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fundamentally heterogeneous markets**

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Taxing financial transactions in fundamentally heterogeneous markets^{*}

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Abstract

The recent global financial crisis has revived a well-honored debate on the desirability and feasibility of taxing financial activities to curb speculation and promote price stability. In this paper we apply agent-based computational techniques to explore this issue in a multi-market environment in which the processes driving the fundamental value of the securities traded in different jurisdictions are heterogeneous. A natural exemplification is to assume that security dealers have the opportunity of submitting orders by choosing among stock markets at different stages of development. We argue that the proper policy objective to be targeted is not volatility in itself, but that in excess of the discounted stream of subsequent dividends, that is price efficiency. In this case, a global coordination is incentive-compatible, given that it minimizes the distortion associated to speculative trading on the one hand, and it ensures that the loss of trading volume is lower if compared to the case of unilateral taxation on the other one. Notwithstanding a fundamental heterogeneity of the markets involved, the optimal tax rate turns out to be uniform.

Keywords: agent-based models; financial transaction tax; heterogeneous traders

JEL classification: C63; D53; G18

1. Introduction

A key by-product of the global financial turmoil of 2007-08 has been a profound rethinking on the set of policy responses that need to be deployed to curb systemic instability, with suggestions ranging from a macroprudential approach for the regulation of financial intermediaries (Schoenmaker, 2014) to restrictions on cross-border capital flows (Ostry *et al.*, 2012). Implicitly assuming that the stunning volatility and skyrocketing trading volume actually observed in securities' markets might just be the flip side of a disproportionate accumulation of risk by traders, in September 2009 the G-20 leaders have brought back to the limelight a renowned proposal long advanced by Keynes (1936) and Tobin (1972; 1978) to limit short-term speculative activities by means of Financial Transaction Taxes (FTTs) (IMF, 2010). Rephrasing Tobin, this amounts to throw a few grains of sand in the well-greased wheel of financial markets.

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This recommendation rests on the assumption that market outcomes result from the interaction of two distinct populations of traders: stabilizing long-term investors and destabilizing short-term speculators. When applied in terms of a small *ad valorem* charge on every transaction regarding equities, bonds, derivatives or currencies – as the argument goes – such a tax constitutes a negligible extra cost for long-term investors but a substantial burden for short-term speculators, thus fostering financial stability. It seems worthwhile to note that the theoretical framework underlying this view has been more recently revived by behavioral economists under the *fundamentalist-vs-chartist* (Frankel and Froot, 1991) and *noise-trader* (Shleifer and Summers, 1990) headings.

The idea of taxing financial transactions has been applied extensively – although with a substantial cross-country heterogeneity in tax bases and a generalized decreasing trend of tax rates – all around the world at least since the 1980s. In fact, data collected by the International Monetary Fund shows that at the dawn of the current decade 23 countries were imposing some kind of FFT, with tax rates between 10 and 50 basis points and revenues amounting on average to 0.5% of GDP (Matheson, 2011). Alas, bolstered by the rather mixed empirical evidence on their real ability to contain market volatility¹ a heated debate on the pros and cons of FFTs is still alive and kicking.

In particular, the difficulties encountered during the last five years by EU negotiators in trying to finalize a harmonized scheme for a regional levy on financial transactions are paradigmatic of the objections commonly raised on this tax and of the major hindrances encountered on the road to an effective international coordination in its application (Kitromilides and González, 2013).² Critics argue that a FFT is disproportionately costly to be administered, leads to a hazardous drop of transaction volume and market liquidity, slows down price discovery and, as a final take-away, shrinks efficiency. Last but not least, any attempt to impose unilaterally a levy on domestic financial transactions in a world where capital flows freely across borders ends up to redirect buying and selling activities towards jurisdictions where exchanges are taxed at a lower rate, if not at all.

Abstracting from the possibility that third-party interests might play a role in orientating the public support towards them, all these criticisms are rooted on the view that financial markets are inherently efficient. Simply stated, the efficient market hypothesis (EMH) asserts that the actual price of a security equals the expected value of subsequent dividends accruing to the share, that is its fundamental value. Since in this case movements of the stock market are just optimal responses to new information about fundamentals, any tax on transactions distorts efficient market pricing. Furthermore, the likelihood of losing significant amounts of activity due to cross-country tax arbitrage even in the presence of tiny tax rates implies that the so-called *home bias* is absent, an instantiation of the EMH when applied to international macroeconomics (Obstfeld and Rogoff, 2000).

