannual surveys show that the FX market has experienced strong consolidation pattern in the last three decades.[5] We evalute the welfare consequences of the increase in market power through the lens of our model. Investors' welfare (indirect utility) has increased by 30% since 1990, with no particular redistribution across competitive and strategic investors. However, it is hard to draw unambiguous policy implications since our measure of welfare refers only to domestic investors, disregarding that other important channels could affect the economy.[6]

1.1 Related literature

Our hybrid modeling approach integrates two branch of studies. It is inspired by the macro approach to exchange rate fluctuations in our choice of a monetary model in the

[5] This is not particularly surprising considering that FX markets are strictly related to the financial industry and the same consolidation trend appears in the financial sector, as document by Corbae and D'Erasmo (2020) and others.

[6] In particular, a less competitive FX market increases exchange rate volatility, which could have welfare consequences through price adjustment, consumption and FDI volatility, etc... Our stylized model does not account for these additional GE forces.

spirit of Mussa (1982) and subsequent papers. As in these papers, our theoretical framework is based on the building blocks of a standard monetary model of exchange rate determination: i) purchasing power parity, ii) interest rate arbitrage and iii) money market equilibrium. It is also reminiscent of the market microstructure literature in the attention devoted to the characteristics of the underlying market structure. Similar to this literature, we model the presence of strategic traders as a fraction of investors that internalize the effect of their tradings on the equilibrium prices.[7] However, we deeply differ in the little role played by other pivotal elements in this strand of literature, like information and trading process.[8]

This paper contributes to the literature that studies exchange rate determination in the presence of frictions. The literature has focused on different forms of frictions: informational frictions (Evans and Lyons (2002) and Bacchetta and Van Wincoop (2006)), infrequent portfolio adjustment (Bacchetta and Van Wincoop (2010) and Bacchetta and Van Wincoop (2019)), imperfect and frictional markets (Gabaix and Maggiori (2015)). To the best of our knowledge, our model is the first to focus on this specific feature of the market structure (the presence of non-competitive traders) for the determination of the exchange rate.

Our work is broadly inspired by the role that investors' heterogeneity can play in the determination of exchange rate, as highlighted in Bacchetta and Van Wincoop (2006). They focus on heterogeneous information among investors and, similarly to them, we show that inverstors' heterogeneity leads to the amplification (dampening) of the impact of non-fundamentals (fundamental) trade on the exchange rate. We focus on another dimension of heterogeneity (strategic vs competitive traders), in a more tractable and directly testable way.

An implication of our model is that the presence of large non competitive traders increases exchange rate volatility. This result connects to a broad literature on the stabilizing role of large players that traces back to Friedman and Friedman (1953). Our finding is in line with Gabaix et al. (2006) and Wei and Kim (1997), which show that large trader positions explain can volatility (the latter has also a specific focus to the FX market).

Finally, our theoretical analysis also relates to the vast literature trying to rationalize major puzzles in international economics. We contribute here providing a new rationale based on imperfectly competitive markets for the failure of macrofundamental to predict exchange rate (exchange rate disconnect, Meese and Rogoff (1983)). As in Bacchetta and

[7]In the microstructure literature, there is consensus in considering the assumption of perfect competition to be unrealistic when studying highly concentrated financial markets like the FX (see footnote 4 for theoretical and empirical arguments).

[8]In our macro approach, we abstract from information heterogeneity or detailed trading dynamics.

Van Wincoop (2006), the amplification mechanism magnifies the effects of non-fundamental trading, reducing exchange rate informativeness and the connection to fundamentals. Differently from Bacchetta and Van Wincoop (2006), the origin of the disconnect relies on the presence of strategic agents, not on information dispersion. We also study the interactions between market structure and UIP violations (Fama (1984)). We do not propose a novel explanations for UIP deviations but the presence of non-competitive traders can explain currency level differencies in UIP deviations, which is relatively unexplored.

Using trading volume concentration data from the NY Fed FXC Reports for 18 currencies from 2005 to 2019, we empirically document that currencies traded in less competitive markets tend to i) be more volatile; ii) have a more predictable excess return, iii) be more disconnected from fundamentals, consistently with our theory. To the best of our knowledge, there is no study trying to address and successfully speak about cross-currencies differences in exchange rate puzzles and dynamics.

The remainder of the paper is organized as follow. Section 2 presents the theoretical framework, the equilibrium concept and the solution method. In section 3, we derive all theoretical and numerical results and discuss key economics intuitions. Section 4 empirically tests and confirms the predictions our model delivers. Section 5 discusses welfare and potential policy implications. Section 6 concludes. Any omitted proofs, derivations and robustness analysis are in the Appendixes.

2 A Monetary Model with Non-Competitive Traders

The model contains all standard elements of an exchange rate monetary model together with i) non-fundamentals trade in the form of noise traders, as in Bacchetta and Van Wincoop (2010), and ii) heterogeneity in investors' market power.

2.1 Basic Set-up

We develop a two-country, discrete time, stochastic general equilibrium model. We assume that agents have rational expectations on the dynamics of the exchange rate. We assume that one economy is infinitesimally small (Foreign country) so that the market equilibrium is entirely determined by the market participants located in the large country (Home country). Variables referring to foreign are indicated with a star. In the Home economy, there is a continuum of traders of mass one. There are overlapping generations of agents that live for two periods and make only one investment decision.[9] Portfolio choices differ across agents and depend upon their degree of market power: a segment $1-\lambda$ of traders is composed by standard atomistic price-takers agents; the complementary segment of size λ of investors are strategic, in the sense that they internalize their effect on prices. λ is assumed to be partitioned into a finite set of N strategic investors with mass λ_i acting as an oligopoly.[10] Investors are born with an exogenous endowment ω and can purchase one-period nominal bonds of both countries with interest rates i_t and $i_t^\star$, respectively, and a technology with fixed real return r. The latter is infinitely supplied while bonds are in fixed supply in their respective currency.

We assume that each economy produces the same good and PPP holds. In log terms:

$$p_t = p_t^\star + s_t$$

where s_t is the log nominal exchange rate. The exchange rate is defined as the value of the foreign currency in term of domestic currency, so that an increase in the exchange rate reflects an appreciation (depreciation) of the foreign (domestic) currency.

We assume asymmetric monetary rules across countries: the Home central bank commits to a constant price level $p_t = 0$ so that $i_t = r$ while the monetary policy in Foreign is stochastic, $i_t^\star = -u_t$ where

$$u_t = \rho_u u_{t-1} + \sigma_u \epsilon_t^u \qquad \epsilon_t^u \sim N(0,1)$$

is the Foreign monetary policy structural shock. The interest rate differential is then

$$i_t - i_t^\star = u_t + r,$$

implying that only the Foreign country influences the dynamics of the exchange rate through its monetary policy, because the interest rate in the domestic country is fixed.[11] In our model, we refer to a shock in the Foreign monetary policy as a fundamental shock.

[9]We abstract from saving decisions by assuming that investors derive utility only from their wealth at the end of life.

[10]Obviously, $\sum_i^N \lambda_i = \lambda$. For simplicity, we focus on the symmetric oligopoly case, meaning that $\lambda_i = \lambda/N$. Results and predictions do not change qualitatively.

[11]Bacchetta and Van Wincoop (2010) specify a simplified Wicksellian rule of the form $i_t^\star = \psi(p_t^\star - \bar{p^\star}) - u_t$ where ψ is set equal to zero, consistent with the low estimates of ψ reported by Engel and West (2005). Bacchetta and Van Wincoop (2010) shows that an exogenous interest rate rule, as in our case, does not compromise the existence of a unique stochastic steady state for the exchange rate.

2.2 Portfolio problem

Each investor $j \in [0,1]$ maximizes mean-variance preferences over next period wealth w^j_{t+1}, with a rate of risk aversion ρ:

$$\max_{b^j_t} E_t(w^j_{t+1}) - \frac{\rho}{2} Var_t(w^j_{t+1})$$

$$\text{s.t. } w^j_{t+1} = (\omega - b^j_t) i_t + (i^\star_t + s_{t+1} - s_t) b^j_t,$$

where the initial endowment (ω) is normalized to one and allocated between domestic and foreign bonds (b^j_t defines the foreign bond holdings).

i_t and $i^\star_t + s_{t+1} - s_t$ are the log-linearized returns of domestic and foreign bonds, respectively. Notice that, under the monetary policy assumptions and PPP, we have that $p^\star_t = -s_t$ and both returns are expressed in real terms. The only difference between the two assets is that the return on foreign bonds is stochastic.[12]

Investors can either act strategically or not. In the former case, they internalize the effects that their demand has on equilibrium prices or, more precisely, on the equilibrium exchange rate. Investors' type has implications for foreign asset demand and portfolio allocation. Let $j = C$ be an atomistic competitive; similarly, let $j = S$ be a strategic investor acting oligopolistically. Appendix B shows that the optimal demand for foreign bonds by investor j is:

$$b^C_t = \frac{E_t(s_{t+1}) - s_t + i^\star_t - i_t}{\rho \sigma^2_t} \qquad \text{if } j = C$$

$$b^S_t = \frac{E_t(s_{t+1}) - s_t + i^\star_t - i_t}{\rho \sigma^2_t + \frac{\partial s_t}{\partial b^S_t}} \qquad \text{if } j = S,$$

where σ^2_t is the variance of next's period excess return conditional to the information set at time t. When we solve for the stochastic steady state, we assume that the variance σ^2_t is time-invariant and the information structure homogeneous across investors. The optimal portfolio choice depends positively on the excess return $q_{t+1} \equiv E_t(s_{t+1}) - s_t + i^\star_t - i_t$ and negatively on its variance and investors' risk aversion.

As standard result in a non-competitive portfolio allocation, market power reduces investors' demand for every level of excess return as if non-competitive traders were more risk

[12] $p_t = 0$ implies $i_t = r$. Similarly, $p^\star_t = -s_t$ implies that the foreign bond return $i^\star_t + s_{t+1} - s_t$ is expressed in real terms as well.

averse. This is captured by $\frac{\partial s_t}{\partial b_t^S}$, which represents investors' own price impact.

In addition to the agents described above, we introduce another set of agents, the noise traders. As standard in this class of models, their presence allows to match exchange rates moments in the data (e.g. the volatility of the exchange rate). Importantly, the presence of strategic investors deeply interplays with the effect of noise traders. As in Bacchetta and Van Wincoop (2010), the noise traders' demand for foreign bonds is exogenously given by:

$$X_t = (\bar{x} + x_t)\bar{W},$$

where $\bar{W}$ is the steady state aggregate financial wealth in the Home economy, $\bar{x}$ is a constant and x_t follows an exogenous process:

$$x_t = \rho_x x_{t-1} + \sigma_x \epsilon_t^x \qquad \epsilon_t^x \sim N(0,1)$$

The demand of foreign assets absorbed by noise traders in the stochastic steady state is equal to $\bar{x}\bar{W}$. Any deviation from the steady state is driven by a random shock x_t which can be interpreted as both supply or demand shock orthogonal to fundamental. Positive shocks to x_t increase the desirability of the foreign assets leading the foreign currency to appreciate without movements in the interest rate differential.

2.3 Market clearing

We close the model imposing the market clearing condition in the foreign bond market.[13] The market clearing condition implies that, at any point in time, demand is equal to the supply of foreign bond when denominated in the same currency:

$$(1-\lambda)b_t^C + \sum_i^N \lambda_i b_t^{S,i} + X_t = Be^{s_t}, \tag{1}$$

where B is the constant supply of foreign bonds in foreign currency and $b_t^{S,i}$ and b_t^C are multiplied by the corresponding investor size.

[13] The market clearing for the domestic bond is not relevant because the bond is perfectly substitutable wth the risk free technology, which is infinitely supplied. Similarly, a monetary model would also require a market clearing condition for the money market. Bacchetta and Van Wincoop (2006) and Bacchetta and Van Wincoop (2010) assume that investors generate a money demand (independent of their portfolio decision) and that money supply accomodates it under the exogenous rule for interest rates. We do not explicitly model a money market in order to limit notation, leaving it in the background.

Manipulating the market clearing condition as shown in Appendix B we derive an expression for the price impact of each oligopolist i, $\frac{\partial s_t}{\partial b_t^{S,i}}$:

$$\frac{\partial s_t}{\partial b_t^{S,i}} = \frac{\lambda_i \rho \sigma_t^2}{B\rho\sigma_t^2 + (1-\lambda)} = \frac{1}{N}\frac{\lambda\rho\sigma_t^2}{B\rho\sigma_t^2 + (1-\lambda)} > 0,$$

which is positive for all values of λ and λ_i. The second equality holds in the case of a symmetric oligopoly ($\lambda_i = \frac{\sum_i \lambda_i}{N} = \frac{\lambda}{N}$).[14] *Ceteris paribus*, oligopolist i's price impact inversely (positively) depends on the fraction of atomistic traders $1-\lambda$ (on its own size λ_i). Similarly, in the of symmetric oligopoly case, the magnitude of the individual price impact depends negatively on the number of strategic traders, N, and positively the size of the non-competitive segment, λ. The larger the number of strategic investors N (or the smaller their average size), the lower the price impact that they have on the exchange rate (as N goes to infinity, the price impact converges to zero, as in a perfectly competitive market). Similarly, given λ, the price impact is maximum in case of a monopolist with positive mass, $\lambda > 0$ and $N = 1$. Without loss of generality, we interpret an increase in λ or a decline in N as an increase in market power since both increase the price impact of strategic investors. In the following sections, we study comparative statics in market power mainly through the lens of changes in λ. The same qualitative predictions hold for changes in N or combination of the two.

The main implication of a positive price impact is that the demand of foreign assets of non-competitive investors is lower compared to competitive investors and decreases when the market becomes less competitive.

Notice that, in our international portfolio model, strategic traders have a lower price impact on the equilibrium price of an asset than in a closed-economy version because the supply of assets is subject to valuation effects.[15] Strategic traders account also for variations in the total value of the supply of assets when they internalize the effect that their demand has on the exchange rate. This explains the presence of B at the denominator, reflecting a peculiarity of a portfolio of international bonds.[16]

[14] Unfortunately, comprehensive trader-level market share data are not avaiable. The NY Fed FX Reports, used for our calibration and empirical analysis, provide information on the aggregate market share of each quintile of the distribution of dealers. See Appendix A. Symmetry is the best simplifying assumption we can do in this case. Notice that qualitative predictions are not altered by our assumption.

[15] See Appendix C for formal argument.

[16] The intuition is as follow: a positive price impact means that the higher the demand, the higher the exchange rate (i.e. the price of the asset). However, an increase in the exchange rate implies that the supply of foreign assets acquires higher value, which constitutes a positive valuation effect. The supply shift dampens

2.4 Equilibrium

Before we derive an explicit equation for the exchange rate, it is useful to define the concept of equilibrium in this model.

Definition 1. *For an history of shocks* $\{\varepsilon_t^x,\ \varepsilon_t^{\Delta i}\}_{t=0}^{-\infty}$*, an equilibrium path is a sequence of quantities* $\{b_t^C,\ \{b_t^{S,i}\}_{i=1}^N\}$ *and foreign currency (asset) price* $\{s_t\}$ *such that investors optimally choose their portfolio and market clearing condition holds.*

The model is simple enough to derive an explicit solution for the exchange rate, which can be solved for from eq. (1):

$$s_t = \underbrace{(1-\mu)\left(\frac{\bar{x}}{b}-1\right)}_{\text{constant}} + \underbrace{\mu\left(E_t s_{t+1} + i_t^\star - i_t\right)}_{\text{fundamental}} + \underbrace{(1-\mu)\frac{1}{b}x_t}_{\text{noise}} \tag{2}$$

with $\mu = \frac{1}{1+\Phi(\lambda,N)}$ and $\Phi(\lambda, N) = \frac{B\rho\,\mathrm{Var}_t(s_{t+1})\left(1+B\rho\,\mathrm{Var}_t(s_{t+1})-\lambda\frac{N-1}{N}\right)}{\left(1+B\rho\,\mathrm{Var}_t(s_{t+1})-\lambda\frac{N-1}{N}\right)-\frac{\lambda^2}{N}}$, where the latter is increasing function of market power (increasing in λ and decreasing in N). The ratio $b = \frac{B}{W}$ represents the share of foreign assets on the aggregate domestic wealth in steady state and it can be interpreted as an inverse measure of home bias.

As usual in this class of models, the exchange rate follows a forward looking autoregressive process with drift where the constant term depends on a set of parameters and the stochastic component depends on future fundamental and noise shocks. However, we differ from standard models in the microfoundatiiioin of the weigth attached to the noise and fundamental components, which now depends on the degree of competition of the financial market. The weigth μ decreases when foreign bond markets are less competitive (higher λ or lower N imply higher Φ and, thus, lower μ). Notce, in the spirit of Kyle (1989), μ represents the informativeness of prices, a measure of how well the variation in exchange rate predicts the variation in fundamentals. Intuitively, as the market becomes less competitive, total demand from optimizing (fundamental-based) traders declines monotonically. Thus, noise traders' demand becomes relatively more important in the determination of the exchange rate and prices carry a smaller information content.[17] Notice also that our price informa-

the initial rise in price, reducing the magnitude of the price impact. In other words, the residual net demand faced by strategic traders is more elastic than iin a case with no valuation effects. The main implication is that non-competitive traders still reduce their exposure to foreign assets compared to competitive investors but not as much as in the case there was no valuation effect.

[17] This is a well known result from Kyle (1989) and subsequent literature: when traders recognize that the residual supply curve is upward-sloped, quantities are restricted and also less elastic. Prices are then less informative. The same intuition applies here.

tiveness index μ relates to the magnification factor in Bacchetta and Van Wincoop (2006), which is microfounded from information dispersion. As in their paper, the behavior of the informativeness index is key for the amplificatioin mechanism analyzed here.

2.5 Parameterization

We consider 18 exchange rate pairs, all defined against the USD, from 1993 to 2019 at daily frequency.[18] Without loss of generality, we set $\bar{r} = 0$, so that the $i_t - i_t^\star = u_t$. The interest rate differential is defined as the difference between the 1-month forward and the spot exchange rate, assuming covered interest rate parity holds. The volatility and the persistence of the fundamental shock, σ_u and ρ_u, are calibrated to match the cross-currency average of the estimated AR(1) parameters. This yields $\sigma_u = 0.012$ and $\rho_u = 0.8$.[19]

The perceived variance of the excess return, σ_t^2, is assumed to be time-invarying and homogeneous across investors. We approximate it to the average variance of the one-period exchange rate change, which is $\sigma(\Delta s_{t+1}) = 0.029$ in the data.

The parameters that control the key amplification mechanism are λ and N. A proper parametrization of the size and number of non-competitive traders would require private data on the trading behavior of market participants, which are not available. We use the NY Fed Biannual FCX Reports from 2005 to 2019 to calibrate them: λ is set equal to the average market share of the top players in the US exchange rate market (market share of the top quintile of size distribution), which is, on average, around 70%; N is set equal to the average number of dealers in the top quintile of the distribution, which is 4.[20]

The process of noise demand x_t, which cannot be observed, is calibrated to match exchange rate dynamics, as standard in this literature. The persistence of the noise shock, ρ_x, is set high enough such that the exchange rate behavior is sufficiently close to a random walk. The volatility of the process is chosen to match the volatility of the one-period change in exchange rate, $\sigma(\Delta s_{t+1})$. Notice that the amplification mechanism our theory delivers implies that $\sigma(\Delta s_{t+1})$ depends also on the market structure, λ and N. Given the benchmark values for λ and N, σ_x is set equal to 0.0998.

[18] The set of currencies includes: Euro, Japanese Yen, Argentinian Peso, Brazilian Real, Canadian Dollar, Swiss Franc, Australian Dollar, Chilean Peso, Indian Rupee, Mexican Peso, British Pound, South African Rand, Russian Ruble, Swedish Krona, Turkish Lira, New Zealand Dollar, Singapore Dollar, Norwegian Krone.

[19] We use daily data averaged at monthly frequency. These values fall inside the set of parametrization used in previous literature.

[20] See Appendix A for a better description of the mapping between data and model in terms of market power.

It is important to underline that there exists a negative relationship between market power (N and λ) and σ_x, for given values of $\sigma(\Delta s_{t+1})$. Everything else equal, an higher level of λ (or lower N) implies a lower volatility of noise shock because the dynamics of noise demand are magnified by the presence of larger traders and the amplification is strong in less competitive markets, as shown in figure 1.[21] This has important implications for the dynamics of the exchange rate. When investors behave strategically, the calibration requires less noise to match the volatility of the exchange rate. In other words, not taking into account the underlying market structure mistakenly attribute exchange rate volatility to a highly noisy non-fundamental component.

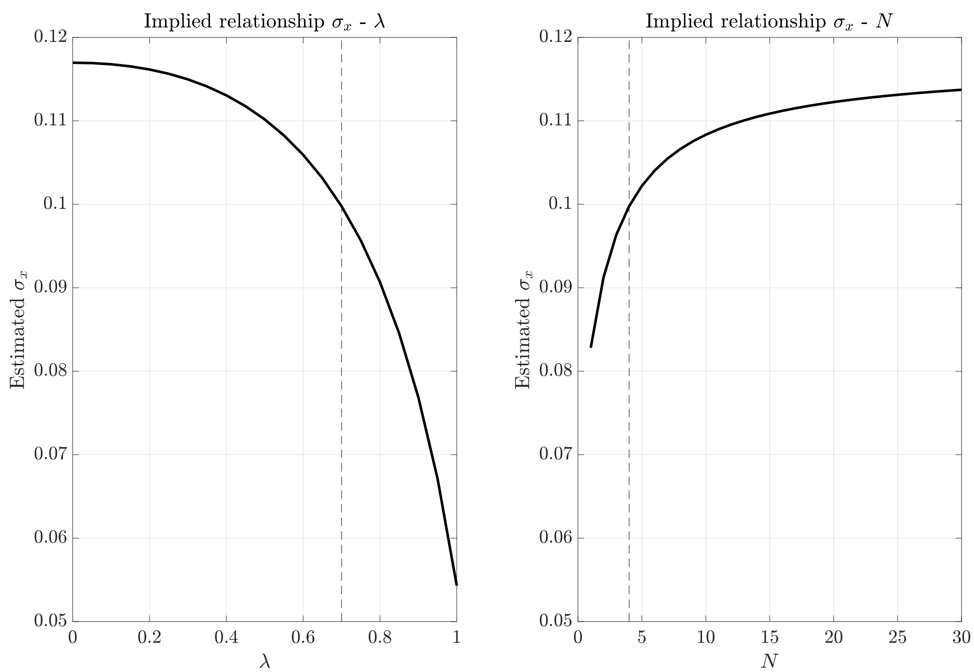

Figure 1: Relationship between λ and σ_x (left) and between N and σ_x (right).