Scholars accentuating behavioral elements of security price determination have unquestionably a good point in stressing that the empirical content of EMH has been robustly disproved by decades of econometric research highlighting a bunch of stylized

¹ See Baltagi *et al.* (2006) and Hau (2006).

² For an exposition on the current state of the debate among EU members, see “Eurozone Financial Transaction Tax Plan Stalls, Says Minister” (<http://www.wsj.com/articles/eurozone-financial-transaction-tax-plan-stalls-says-minister-1457606638>; last accessed on May 16th, 2016).

facts that contradict its predictions (Shleifer, 2000; Shiller, 2003).³ Before attaining a full acceptance of the idea in political circles and the public opinion at large, however, it is also clear that the burden of proof on the actual effectiveness of FTTs in stabilizing financial markets lies primarily upon their advocates.

From this point of view interesting results have been recently obtained in the field of agent-based financial modeling, which entails simulating on a computer the dynamics of a stock market populated by a large number of interacting heterogeneous artificial traders (Hommes, 2006, LeBaron, 2006). Since these models are able to replicate many of the stylized facts characterizing financial market data with parsimonious analytical structures, the basic idea consists in using them as computer laboratories for conducting policy experiments, where alternative assumptions on trading strategies and market protocols can be tested in a controlled environment.⁴ Three findings emerge neatly from this literature. First, in a market in which traders can endogenously switch between technical and fundamental trading rules or remain idle altogether, the imposition of a FTT causes a reduction in volatility that depends on the proportion of chartists retreating from trading or switching to a fundamentalist strategy. Second, the drop in volatility is also associated to the liquidity secured by the market microstructure, since liquidity is inversely related to the price responsiveness of a given order. In fact, in the absence of a market-maker providing abundant liquidity the imposition of a tax may even result in higher market instability. Third, when agents are allowed to operate in several distinct markets, introducing unilaterally a tax generates a negative spillover, in that that taxed market is stabilized at the expenses of the untaxed ones, whose volatility increases.

In this paper we are mainly concerned with the last point. A modeling choice usually employed in assessing the impact of FTTs in multi-market agent-based financial models is that of assuming that the various markets are separated from an institutional point of view, but share an equal fundamental value for the stock exchanged in each one of them. This hypothesis has profound implications for the issue at hand, since it introduces a cross-market symmetry in excess volatility relative to the fundamental. Once one recognizes that the unilaterally imposition of a tax generates negative spillovers, the natural policy implication is that of suggesting a common tax rate for all jurisdictions. It seems worthwhile to ask whether this conclusion holds true when markets are characterized by diverse fundamentals' dynamics, due for instance to differences in the speed with which news are incorporated into the present value of subsequent dividends (Andersen *et al.*, 2007), the risk-return profile associated to different stages of development (Kohers *et al.*, 2006), or the degree of macroeconomic volatility (Easterly *et al.*, 2001). Is the proposal of a one-size-fits-all tax rate reasonable when international financial markets are structurally heterogeneous? Does the inherent heterogeneity of financial markets add a motivation to deviate from policy coordination once an agreement has been achieved?

To address these questions, we simulate a prototypical small-type agent-based multi-market asset pricing model, slightly amended to accommodate the possibility that the dynamic path of the present value of future cash flows accruing to a standardized

³ But see also Malkiel (2003) for a rebuttal of the criticisms against the EMH.

⁴ See for example Westerhoff (2003), Ehrenstein *et al.* (2005), Westerhoff and Dieci (2006), Mannaro *et al.* (2008), Pellizzari and Westerhoff (2009), Demary (2010), Fricke and Lux (2015).

security might depend on the market in which the asset is exchanged. We find that the strategy of levying symmetric FTT rates continues to be optimal even after cross-market structural heterogeneity is taken into account. The endogenous evolution of trading strategies across the population of agents generates a concave relationship between tax rates and market efficiency, directly related to the market share of investors adopting fundamental forecasting rules. In fact, an international coordination in setting a common tax rate allows to reach simultaneously two results: *i*) to increase the market efficiency globally; *ii*) to individually maximize tax revenues in comparison to the case of a unilaterally imposition. This implies that coordinating on a symmetric tax rate is an incentive-compatible solution even for heterogeneous jurisdictions.