In the benchmark parametrization we set b, the inverse home bias measure, equal to 0.33, meaning that foreign assets account for one third of the total domestic financial wealth. This is an approximate average obtained from the IMF IIPS dataset as in Bacchetta and Van Wincoop (2019).

$\bar{x}$ is calibrated such that the value of the exchange rate in the stochastic steady state is zero.[22] This is guaranteed by the following condition, $\bar{x} = b$. For simplicity, the supply of

[21] In the case of perfectely competitive markets, $\sigma_x = 0.12$, which is an order of magnitude higher than the fundamental shock, in line with the literature.

[22] This parametrization choice excludes any trend in the dynamics of exchange rate but does not affect

foreign assets, B, is normalized to one. To consistently close the model, we set ω, the initial endowment of each investor, equal to 3.[23]

Finally, the rate of relative risk aversion ρ is set to 50, as in Bacchetta and Van Wincoop (2019). In the model, risk aversion is the only source of currency premia, which would be very small for standard rates of risk aversion. Our results are nevertheless qualitatively robust to different values of different risk aversion coefficients.[24]

3 Results

The main implication of non perfectly competitive FX markets is the magnification of the impact of non-fundamentals (noise) trade on the exchange rate, as shown by the conditional response of the exchange rate to exogenous shocks. The presence of this market structure-based amplification mechanism has key implications for the conditional and unconditional variance of the exchange rate and, therefore, exchange rate disconnect. Moreover, the degree of competition interacts with the amount of risk absorbed by investors and, thus, with foreign asset excess return and its predictability. In this section, a lower level of competition in the market is assumed to take the form of an increase in the size of strategic traders, λ, for a given N.

Amplificationi mechanism Given the law motion of the exchange rate in equation (2), the effect of strategic investors on the exchange rate conditional to a shock can be summarized as follow:

Proposition 1. *An increase in market power amplifies (dampens) the response of the exchange rate to noise (fundamental) shock.*

Proof. See Appendix C. ■

Appendix C shows that the result is independent of the parameterization of the model. Figure 2 plots the impulse response function to one standard deviation shock in fundamental (first row) and noise shock (second row).

the results of our model.

[23]This comes from the fact that $b = \frac{B}{W}$. Calibrating b and normalizing B mean that $\bar{W} = 3$. Total financial wealth in equilibrium is equal to the initial endowment, ω.

[24]Bacchetta and Van Wincoop (2019) also avoid to introduce other features to increase the premium, e.g. disaster risk, because they would distract from the main focus of the paper. Moreover, notice that ρ and B enter multiplicative in the model, and $\rho = 50$ could be different if B was normalized differently.

A positive noise shock can be interpreted either as a positive demand shock or a negative supply shock. Either way, it increases the price of the foreign assets without any change in fundamentals. The excess return falls below the steady state because the exchange rate (the price of the foreign bond) increases. Lower excess return pushes investors to purchase less foreign assets, re-balancing in favor of domestic ones (and partially offsetting the increase in exchange rate). In a world where traders internalize the effect of their tradings on the exchange rate, the larger the non-competitive investors, the stronger the effect on exchange rate. Non-noisy investors' total demand reacts less when concentration is higher (see bottom right panel). A lower decline in investors' demand means that their demand is higher. The demand of foreign assets is therefore higher, exerting upward pressure on the exchange rate, which jumps more at impact for higher lambdas.[25] Even if non-competitive investors decreases their position by less, the excess return drops by more. This is due to the fact that non-competitive traders act as if they were more risk averse. The risk compensation per unit of asset is therefore higher.

A contraction in monetary policy in the foreign country leads the interest differential to drop, increasing the excess return and calling investors' demand of foreign asset to increase. This results in the appreciation of the foreign currency. In a world in which investors are heterogeneous, the more investors have market power, the less exchange rate is responsive to fundamentals shocks. Total demand is illustrative of the mechanism. Investors increase their holdings of foreign assets by less when they are able to exert market power, due to the presence of price impact, for a given shock to fundamentals. Consequently, a smaller impact on total demand dampens the effects on exchange rate. The amplified reaction of the excess return is again driven by the fact that the monopolist investor is, *de facto*, more risk averse and requires larger risk premia to absorb foreign assets.

Notice that the result in Proposition 1 can be generalized in terms of excess return dynamics.

Remark 1. *The presence of non-competitive traders dampens (amplifies) the effects on exchange rate when the impact on the excess return on foreign assets has the same (opposite) sign as the impact on the exchange rate.*

[25] The dynamics of total demand are the results of the underlying compositional forces. Both competitive and monopolistic investors' demands, b_t^C and $b_t^{S,i}$, drop when the excess return falls. However, when market power increases, the reaction of $b_t^{S,i}$ is smaller, conditional to the same change in excess return. The smaller response of total demand for larger concentration is then explained by the fact that, as λ increases, more weight is given to the demand of non-competitive traders.

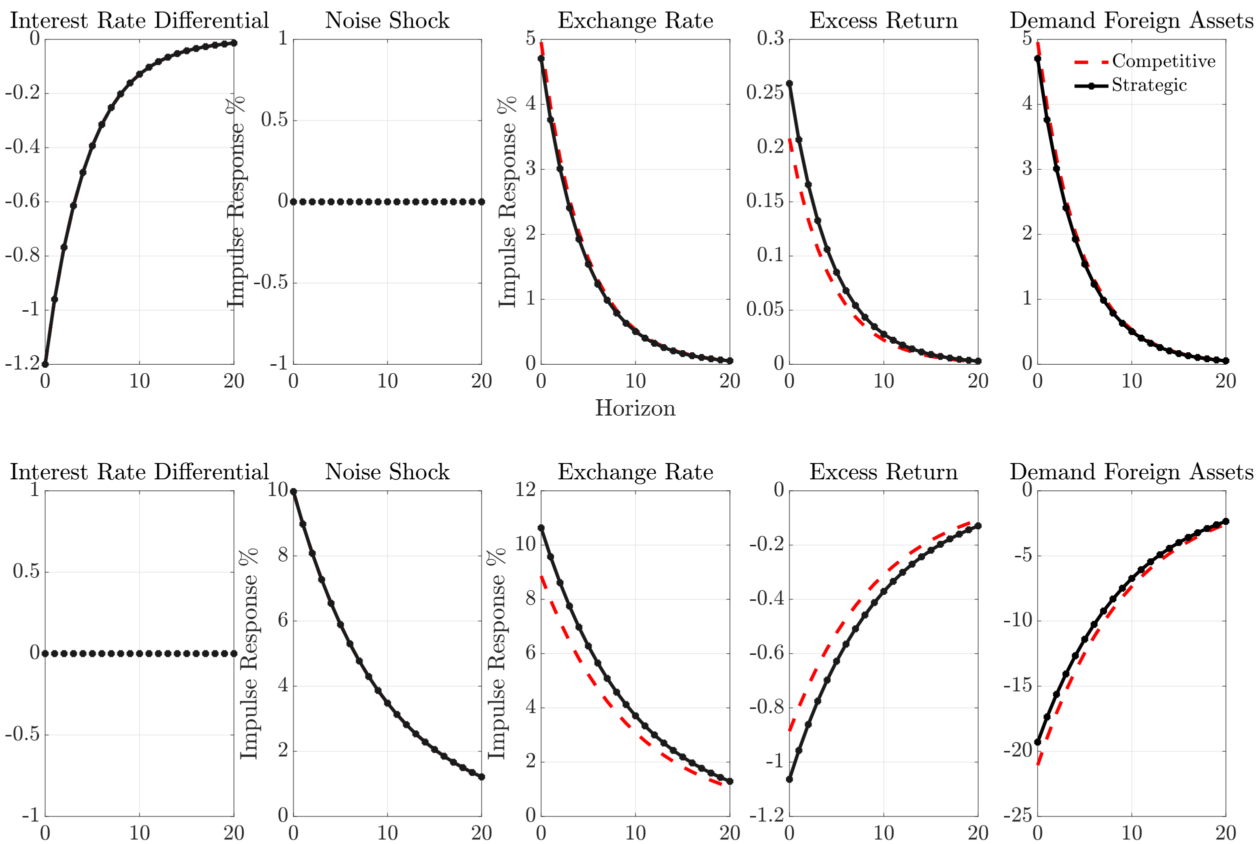

Figure 2: Impulse response to one standard deviation shock in fundamental (first row) and noise shock (second row).

Conditional and unconditional variance. Our model allows us to study the implication of market power on both conditional and unconditional volatility of the exchange rate.

We simulate the model and estimate the conditional volatility in response to exogenous shock and how it evolves for different levels of market power.[26]

Proposition 2. *The volatility of exchange rate explained by noise shocks is monotonically increasing in market power.*

The left panel of figure 3 show that, conditional to exogenous shocks, the volatility of the exchange rate due to noise are increasing in market power. Under our benchmark parametrization, the variance explained by noise is $\approx 84\%$ of the total variance at the impact. Assuming fully competitive markets, the noise component explain only $\approx 76\%$ of

[26]The number of simulations is 3000 and, for each iteration, the model runs for 1000 periods with 4000 burn-in.

the total variance in exchange rate. The reason is a direct consequence of the behavior of exchange rate informativeness. Less competitive markets decrease the information content of exchange rate, amplifying the response of the exchange rate to noise shock. Thus, the overall variance due to the noise component is increasing in market power. The conditional variance at longer horizon is increasingly explained by noise because the noise process is more persistent.[27]

The unconditional variance of the exchange rate can be derived from the law motion in equation 2:

$$\mathrm{Var}(s) = \frac{\mu^2}{(1-\mu\rho_u)^2}\left[\frac{1}{1-\mu^2} + \frac{\rho_u^2}{1-\rho_u^2}\right]\sigma_u^2 + \frac{(1-\mu)^2}{(1-\mu\rho_x)^2 b^2}\left[\frac{1}{1-\mu^2} + \frac{\rho_x^2}{1-\rho_x^2}\right]\sigma_x^2$$

As expected, the unconditional volatility is a combination of the variances of both fundamental and noise shocks.

Result 1. *Given standard parametrizations, the unconditional variance of the exchange rate is monotonically increasing in market power.*

The right panel of figure 3 shows result 1. The rational relies again on the dynamics of exchange rate informativeness. An increase in market power decreases the information content of s_t, attributing relatively more weight to one of the two processes, the noise shock. Since the volatility of the noise process is higher, an higher weight to the noise component increases the unconditional volatility of the exchange rate. Appendix C shows that, theoretically, the effect of an increase in market power is not monotonic. There exists a threshold value in the ratio between the variance of the fundamental and noise shocks such that if the ratio is higher, the volatility is monotonically increasing in market power. Given our parametrization, the noise process is sufficiently more volatile than fundamentals and the condition is always satisfied, implying a monotonic relationship. The robustness of this result ultimately depends on the values of few others parameters like the persistence of the two processes and b. Our calibration is very conservative because other reasonable parametrizations (with higher ρ_x, lower ρ_u or b) would all strengthen presence of monotonicity.[28]

[27]Panel C in figure 2 in Bacchetta and Van Wincoop (2006) shows that the exchange rate change variance explained by noise is higher when information is dispersed and declines at longer horizons. Investors' heterogeneity in market power increases the share of variance explained by noise as information dispersion. However, differently from their framework, the persistence of our fundamental shock is lower, resulting in opposite long-run predictions.