The remainder of the paper is organized as follows. Section 2 presents the building principles and the analytical structure of our modeling approach. Section 3 offers simulation results showing the degree of accuracy of the model in capturing several stylized facts of real financial markets, and an assessment of how alternative assumptions on the dynamics of the fundamental price affect market outcomes. Section 4 studies the impact of transaction taxes in this multi-market heterogeneous environment. Section 5 concludes.

2. The market environment

As already observed, the motivation for a tax on financial transactions as a tool to restrain price volatility must be grounded on some sort of market inefficiency. Indeed, observed volatility in itself is not a sufficient argument, given that it could represent the optimal response of rational traders to news about the intrinsic value of the underlying asset. Starting with the pioneering work of Shiller (1981), however, a huge amount of empirical evidence has persuasively shown that stock prices move too much to be justified by subsequent changes in dividends, a phenomenon which is nowadays universally known as *excess volatility*.

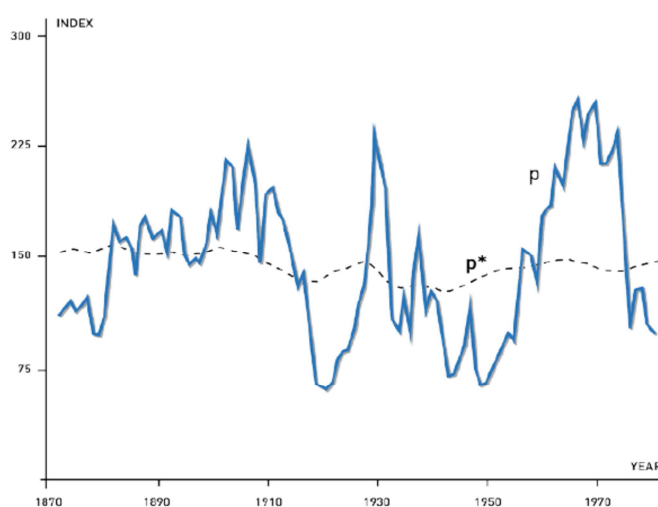


Figure 1. Real stock prices and present value of subsequent dividends. Annual data for the S&P Composite Price Index over the time span 1871-1979.

Figure 1, taken from the scientific background paper issued by the Economic Sciences Prize Committee of the Royal Swedish Academy of Sciences (2013) on the occasion of the award of the Nobel Prize to Shiller himself, illustrates clearly the point. The solid line p traces the evolution of the S&P Composite Stock Price Index over the period 1871-1979, expressed in real terms and detrended by means of a long-run exponential growth factor. The dotted line p^* is the present value of actual subsequent real detrended dividends, which represents the optimal price forecast. The distance between the two is therefore a measure of how much the market violates the EMH or, to put it differently, the degree of market inefficiency. It appears that the actual price dynamics is characterized by pronounced bubbles and crashes with respect to its fundamental value; that this pattern is slowly mean-reverting; and that the fundamental itself varies, although at a much lower frequency.

A persuasive common explanation of the first two features – boom-and-bust dynamics and slow mean-reversion – can be obtained by means of a model postulating the existence of a population of traders who employ heterogeneous trading strategies at any point in time, but are allowed to switch among them from one trading period to the next. In a typical 2-type agent-based model, for instance, any autonomous trader can choose between a fundamentalist forecasting rule, according to which asset prices are expected to return to their fundamental value, and a chartist forecasting rule, which is based on the assumption that prices move in trends. The probability that fundamental traders switch to technical trading (and vice-versa) depends adaptively on the relative profitability of the rules. Although the EMH maintains the chartist strategies should not be profitable and therefore bound to be discharged in the long-run, this is not necessarily true if the market is driven outside of an efficient equilibrium for a significant amount of time. To understand why, suppose that at a given trading period a large number of traders is adopting a chartist forecasting strategy. It may then be rational for a fundamentalist to follow suit and become a chartist too, so that the chartist expectations may lead to a self-fulfilling prophecy in the form of a speculative bubble. As the price moves significantly away from its fundamental values, however, the prospective attractiveness of adopting a fundamentalist strategy increases, thus eventually leading to a mean-reverting market movement.