[28]Appendix C shows that noise shocks should be at least 45% less volatile than in our calibration in order not to have a monotonic relationship between market power and unconditional variance. σ_x should be an

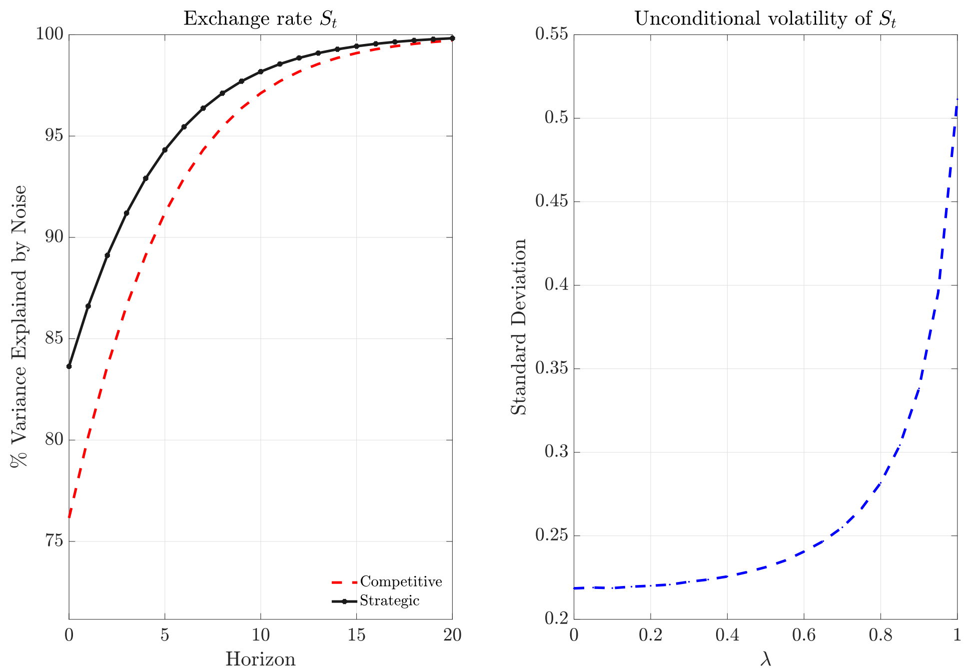

Figure 3: Conditional (left panel) and unconditional (right panel) volatility of the exchange rate.

Excess return predictability. A major puzzle in the literature is to explain why currencies tend to appreciate when interest rates are high. We show that the model is able to account for the forward premium puzzle and the implication of an increase in market power on excess return predictability.

Define the k-period ahead excess return $q_{t+k} = s_{t+k+1} - s_{t+k} - (i_{t+k} - i^*_{t+k})$ and consider the following regression:

$$q_{t+k} = \alpha + \beta_k(i_t - i^*_t) + \epsilon_{t+k} \tag{3}$$

Proposition 3. *The Fama predictibility coefficient, β_1, is negative and decreasing in market power or, in other words, the excess return is more predictable as market power increases.*

Proof. See Appendix C. ■

The right panel of figure 4 shows the numerical relationship between the excess return predictability coefficient β_1 as a function of market power (in this case λ). The coefficient is negative for all values of λ and its magnitude is monotonically increasing in market power.

order of magnitute lower for higher ρ_x, lower ρ_u or b, implying unreasonable values considering that it is common belief that fundamentals are less volatile than noise.

To understand that, re-write the excess return from equation 2 as:

$$E_t q_{t+1} = \frac{\Phi}{B}\left(Be^{s_t} - X_t\right) \tag{4}$$

where the right-hand side represents the deviation from UIP which can interpret as the risk premium required by investors for holding a foreign asset. The risk premium depends on two components: the net supply of foreign assets and the size of non-competitive investors captured by Φ, which is increasing in λ or decreasing in N. Our model predicts that an increase in market power increases the risk premium on holding a foreign asset: less competitive markets mean lower market risk appetite because investors' positions are less elastic and, thus, an higher risk premium to absorb the net supply foreign assets. Notice that our model predicts systematic deviations from UIP, even in the presence of fully competitive markets. When markets are competitive, a risk premium is required to clear the market, absorbing the net supply $Be^{s_t} - X_t$. Changes in market power modify the premium required to absorb the imbalance in the supply of assets.

While UIP implies that the Fama coefficient is zero, empirical evidence typically finds a negative number. Our model predicts that β_1 is given by:

$$\beta_1 = -(1-\mu)\frac{1}{1-\mu\rho_u} < 0$$

The negative covariance between the expected risk premium on a foreign asset and the interest rate differential is increasing in market power. A shock in interest rate differential moves the excess return and thus the risk premium. An higher level of λ means that investors' positions are less elastic which, in turn, requires larger movements in the risk premium to make investors willing to take larger positions. Therefore, the excess return reacts more to changes in fundamentals, making it more predictable.[29] This is consistent with the variance decomposition of the excess return shown in the bottom left panel of figure 3: higher shares of the variance in excess return are explained by fundamental when market concentration increases.

Appendix C generalizes the result in Proposition 3 showing that β_k is monotonically increasing in k and approaching zero for $k = \infty$, as shown in the left panel of figure 4.

[29]Interestingly, β_1 is equal to zero if the supply of asset is constant when denominated in domestic currency, that is, B is not multiplied by e^{s_t}. In this particular case, the excess return depends only on the noise component X_t, which is orthogonal to fundamental shocks. Therefore, β_1 is equal to zero even if there are systematic deviations in UIP. In other words, risk premium is still positive (UIP does not hold) but it is not predictable ($\beta_1 = 0$).

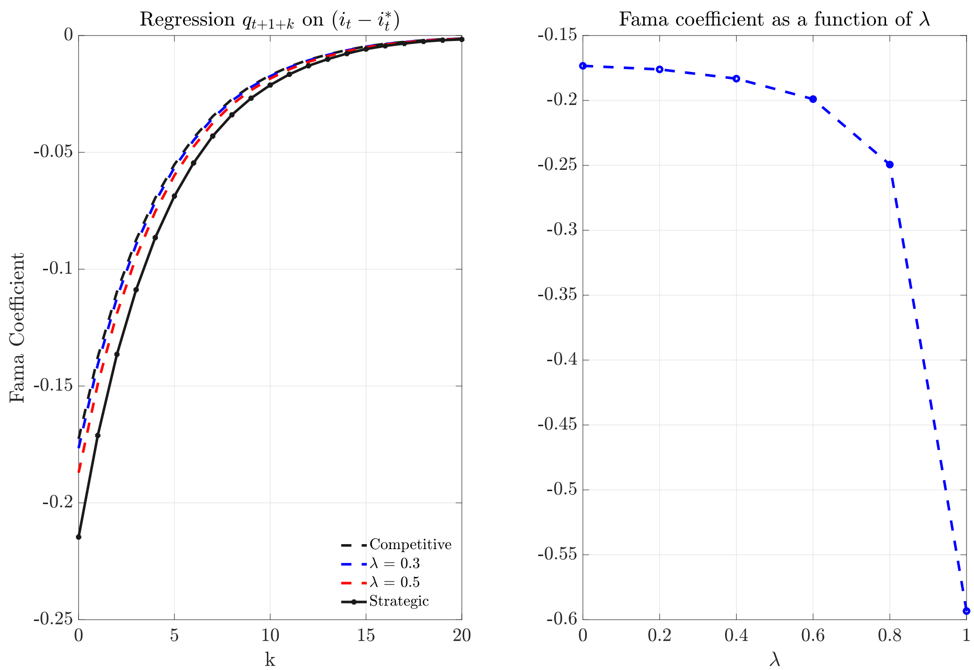

Figure 4: β_k (left) and excess return predictability (right).

This is not consistent with the predictability reversal puzzle documented in Bacchetta and Van Wincoop (2010) and Engel (2016), which refers to the fact that there is a reversal in the sign of expected excess returns at longer horizons. We are not surprised of this because market power works through an amplification mechanism that does not entail any adjustment friction.[30]

Exchange rate disconnect. A main concern in the literature is the poor explanatory power of standard theories of nominal exchange rate. Meese and Rogoff (1983) first documented that exchange rates are disconnected from fundamentals, at least in the short run. We provide a rationale for this puzzle levereging on investors' heterogeneity, in the spirit of Bacchetta and Van Wincoop (2006), and focusing on the role of financial markets, as in Gabaix and Maggiori (2015).[31] The standard measure used to evaluate the puzzle is the

[30] Bacchetta and Van Wincoop (2010) and Bacchetta and Van Wincoop (2019) impose infrequent portfolio ajdustment frictions to match the reversal and other puzzles. Our model is consistent with their frictionless case (or "actively managed portfolio" case), see figure 3 in Bacchetta and Van Wincoop (2010).

[31] Differently form the latter, which introduces financial variables to predict exchange rates, we study the underlying market structure to explain the poor performance of standard macro variables.

R-squared of the following regression:

$$s_{t+1+k} - s_t = \alpha + \beta_k(i_t - i_t^\star) + \varepsilon_{t+k+1} \tag{5}$$

Figure 5 shows the R-squared at different horizons (k up to 20) and for different levels of market power. Independently of the level of market concentration, the model predicts that the puzzle is less acute for long-run exchange rate movements, consistently with the literature. A competitive market predicts that current fundamentals explains from 4% to 12%

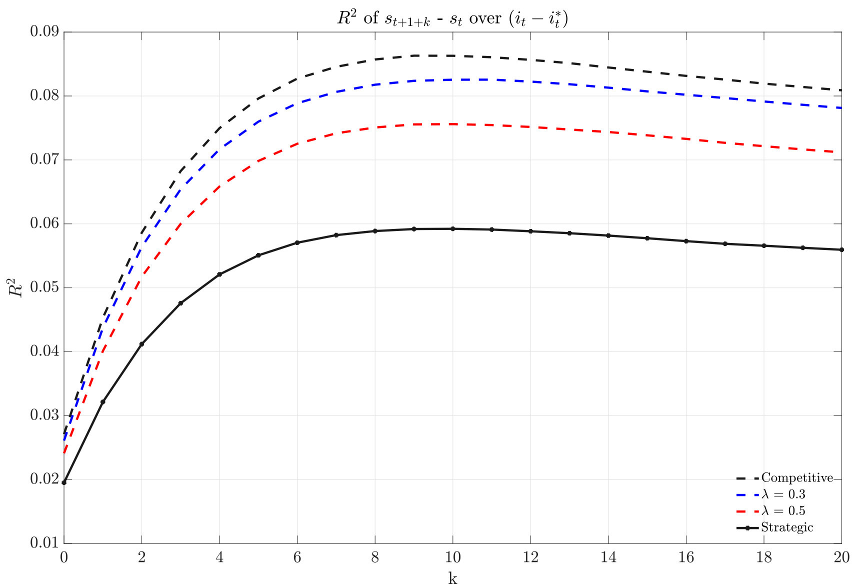

Figure 5: Exchange rate disconnect at different horizons.

of the fluctuations in the exchange rate, depending on the horizon. Instead, our benchmark calibration implies that current fundamentals explain from 2 to $\approx 5\%$ of the fluctuations in the exchange rate. Less competitive financial markets are able to rationalize a low explanatory power because noise shocks are amplified by the presence of non-competitive investors. Exchange rate informativeness is decreasing in market power and, thus, exchange rate fluctuations are overwhelmingly explained by the noise component.