As regards the exogenous process forcing the evolution of the fundamental value, the existing literature has considered two alternative assumptions only – a constant and a random walk – to conclude that the market outcomes remains basically unaffected (Westerhoff, 2010). Probably inspired by this finding, all available extensions to a multi-market framework have assumed so far that traders can post orders in two or more separated markets characterized by a common fundamental. The key value added of this paper consists in relaxing this assumption, in order to study the issue of optimal taxation on financial transactions in heterogeneous markets.

To ensure full comparability with previous results, we will make use of the prototypical framework developed by Westerhoff and Dieci (2006), suitably amended to take into account cross-market heterogeneity. A large, fixed number of traders (ideally, a continuum in the unit interval) N is allowed to submit buy or sell orders for marketable securities with similar characteristics (say, exchanged-traded funds tracking stock indexes) on I separated markets. The fundamental values of the I risky assets are publicly available to all agents, but they have different beliefs about the persistence of

deviations of market prices from the fundamental benchmark. In particular, after having decided the market in which she wants to operate, each trader can submit orders according to two different trading strategies – i.e., being a fundamentalist who predicts that the market price will eventually converge towards fundamentals, or a chartist riding on the price trend – or remain idle altogether. This implies that at any time period the number of available trading options for any trader is $(2I+1)$. The prices registered on the different markets after the orders have been executed define the profit attained by each trader, that in turn forms the basis for updating her choices as regards the market and the trading strategy for the following period. A market or a strategy attract more agents if they performed relatively well in the recent past compared to other markets and strategies. An evolutionary selection mechanism based on relative past profits governs the dynamics of the fractions and switching of agents between different beliefs or forecasting strategies.

In each market $i \in I$, the log of the price of the security S at time $t+1$ is determined according to a log-linear impact function (Farmer and Joshi, 2002), which expresses how the asset price changes due to the buy and sell orders by active traders:

$$S_{t+1}^i = S_t^i + \alpha(W_t^{F,i}D_t^{F,i} + W_t^{C,i}D_t^{C,i}) + u_t^i \quad (1)$$

where α is a positive price adjustment coefficient, $D^{F,i}$ and $D^{C,i}$ represent respectively the orders by fundamentalists and chartists, $W^{F,i}$ and $W^{C,i}$ are the fractions of traders following these strategies, and u^i is a random term normally distributed with mean 0 and variance $\sigma^{I,i}$ capturing possible frictions in the execution mechanism. The price impact function is a short-cut for a microstructure consistent with the presence of a market-maker who holds inventories of the traded security and uses them to adjust any excess of demand or supply. In doing so, the market-maker provides exogenous infinite liquidity to the market, a situation in which it is well known that a transaction tax is stabilizing (Pellizzari and Westerhoff, 2009).

The net demands for the asset exchanged in market i expressed on average by fundamentalist and chartist traders are given by:

$$D_t^{F,i} = \beta^F(F_t^i - S_{t-1}^i) + \varepsilon_t^{F,i} \quad (2a)$$

$$D_t^{C,i} = \beta^C(S_t^i - S_{t-1}^i) + \varepsilon_t^{C,i} \quad (2b)$$

where β^F and β^C are positive reaction parameters capturing how strongly agents react to market signals. According to equations (2), fundamentalists buy (sell) when the price is below (above) its fundamental value F^i , while chartists buy (sell) when the price is increasing (decreasing). In order to capture within-group heterogeneity as regards the intensity of reaction or the possibility of experimentation with slightly different trading rules, independent and normally distributed noise terms are added to each demand components, ε^F and ε^C .