4 Testable prediction

We use the disaggregate, currency-level, information provided by the New York Fed Biannual FXC Report to test a set of testable implications delivered by our theory. We look at four main testable predictions: (i) exchange rate unconditional variance increasing in λ;

(ii) excess return predictability decreasing in λ; (iii) exchange rate disconnect decreasing in λ; (iv) trading volume decreasing in λ. We use the share of total transactions in the FX intermediated by the top first quintile of dealers as reported by the NY Fed FXC as our measure of market power in the FX. We consider the same of currencies used to calibrate the model.[32] We consider the a shorter period of time, from 2005 to 2019, because the FXC reports are available only since April 2005. The FXC report is published in April and October of each year and contains informationi relative to those months about aggregate turnover, transactions and concentration in dealership. We match these data with measures of exchange rate volatility, excess return predictability and exchange rate disconnect. We use data on exchange rate at daily frequency to compute the standard deviation of each currency in a 8-week window around April and October of each year.[33] Similarly, using data on interest rate diifferentials, we compute exchange rate disconnect R^2s and Fama coeffcients β in 6-month windows around April and October of each year.[34]

Figure 6 shows simple correlations between λ and the variables of interest using cross-sectional data from April 2019. Tables 1, 2 and 3 strengthen the suggestive empirical evidence, capitalizing on the panel nature of our data.

Our model predicts that exchange rate (unconditional) volatility is increasing in market concentration (result 1). In line with our model, the top-left panel in figure 6 shows that an increase in market concentration is strongly associated with an increase in currency volatility. Table 1 confirms our theoretical predictions documenting a strong positive and statistically significant relationship between our measure of competition in the financial markets and exchange rate volatility. The panel nature of our dataset and the use of currency and time fixed effects help to mitigate potential spurious correlation concerns. Low market thickness could be the underlying driving force for higher volatility and higher concentration in turnover. Currency (and, to a certain extent, time) fixed effects alleviate endogeneity concerns while controlling for time-invariant currency-specific market deepness characteristics.

Our theory delivers clear testable implications about the behavior of excess return predictability and exchange rate disconnect. Given the amplication mechanism, as markets become less competitive, currencies are more predictable (figure 4) and more disconnected

[32]To check the robustness of our results, we exclude Euro, British Pound and Japanese Yen as the small open economy assumption could not hold for those countries.

[33]As robustness, we construct different measures of volatility considering also 3- and 5-months windows. Results do not change. See Appendix D for robustness results.

[34]Using daily data, each β and R^2 coefficient is estimated using around 120 observations. We control for different window-size in Appendix D; βs and R^2s do not seem to be affected by the small sample size.

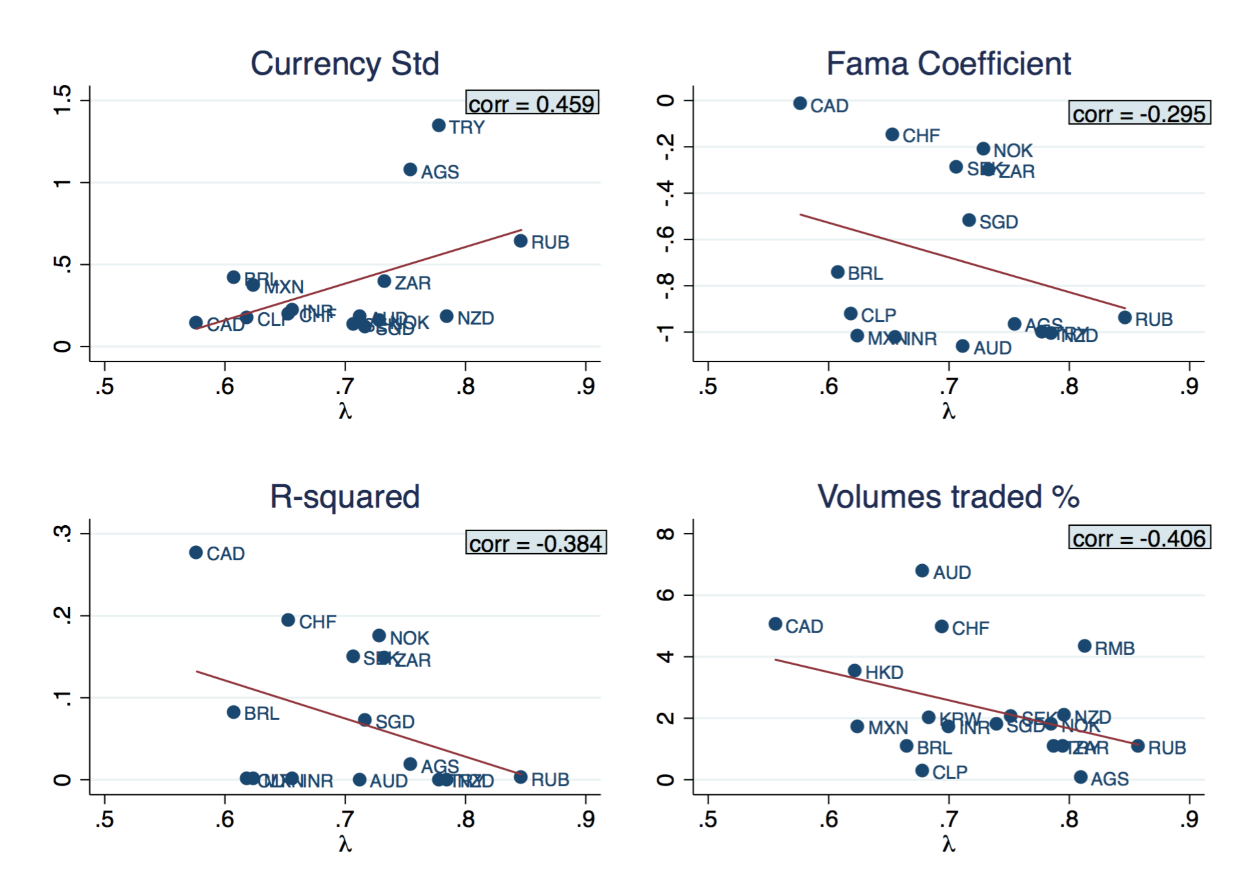

Figure 6: Testable predictions: correlation between λ and each variable of interest using cross-sectional data from April 2019.

to fundamentals (figure 5). The top-right panel and bottom-left in figure 6 show a negative cross-section relationship between λ and the fama coefficient β and the exchange rate disconnect R^2, respectively. The suggestive correlations in figure 6 hold also when tested in our panel dataset as shown in table 2. The first column reports a strong negative relationship between exchange rate connection to fundamentals and our measure for imperfectly competitive FX market. In the case of excess return predictability (second column), the coefficient of interest has the correct sign and magnitude but is not statistically significant. Notice that the coefficients reported in table 2 predict a negative relationship almost identical to the one we obtained from simulated data, that is, the right panel of figure 4. This is reassuring of the relevance of our mechanism.

Finally, a general prediction of our model is that a less competitive market discourages participation. Standard market microstructure arguments show that frictions like the pres-

	(1) StDev	(2) StDev
Concentration	0.035	0.023
	(0.006)***	(0.009)**
	[0.013]**	[0.011]**
Constant	-0.007	-0.001
	(0.004)*	(0.006)
	[0.008]	[0.007]
Year FE	No	Yes
Country FE	Yes	Yes
N	325	325

(): clusterd standard errors;

[]: Driscoll-Kraay standard errors.

* p<0.10, ** p<0.05, *** p<0.01

Table 1: Exchange rate volatility and market power.

ence of strategic investors can decrease the volume of trading (see, for instance, Foucault et al. (2013)). This happens also in our setting as the optimal portfolio allocation, $b_t^{S,i}$, decreases for higher degrees of market power. Therefore, we expect to see that currencies with higher concentration are also the ones with lower volumes traded in the market. The bottom-right panel of figure 6 shows this type of correlation in the cross section of currencies using the share of each currency over the total trading volume. As in the case of exchange rate volatility, a major concern is that the correlation between total trading volume and our measure of market concentration is driven by market thickness or liquidity dynamics. To mitigate endogeneity concerns, we estimate the effect of market power on total trading volume introducnig currency and year fixed effect, as for exchange rate volatility, and also controlling for the number of total transaction executed in the market for each currency pair as a measure of market deepness.[35] Even controlling for market thinness, table 3 shows that our prediction is empirically supported. The effect of market concentration on trading volumen is negative and statistically significant, in line with our theory.

[35]In Appendix D, we show that controlling for the number of transaction in the analysis of exchange rate volatility does not change the predictions or the significance of the coefficients.

	R^2	β^{UIP}
Concentration	-0.275	-1.574
	(0.099)***	(2.341)
	[0.045]***	[2.733]
Constant	0.299	-0.103
	(0.078)***	(1.170)
	[0.028]***	[1.800]
Year FE	Yes	Yes
Country FE	No	Yes
N	325	325

(): clusterd standard errors;

[]: Boostrapped standard errors.

* p<0.10, ** p<0.05, *** p<0.01

Table 2: Cross-currency analysis between exchange rate puzzles and market power.

5 Welfare and Policy Implications

Since we explicitly model preferences of all market participants, our model can study the welfare implications of a change in the underlying market organization. Notice that the tractability of our model comes at the expense of a comprehensive analysis of the welfare effects, as discussed in the policy implication section.

Welfare. Mean-variance preferences imply that the indirect utility of investor j is quadratic its portfolio positions b^j and ultimately depends on the variance of the excess return q_{t+1}.[36]

Let define the excess return $q_{t+1} = E_t s_{t+1} - s_t - \Delta i_t$. The expected welfare for a competitive trader is given by:

$$E(u^C) = \omega + E\left(\frac{q_{t+1}^2}{2\rho\sigma_t^2}\right),$$

while the expected welfare for a strategic investor i is:

$$E(u^{S,i}) = \omega + E\left(\frac{q_{t+1}^2}{2\rho\sigma_t^2}\right)\frac{2\alpha_i - 1}{\alpha_i^2} \qquad \alpha_i = 1 + \frac{\lambda_i}{1 + B\rho\sigma_t^2 - \lambda}.$$

The presence of imperfectly competitive markets unambiguously increases competitive traders' welfare. The less competitive the market, the lower the average risk appetite of market participants, the higher the excess return. Higher q_{t+1} benefits competitive traders.

[36]Precisely on the squared of the excess return, since q_{t+1} has zero mean.

	Total Volume
Concentration	-20201.9
	(11575.90)*
	[9038.05]**
Transactions	1.266
	(0.06)***
	[0.08]***
Constant	40784.6
	(6259.47)***
	[5457.15]***
Year FE	Yes
Country FE	Yes
N	343

(): clusterd standard errors;

[]: Driscoll-Kraay standard errors.

* p<0.10, ** p<0.05, *** p<0.01

Table 3: Total trading volume and market power.

Strategic investors' welfare can be written as the product of two terms. One is the average welfare of a competitive trader, which is decreasing in the level of competition. The other is a term that depends on the underlying market structure (λ_i, λ and N). The latter adjusts investor's welfare accounting for the presence of price impact and higher perceived risk aversion. For the same level of excess return, strategic investors have a lower utility. Notice that the second term in increasing in the level of competition, implying an overall non monotonic relationship between $E(u^{S,i})$ and market power. Strategic investors' welfare decreases when markets are highly non competitive because, even if the excess return increases, the price impact is so high that the excess return is discounted more, as in Kacperczyk et al. (2018). The left panel of figure 7 shows the hump shaped dynamics of the welfare of a strategic investor when competition decreases.[37]

Given individual welfare, we define the average aggregate welfare (in a symmetric oligopoly case) as:

$$E(u) = \sum_i \lambda_i E(u^{S,i}) + (1-\lambda)E(u^C) = \omega + E\left(\frac{q_{t+1}^2}{2\rho\sigma_t^2}\right)\left[1-\lambda\left(\frac{\alpha-1}{\alpha}\right)^2\right],$$

[37]In this case we fix a certain value for λ and change N. The same dynamics qualitatively hold in the opposite case.

where $\alpha = 1 + \lambda N^{-1}(1 - \lambda + B\rho\sigma_t^2)^{-1}$[38]

We use our framework to explore the welfare consequences of the consolidation and rise in concentration experienced in the last three decades in the foreign exchange rate markets, as extensively documented by the BIS Triennial Survey of Foreign Exchange Markets.[39]

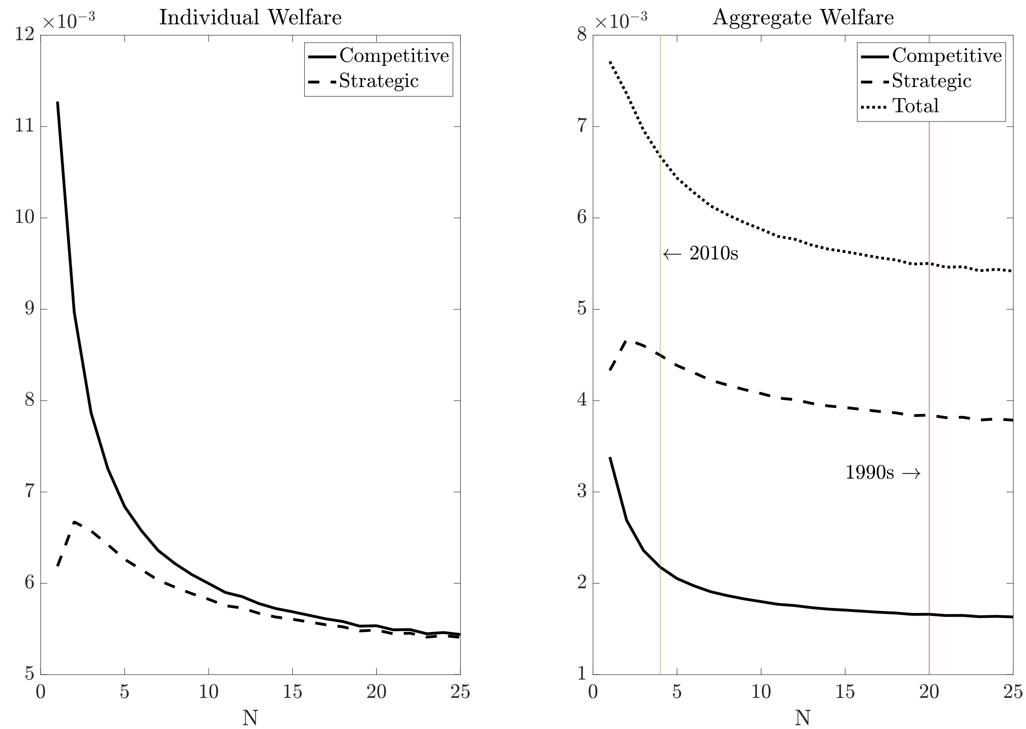

Figure 7: Individual welfare (left) and welfare dynamics over time (right).

Focusing on the US foreign exchange rate market, the number of dealers accounting for (at least) 75% of total volume in 1990 was around 20.[40] Today, the same share of total transactions is intermediated by just four large banks, as we calibrated N from the NY Fed FX report (2019). The right panel of figure 7 shows that aggregate and individual welfare has increased since the 90s. Aggregate welfare has increased by 31% and competitive investors has benefited relatively more (competitive investors' welfare share over aggregate welfare has increased from 30% to 33%).

[38] See Appendix B for the derivation of all equations.

[39] These trends are not particularly surprising given that all players in the FX are banks and the consolidation forces that the whole financial sector experienced in those years, as reported by Corbae and D'Erasmo (2020) and others.

[40] BIS Triennial Survey of Foreign Exchange Markets, 1990.

Policy implications. Is further consolidation in the FX market desirable? Through the lens of our model, aggregate welfare could decrease depending on whether the increase in market power takes the form of a fall in the number of strategic investors ($N \downarrow$) or a rise in the size of non-competitive traders ($\lambda \uparrow$). In the former case, aggregate welfare would increase, as shown in the right panel of figure 7. However, distributional concerns would arise, as strategic investors would be worsen off. In the latter case, it can be shown that aggregate welfare could decrease because an increase in λ would give more weight to strategic investors' welfare, which is declining for extremely high levels of market power. Aggregate welfare could become hump shaped as λ rises. Therefore, given our parametrization, consolidation in the FX market has already expressed all the potential benefits in the last thirty years.

More generally, it is hard to draw unambiguous policy implications because our measure of welfare refers to Home FX investors only, disregarding that other important channels could affect the economy. In particular, a less competitive FX market increases exchange rate volatility, which could have welfare consequences through price adjustment, consumption and FDI volatility, uncertainty, and other forces highlighted by the literature (see, for instance, Singleton (1987) and subsequent). Our stylized model does not account for all these additional GE forces because they are outside of the scope of this paper.

6 Conclusion

The foreign exchange market is opaque and highly concentrated, reasons due to which the assumption of perfectly competitive financial markets is unrealistic. We have explored the implications of the presence of strategic traders for the dynamics of the exchange rate. We have shown that market concentration dampens or amplifies the response of the exchange rate, depending on the shock, and increases exchange rate volatility. Moreover, it can help rationalizing the weak empirical link between fundamentals and exchange rate dynamics (exchange rate disconnect) and cross-currency differences in excess return predictability. Welfare analysis shows that investors' welfare has increased by 30% in the last three decades due to the consolidation dynamics in the financial sector and has not produced substantial redistribution among investors' types.

The analysis has focused on the role of non-competitive financial markets in the determination of exchange rate dynamics, which was underexplored. The model is stylized in order to derive basic insights and analytical results. At the same time, it delivers a set of theoretical predictions that are confirmed by iin a cross-currency analysis, proving the relevance of our theory. Our model is tractable and can be generalized to address richer settings. Future works should be directed to a much rigorous documentation of the effects of strategic investors on the dynamics of exchange rate, the interaction between non-competitive markets and more complex information structures, a more accurate welfare analysis in order to derive sound policy implications.

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Appendix A

Mapping market power from data to model

Data sources on the foreign exchange market are hardly available or comprehensive, reflecting the opaque and decentralized structure that characterized the market. Since 1990, the Bank of International Settlements collects and publishes information on turnover, instruments used, market participants etc..., providing one of few sources of data at global level. The BIS Triennial Surveys provide a clear picture of the high concentration in the foreign exchange market, both geographically and within market.

The Triennial Survey complements more frequent regional surveys conducted by national foreign exchange committees like the New York Fed Biannual FXC Report, which provides similar information at higher frequency (biannual) since 2005 for the US market (see figure 8).

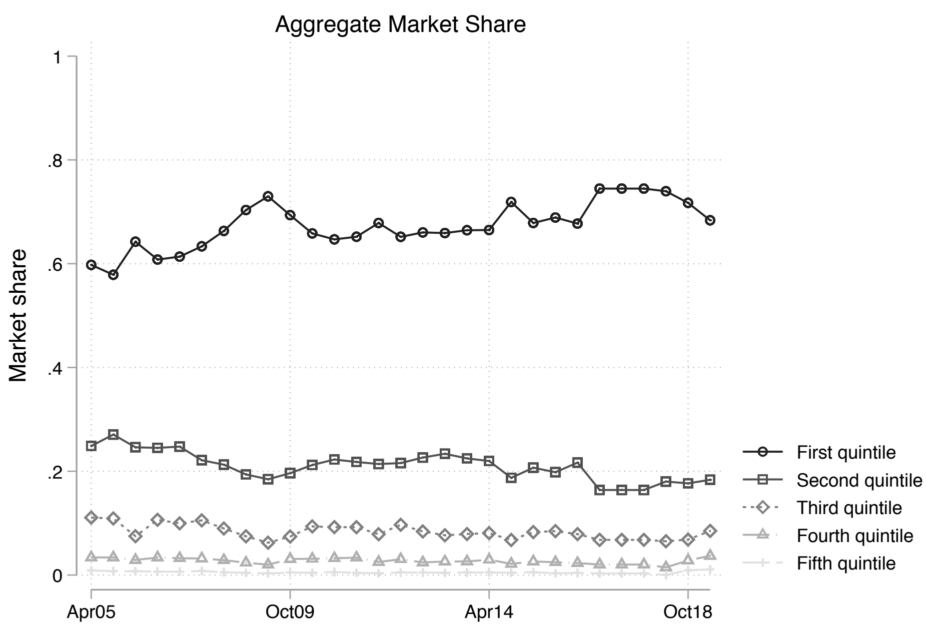

Figure 8: Market concentration in the NY OTC Forex market (Source: NY Fed Biannual FXC report).

We choose to calibrate our model focusing on the US market because i) we believe it closely reflects the overall global dynamics in the foreign exchange rate market since it represents the second market worldwide and ii) data are more granular and allow cross-sectional analysis. In our model we use the market share of the top dealers to calibrate the size of the non-competitive segment, λ. From figure 8, a reasonable value is 70%, which is the average share of the first quintile of dealers. The number of large investors that have strategic behavior in the foreign market, N, is calibrated to the number of players falling into the first quintile of the distribution. The average number of top traders over the time horizon considered is $4-5$.

Importantly, the NY Fed also provides information for each currency pairs (USD againt other currencies). In particular, for each currency pair, the report provides information on the market share for each quintile of the distribution. In other words, we have a cross-currency measure of λ. The number of institutions in the first quintile does not change across currency (N is constant). This variation allows us to validate the implications of the model cross currencies because it reflects variation in the level of market power.

When using foreign exchange rate data, it is important to keep in mind that FX is a decentralized market based on a OTC structure in which dealers play a pivotal role. The data available generally refer to the market-making desks of large financial players which have to report their currency activities (frequently called "reporting dealers"). On the other hand, our model is phrased in terms of investors and this could cause some inconsistency in mapping the data into the model. We argue that concentration in dealership reflects (to some extent) market power among investors because i) dealers often take substantial open positions and undertake their own investment activities, as highlighted by Lyons (1997) or Lyons et al. (2001); ii) large investors can have the endogenous incentives to enter in OTC markets and play the role of intermediaries (see Atkeson et al. (2015) and Dugast et al. (2019)); iii) the very same top dealers in the Forex market are also among the largest global investment banks (Citigroup, Barclays, JP Morgan, UBS, HSBC, Deutsche Bank, etc...).[41]

Finally, we evaluate the relevance of our proxy for market power, testing a standard theoretical relationship between market power and liquidity. An extensive literature in market microstructure associates the presence of non-competitive traders to higher bid-ask spreads, which can be considered as a markup measure.[42] We collect the daily bid-ask spread from Bloomberg for a set of 15 currencies for the 2019 calendar year.[43] Figure 9 shows the ex-

[41]In the FX in 2019, among the top 50 global dealers, only six were non-bank institutions (Euromoney, 2019).