The fundamental value of the asset traded in market i is assumed to evolve according to a jumping random walk:

$$F_t^i = F_{t-1}^i + (1-\phi)^i z_t^i \quad (3)$$

where z^i is a normally distributed random term, and 1_ϕ is the indicator function:

$$(1_\phi)^i = \begin{cases} 1 & w.p. \quad \phi^i \\ 0 & w.p. \quad 1 - \phi^i \end{cases} \quad (4)$$

with ϕ being a well-defined probability. The role of ϕ is that of tuning the speed with which new information is incorporated into the fundamental value of the stock, and allows us to introduce a source of cross-market heterogeneity additional to those associated with different values of the mean and variance of z^i . Differences in the speed of reaction to news of the optimally forecasted present value of future dividends may be due institutional factors affecting the quality and precision of the signals, or to differences in the cost of acquiring information. In any case, it is clear that all these factors vary with the stage of development of financial systems. In fact, the available cross-country empirical evidence lends convincing support to the hypothesis of large international dissimilarities in the information content of earnings announcements and other major news events, as well as in the promptness with which they are incorporated into the evaluation of securities (DeFond *et al.*, 2007; Griffin *et al.*, 2008).

At the end of any trading period t , agents compute the attractiveness (or fitness) of the trading rules as they are applied in each market i :

$$A_t^{F,i} = [\exp(S_t^i) - \exp(S_{t-1}^i)]D_{t-2}^{F,i} - 2\tau^i |D_{t-2}^{F,i}| + \delta A_{t-1}^{F,i} \quad (5a)$$

$$A_t^{C,i} = [\exp(S_t^i) - \exp(S_{t-1}^i)]D_{t-2}^{C,i} - 2\tau^i |D_{t-2}^{C,i}| + \delta A_{t-1}^{C,i} \quad (5b)$$

$$A_t^0 = 0. \quad (5c)$$

Four facts are worth noting. First, due to the market timing – orders submitted in period $t-2$ are executed at time $t-1$ – profits depends on the price return between $t-1$ and t . Second, if a positive transaction tax rate τ is levied, traders incurs a cost which must be incurred when positions change. Third, agents have a memory of the past attractiveness of the rule, where δ is a parameter which measures how quickly agents discount this piece of information. Fourth, the fitness associated to inaction is 0.

The final step consists in defining how agents make use of the options' attractiveness to select where to submit orders the next period, and the strategy for doing it. We recur to the standard hypothesis that the fraction of traders choosing a certain option is driven by a discrete choice model (Manski and McFadden, 1981), in which the fractions W depend positively on the fitness of a strategy as it is applied in a given market:

$$W_t^{F,i} = \frac{\exp(\gamma A_t^{F,i})}{\sum_{i=1}^I \exp(\gamma A_t^{F,i}) + \sum_{i=1}^I \exp(\gamma A_t^{C,i}) + \exp(0)} \quad (6a)$$

$$W_t^{C,i} = \frac{\exp(\gamma A_t^{C,i})}{\sum_{i=1}^I \exp(\gamma A_t^{F,i}) + \sum_{i=1}^I \exp(\gamma A_t^{C,i}) + \exp(0)} \quad (6b)$$

$$W_t^0 = 1 - \sum_{i=1}^I W_t^{F,i} - \sum_{i=1}^I W_t^{C,i} \quad (6c)$$

The parameter $\gamma \geq 0$ measures the sensitivity of traders in selecting the most attractive option. If $\gamma = 0$ all agents are divided evenly across the market/strategy options; while if $\gamma \rightarrow +\infty$ all agents select the option with the best performance. In what follows we adopt a frequentist approach: the fraction of traders adopting at any period a given strategy is simply assumed to be equal to the probability with which that same strategy is chosen. This allows us to get rid of one parameter when the model is taken to the computer – namely, the overall population size N .

3. Results

The key features of the environment sketched above are explored by recurring to agent-based simulations. In this section we focus on the ability of the model to capture several stylized facts of financial markets in an extremely parsimonious framework. We will assess the case of closed heterogeneous markets first (autarky), to subsequently move to analyze what happens when traders are allowed to choose the market in which to submit their buy or sell orders without any friction (openness). The issue of how the introduction of FTTs affects market outcomes is left for the next section.

Table 1 presents the parameters' constellation for benchmark simulations. Since the purpose of this paper is merely theoretical, no serious attempt to calibrate the model has been made. In fact, we generally use values employed in similar exercises by Westerhoff and Dieci (2006) and Westerhoff (2010). Nevertheless, a couple of distinctive choices deserve to be discussed in some detail.