[42]For instance, standard argument in a market microstructure textbook is that opaqueness and information asymmetry can lessen competition among dealers and thus reduce market liquidity, increasing the bid-ask spread (Foucault et al. (2013), Chapter 8).

[43]Refer to footnote 17 for details on the set of curriencies considered.

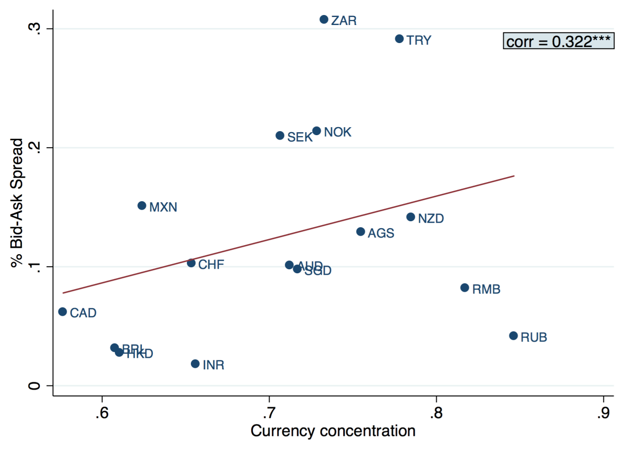

Figure 9: Cross-currency relationship between λ and bid-ask spread.

istence of a positive relationship between our measure of market power and the average daily bid-ask spread on the cross section of currencies. Therefore, figure 9 is empirically supporting our conjecture that concentration in the dealership market can be considerd as a (approximate) measure of the size of non-competitive traders in the market.

Appendix B

Derivation Demand Functions

Each investor j solves the following problem:

$$\max_{b_t^j} E_t(w_{t+1}^j) - \frac{\rho}{2} Var_t(w_{t+1}^j)$$

$$\text{s.t. } w_{t+1}^j = (\omega - b_t^j)i_t + (i_t^\star + s_{t+1} - s_t)b_t^j$$

Taking the derivative of the objective function w.r.t. b_t^j, we find:

$$b_t^j = \frac{E_t(s_{t+1}) - s_t + i_t^\star - i_t}{\rho Var_t(s_{t+1}) + \frac{\partial s_t}{\partial b_t^j}}$$

for each investor $j \in [0,1]$. Only a fraction $1-\lambda$ of investors are atomic; λ is divided into N non-competitive segmenst of size λ_i (with $i \in \{1, N\}$). Therefore:

$$b_t^C = \frac{E_t(s_{t+1}) - s_t + i_t^\star - i_t}{\rho Var_t(s_{t+1})}$$

$$b_t^{S,i} = \frac{E_t(s_{t+1}) - s_t + i_t^\star - i_t}{\rho Var_t(s_{t+1}) + \frac{\partial s_t}{\partial b_t^{S,i}}}$$

where the $\frac{\partial s_t}{\partial b_t^j}$ is 0 for the competitive investors and is positive for the non-competitive.

Derivation Price Impact

Consider the market clearing condition:

$$(1-\lambda)b_t^C + \sum_i^N \lambda_i b_t^{S,i} + (x_t + \bar{x})\bar{W} = B(1+s_t)$$

where

$$b_t^C = \frac{E_t(s_{t+1}) - s_t + i_t^\star - i_t}{\rho Var_t(s_{t+1})}$$

and

$$b_t^{S,i} = \frac{E_t(s_{t+1}) - s_t + i_t^\star - i_t}{\rho Var_t(s_{t+1}) + \frac{\partial s_t}{\partial b_t^{S,i}}}$$

From standard Implicit function theorem, we can write:

$$(1-\lambda)\frac{\partial b_t^C}{\partial s_t}\frac{\partial s_t}{\partial b_t^{S,i}} + \lambda_i = B\frac{\partial s_t}{\partial b_t^{S,i}}$$

Thus:

$$\frac{\partial s_t}{\partial b_t^{S,i}} = \frac{\lambda_i}{B - (1-\lambda)\frac{\partial b_t^C}{\partial s_t}} \qquad \text{with } \frac{\partial b_t^C}{\partial s_t} \equiv -\frac{1}{\rho Var_t(s_{t+1})}$$

Therefore:

$$\frac{\partial s_t}{\partial b_t^{S,i}} = \frac{\lambda_i \rho Var_t(s_{t+1})}{B\rho Var_t(s_{t+1}) + (1-\lambda)} \equiv \frac{1}{N}\frac{\lambda\rho\sigma_t^2}{B\rho\sigma_t^2 + (1-\lambda)} > 0$$

where the last equality holds in case of a symmetric oligopoly. The price impact is positive for $\forall(B, \lambda, N, \lambda_i, \rho, \sigma)$.

Welfare

We can derive the expected welfare of each investor plugging the demand schedule into the budget constrain and the level of wealth into investors' preferences.

Consider a competitive investor with demand b_t^C defined previously. End-life wealth w_t^C is therefore:

$$w_t^C = \omega + q_{t+1}\frac{s_{t+1} - s_t + i_t^\star - i_t}{\rho\sigma_t^2}$$

where $q_{t+1} = E_t(s_{t+1}) - s_t + i_t^\star - i_t$.

Given mean-variance prefernces and assuming rational expectations, utility of an atomic investors is:

$$\begin{aligned}
u_t^C =& E_t(w_t^C) - \frac{\rho}{2}Var_t(w_t^C) \\
& \omega + E_t\left(\frac{s_{t+1} - s_t + i_t^\star - i_t}{\rho\sigma_t^2}q_{t+1}\right) - \frac{\rho}{2}Var_t\left(\frac{s_{t+1} - s_t + i_t^\star - i_t}{\rho\sigma_t^2}q_{t+1}\right) \\
& \omega + \frac{q_{t+1}^2}{\rho\sigma_t^2} + E_t(\varepsilon_q) - \frac{\rho}{2}\frac{q_{t+1}^2}{(\rho\sigma_t^2)^2}Var_t(s_{t+1} - s_t + i_t^\star - i_t) \\
& \omega + \frac{q_{t+1}^2}{2\rho\sigma_t^2}
\end{aligned}$$

where $E_t(\varepsilon_q) = 0$ under rational expectation and $Var(s_{t+1} - s_t + i_t^\star - i_t) = \sigma_t^2$ by the definition.[44]

Therefore the expected (average) welfare for an atomistic investor is simply the unconditional expectation of u_t^C, which depends ultimatly on the variance of the excess return.

Similarly, we can derive the welfare for a strategic investor.

$$\begin{aligned}
u_t^{S,i} =& E_t(w_t^{S,i}) - \frac{\rho}{2}Var_t(w_t^{S,i}) \qquad \text{where } w_t^{S,i} = \omega + q_{t+1}\frac{s_{t+1} - s_t + i_t^\star - i_t}{\rho\sigma_t^2 + \frac{\partial s_t}{\partial b_t^{S,i}}} \\
& \omega + \frac{q_{t+1}^2}{\alpha_i\rho\sigma_t^2} - \frac{\rho}{2}\frac{q_{t+1}^2}{(\alpha_i\rho\sigma_t^2)^2}\sigma_t^2 \qquad \text{where } \alpha_i = 1 + \frac{\lambda_i}{B\rho\sigma_t^2 + 1 - \lambda} \\
& \omega + \frac{q_{t+1}^2}{\rho\sigma_t^2}\left(\frac{1}{\alpha_i} - \frac{1}{2\alpha_i^2}\right) \\
& \omega + \frac{q_{t+1}^2}{\rho\sigma_t^2}\left(\frac{2\alpha_i - 1}{\alpha_i^2}\right)
\end{aligned}$$

Finally, (average) total welfare is the aggregation of individual welfare weighted by the

[44] Under rational expectation $s_{t+1} = E_t s_t + \varepsilon_q$.

size of each segment, as follow:

$$\begin{aligned} E(u) =& (1-\lambda)E(u^C) + \sum_i^N \lambda_i E(u_t^{S,i}) \\ & \omega + \left(\frac{q_{t+1}^2}{\rho\sigma_t^2}\right)\left[1-\lambda+\sum_i^N \lambda_i\left(\frac{2\alpha_i-1}{\alpha_i^2}\right)\right] \\ & \omega + \left(\frac{q_{t+1}^2}{\rho\sigma_t^2}\right)\left[1-\lambda\left(\frac{\alpha-1}{\alpha}\right)^2\right] \end{aligned}$$

where the last equation holds in case of a symmetric oligopoly (with $\alpha = 1 + \frac{\lambda}{N(1-\lambda+B\rho\sigma^2)}$).

Appendix C

Lemma 1

In international portfolio choice models, the value of the supply of foreign assets in domestic currency (indirectly) depends on the value of the exchange rate when foreign assets are denominated in foreign currency. Differently from standard models of strategic trading (as Kyle (1989)), non-competitive traders internalize not only their price effect on the quantity demanded but also on the quantity (value) supplied. Compared to closed economy models or cases in which foreign assets are denominated in domestic currency, the presence of this "supply effect" implies a weakly lower price impact.

Let pi^F and pi^D be the price impact on a foreign and a domestic asset, respectively.

$$pi^F \equiv \frac{\partial s_t}{\partial b_t^{S,i}} = \frac{\lambda_i\rho\sigma_t^2}{B\rho\sigma_t^2+(1-\lambda)} \qquad pi^D \equiv \frac{\partial p_t}{\partial b_t^{S,i}} = \frac{\lambda_i\rho\sigma_t^2}{(1-\lambda)}$$

where p_t is the price of the domestic asset. It is easy to show that $pi^F \leq pi^D \quad \forall(B,\rho,\sigma_t^2,\lambda_i,\lambda)$. The intuition is fairly simple. The increase in the price of a currency (foreign currency appreciates) rises the nominal value of the supply of foreign assets when denominated in domestic currency. The overall effect of tradings on the exchange rate is lower due to the presence of a revaluation effect.

Proposition 1

According to proposition 1, an increase in market power amplifies (dampens) the response of the exchange rate to noise (fundamental) shock.

Proof. Consider the law motion of the exchange rate, equation 2. s_t can be rewritten as a forward looking sum of fundamentals and noises as follow:

$$s_t = -\mu \sum_{k=0}^{\infty} \mu^k \left(\Delta i_{t+k}\right) + \frac{1-\mu}{b} \sum_{k=0}^{\infty} \mu^k \left(x_{t+k}\right)$$

Therefore, the impulse response to a unit shock in noise and fundamental that raises the exchange rate at impact are:

$$\text{IRF}\left(s_{t+j}, j=0\right) = \begin{cases} \dfrac{\mu}{1-\mu\rho_u}, & \text{for } \varepsilon_u = -1 \\ \\ \dfrac{(1-\mu)}{(1-\mu\rho_x)b}, & \text{for } \varepsilon_x = 1 \end{cases}$$

Taking the derivative w.r.t. μ, we find:

$$\frac{\partial \text{IRF}(s_{t+j}, j=0)}{\partial \mu} = \begin{cases} \dfrac{1}{(1-\mu\rho_u)^2} > 0 \\ \\ -\dfrac{(1-\rho_x)}{(1-\mu\rho_x)^2 b^2} < 0 \end{cases}$$

Since μ is decreasing (increasing) function of λ (N), the response of the exchange rate to a unit shock in fundamental is dampened while noise shock are amplified as λ increases (N decreases). ■

Result 1

According to result 1, the unconditional volatility in exchange rate is non-monotonic in market power.