Table 1. Parameter setting for benchmark simulations

<i>Parameter</i>	<i>Description</i>	<i>Value</i>
T	Trading days per simulation	5000
I	Number of markets	2
α	Market impact factor of demand	1
σ_1^I	Noise in price formation in market 1	0.01
σ_2^I	Noise in price formation in market 2	0.01
β^F	Aggressiveness of fundamentalists	0.05
β^C	Aggressiveness of chartists	0.065
σ_ε^F	Noise in fundamentalist demand	0.01
σ_ε^C	Noise in chartist demand	0.05
ϕ^1	Probability of fundamental's jumping in market 1	0.06
ϕ^2	Probability of fundamental's jumping in market 2	0.024
σ_z^1	Noise of fundamental dynamics in market 1	0.06
σ_z^2	Noise of fundamental dynamics in market 2	0.03
δ	Memory in updating attractiveness	0.975
γ	Sensitivity in selecting options	300

Assuming that the typical trading period is 1 day, each simulation covers a time span of approximately 20 years. For ease of analysis we consider just two markets, that differ as regards the speed and resonance with which new information is incorporated into fundamentals. In particular, in the first market the probability that news regarding subsequent dividends is disseminated and processed by agents is equal to 6% per day.

This amounts to 15 variations on average per annum. In the second market news arrives with a probability of 2.4% per day, meaning that the fundamental jumps on average 6 times per year. Likewise, the volatility of the fundamental in market 1 when a jump occurs is two times that of market 2. It follows that the first market is *fundamentally* more volatile than the second one. Besides their demand being more noisy, moreover, chartists are assumed to be more aggressive in submitting orders than fundamentalists. This feature is consistent with recent estimates of the model obtained by means of the method of simulated moments (Franke and Westerhoff, 2016).

Figure 2 presents results for a representative simulation run, as we assume that traders can operate in one market only (in this case market 2, that is the less fundamentally volatile one). All the following findings have been extensively reported in the literature dealing with the *fundamentalist-vs-chartist* approach. We cover them as a quick reminder of the ability of small-type agent-based computational models to capture a wide range of styled facts of actual asset returns within an extremely parsimonious framework on the one hand, and as a benchmark against which to measure the impact of alternative assumptions on the stochastic process driving the fundamental on the other one.

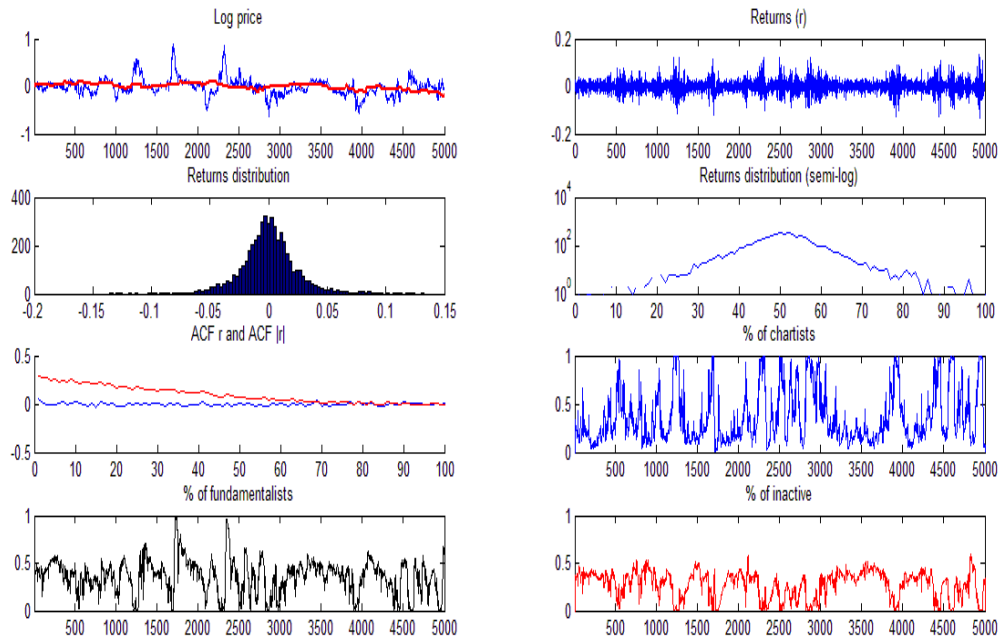


Figure 2. Numerical simulation of the model with parameters as in Table 1, except for $I = 1$. The values for σ_f^i , σ_z^i and ϕ^i are those for market 2.