Proof. Consider the law of motion of the exchange rate, equation 2, substituting the process for fundamental and noise in s_t we write:

$$s_t = -\mu \sum_{k=0}^{\infty}\sum_{j=0}^{\infty} \mu^k \rho^j \varepsilon^u_{t+k-j} + \frac{1-\mu}{b} \sum_{k=0}^{\infty}\sum_{j=0}^{\infty} \mu^k \rho_x^j \varepsilon^x_{t+k-j}$$

After some algebra, s_t can be written as summation of its backward and forward components:

$$s_t = -\frac{\mu}{1-\mu\rho_u}\left[\sum_{k=0}^{\infty}\mu^k\varepsilon^u_{t+k} + \sum_{k=1}^{\infty}\rho_u^k\varepsilon^u_{t-k}\right] + \frac{1-\mu}{b(1-\mu\rho_u)}\left[\sum_{k=0}^{\infty}\mu^k\varepsilon^x_{t+k} + \sum_{k=1}^{\infty}\rho_x^k\varepsilon^x_{t-k}\right]$$

and derive the unconditional variance of the exchange rate:

$$\mathrm{Var}(s) = \frac{\mu^2\sigma_u^2}{(1-\mu\rho_u)^2}\left[\frac{1}{1-\mu^2} + \frac{\rho_u^2}{1-\rho_u^2}\right] + \frac{(1-\mu)^2\sigma_x^2}{(1-\mu\rho_x)^2 b^2}\left[\frac{1}{1-\mu^2} + \frac{\rho_x^2}{1-\rho_x^2}\right]$$

which tells us that the unconditional volatility of the exchange rate is a combination of the variances of fundamental and noise shocks.

Taking the derivative of $\mathrm{Var}(s)$ w.r.t. μ, we find:

$$\begin{aligned}\frac{\partial \mathrm{Var}(s)}{\partial\mu} =& \frac{\mu\sigma_u^2}{(1-\mu\rho_u)^3}\left[\frac{1}{1-\mu^2} + \frac{\rho_u^2}{1-\rho_u^2}\right] + \frac{\mu^3\sigma_u^2}{(1-\mu\rho_u)^2(1-\mu^2)^2} - \\ & \frac{(1-\mu)(1-\rho_x)\sigma_x^2}{(1-\mu\rho_x)^3 b^2}\left[\frac{1}{1-\mu^2} + \frac{\rho_x^2}{1-\rho_x^2}\right] + \frac{\mu(1-\mu)^2\sigma_x^2}{(1-\mu\rho_x)^2(1-\mu^2)^2 b^2}\end{aligned}$$

Therefore, the unconditional volatility of the exchange rate is increasing in λ iff:

$$\begin{aligned}&\frac{(1+\mu\rho_x)\sigma_x^2}{(1-\mu\rho_x)^2(1+\mu)(1+\rho_x)b^2} - \frac{\mu\sigma_x^2}{(1-\mu\rho_x)^2(1+\mu)^2 b^2} > \\ &\frac{\mu\sigma_u^2}{(1-\mu\rho_u)^2}\frac{(1+\mu\rho_u)}{(1-\mu^2)(1-\rho_u^2)} + \frac{\mu^3\sigma_u^2}{(1-\mu\rho_u)^2(1-\mu^2)^2}\end{aligned}$$

which can finally re-written as the condition:

$$\frac{\mathrm{Var}(x)}{\mathrm{Var}(\Delta i)}\frac{1}{b^2} > \left[\frac{(1+\mu^2\rho_x)(1-\rho_x)}{\mu(1+\mu\rho_u)(1-\mu^2)+\mu^3(1-\rho_u^2)}\frac{(1-\mu\rho_u)^2(1-\mu)^2}{(1-\mu\rho_x)^2}\right]^{-1}$$

which intuitively happens whenever the variance of the noise shock is sufficiently high.

■

We believe that the non monotonic case is not relevant given our parametrization or other reasonable/standard values of the calibration. The validity of result 1 depends upon the fact that the noise process is more volatile and more persistent than the fundamental one. Let define $\underline{\sigma_x}$ as the minimum value of the volatility of the noise process such that the relationship between market power and exchange rate variance is not monotone anymore. In our benchmark case, $\underline{\sigma_x} \approx 0.03$, 65% lower than our benchmark value of σ_x. Figure 10 shows $\underline{\sigma_x}$ for different combinations of N and λ.

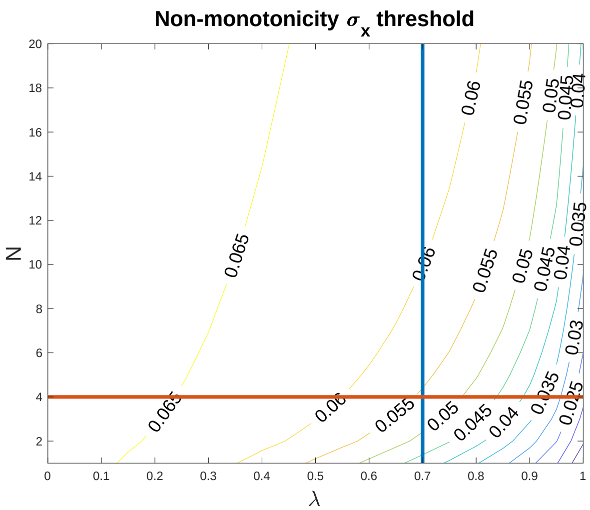

Figure 10: $\underline{\sigma_x}$ for different combinations of N and λ.

For other values of λ or N, $\underline{\sigma_x}$ is at least 50% lower than the implied value of σ_x by figure 1. In a competitive market, $\sigma_x \approx 0.12$ and monotonicity does not arise if $\underline{\sigma_x} < 0.066$. In highly non-competitive markets, $\sigma_x \approx 0.06$ and monotonicity does not arise if $\underline{\sigma_x} < 0.015$.

Moreover, notice that the threshold value depends on ρ_x, ρ_u and b. Result 1 is robust because our calibration is particularly conservative. Only more persistent noise processes or less persistent fundamental processes would be consistent with standard calibrations; similarly, only higher values of home bias (lower b) would be acceptable. Higher values of ρ_x, lower values of ρ_u and lower b all decrease the threshold, relaxing the condition for monotonicity.

Proposition 3

According to proposition 3, excess returns are more predictable as market power increases.

Proof. Consider the law motion of the exchange rate, equation 2:

$$s_t = \mu \left(E_t\left(s_{t+1}\right) + i_t^\star - i_t\right) + (1-\mu)\frac{\bar{x}}{b} + (1-\mu)\frac{1}{b}x_t$$

where only the first term depends on fundamentals.

The j-period change in currency price can be obtained from the law motion for the exchange rate as follows:

$$\Delta s_{t+j} = -\mu \sum_{k=0}^{\infty} \mu^k \left(\Delta i_{t+j+k} - \Delta i_{t+k}\right)$$

With Δs_{t+j} in hand, we can calculate:

$$\begin{aligned}
\beta_1 = \frac{\mathrm{Cov}\left(\Delta s_{t+1} - \Delta i_t; \Delta i_t\right)}{\mathrm{Var}(\Delta i_t)} &= \left[\mathrm{Cov}\left(-\mu \sum_{k=0}^{\infty} \mu^k \left(\Delta i_{t+k+1} - \Delta i_{t+k}\right); \Delta i_t\right) - \mathrm{Var}\left(\Delta i_t\right)\right] / \mathrm{Var}(\Delta i_t) \\
&= \left[-\mu \sum_{k=0}^{\infty} \mu^k \mathrm{Cov}\left(\Delta i_{t+k+1} - \Delta i_{t+k}; \Delta i_t\right) - \mathrm{Var}\left(\Delta i_t\right)\right] / \mathrm{Var}(\Delta i_t) \\
&= \left[-\mu \sum_{k=0}^{\infty} \mu^k \rho_u^k (\rho_u - 1)\mathrm{Var}(\Delta i_t) - \mathrm{Var}(\Delta i_t)\right] / \mathrm{Var}(\Delta i_t) \\
&= -(1-\mu)\frac{1}{1-\mu\rho_u} < 0
\end{aligned}$$

which is negative for each value of μ and increasing (decreasing) in μ (in market power). ■

Notice that predictability reversal does not arise in our model, differently from Bacchetta and Van Wincoop (2010) and Engel (2016). Formally define the j-period ahead excess return $q_{t+j} = s_{t+j+1} - s_{t+j} - (i_{t+j} - i^*_{t+j})$ and consider the following regression:

$$q_{t+j} = \alpha + \beta_j (i_t - i_t^*) + \epsilon_{t+j} \tag{6}$$

It can be shown from the fact that the regression coefficient β_j is monotonically decreasing to zero for j that goes to infinity.

Consider $q_{t+j} = \Delta s_{t+j} - \Delta i_{t+j-1}$ where Δs_{t+j} is defined as above. We can write:

$$
\begin{aligned}
\beta_j =& \frac{\text{Cov}(q_{t+j}, \Delta i_t)}{\text{Var}(\Delta i_t)} \\
& \frac{1}{\text{Var}(\Delta i_t 9} \left(\text{Cov}(\Delta s_{t+j}, \Delta i_t) - \text{Cov}(\Delta i_{t+j-1}, \Delta i_t)\right) \\
& \frac{1}{\text{Var}(\Delta i_t)} \left[\text{Cov}\left(-\mu \sum_{k=0}^{\infty} \mu^k \left(\Delta i_{t+k+j} - \Delta i_{t+k+j-1}\right); \Delta i_t\right) - \text{Cov}\left(\Delta i_{t+j-1}, \Delta i_t\right)\right] \\
& \frac{1}{\text{Var}(\Delta i_t)} \left[\left(-\mu \sum_{k=0}^{\infty} \mu^k \text{Cov}\left(\Delta i_{t+k+j} - \Delta i_{t+k+j-1}\right); \Delta i_t\right) - \text{Cov}\left(\Delta i_{t+j-1}, \Delta i_t\right)\right] \\
& -\mu \sum_{k=0}^{\infty} \mu^k (\rho_u^{k+j} - \rho_u^{k+j-1}) - \rho_u^{j-1} \\
& -\mu \rho_u^{j-1} (\rho_u - 1) \frac{1}{1 - \mu \rho_u} - \rho^{j-1} = -\rho^{j-1} \frac{1-\mu}{1-\mu\rho_u} \leq 0
\end{aligned}
$$

Moreover, notice that $\frac{\partial \beta_j}{\partial j} = -(j-1)\rho_u^{j-1}\left(\frac{1-\mu}{1-\mu\rho_u}\right) < 0$. Therefore, for $j \to \infty$, the coefficient $\beta_j \to 0$ monotonically, excluding any reversal. This is not surprise since, differently from Bacchetta and Van Wincoop (2010) and Engel (2016), our framework does not entail any adjustment friction.

Appendix D

TBD