The time series for the (log) price exhibits a typical bubbles-and-crashes dynamics and excess volatility, meaning that the occurrence of positive and negative large returns cannot be generally explained by the arrival of news on the market. In particular, the volatility of market prices is much higher (around 3 times) than that of the fundamental. Returns are characterized by a heavy-tailed (leptokurtic) distribution, with an excess kurtosis around $K \sim 7$. As shown in the semi-logarithmic histogram plot, furthermore,

the tails display an approximately exponential decay, a result in line with the evidence reported in various studies employing daily data (see e.g. Ding *et al.*, 1993). While the sample autocorrelation function of returns is insignificant at all lags – indicating the absence of linear serial dependence – the autocorrelation function of absolute returns is significant and slowly decaying over many time lags, a typical signature of volatility clustering. The whole system dynamics is driven by the evolutionary competition between trading strategies, which translates into an endogenous evolution of adoption frequencies. Periods characterized by bursts in volatility and large market mispricing are associated with the preponderance of chartist traders, while mean-reverting movements are caused by the action of fundamentalists. Since the price return volatility is given by $V = (W^F)^2(\sigma_\varepsilon^F)^2 + (W^C)^2(\sigma_\varepsilon^C)^2$, its path is dependent on how the market is divided between fundamentalists and chartists, and its value would change even if the noise in their respective demand were equal.

Notable results emerge as we allow the jumping random process for the fundamental value to diverge across markets. The upper line of Figure 3 reports a comparison between the performance registered in two closed, fundamentally heterogeneous markets, obtained by averaging market prices across 5000 Montecarlo repetitions. In addition to the market already examined, we consider a closed jurisdiction in which new information on future dividends arrives more frequently and resonates more widely on the optimal forecasts of agents (market 1 in Table 1). In turn, the parameters governing the behavior of traders and the price impact function are equal in the two markets. It appears that the process for the fundamental matters for the statistical properties of the market price and – as we will argue momentarily – the degree of market efficiency, a feature which to our knowledge has never been explored before.

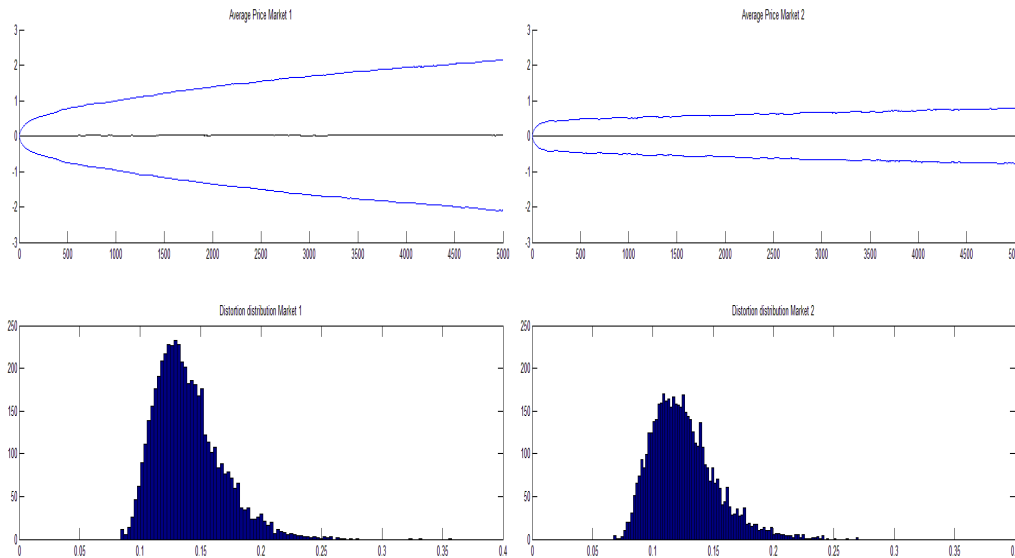


Figure 3. Comparison between two closed markets characterized by different stochastic processes for the evolution of fundamentals. Parameters are those of Table 1. Plots in the first line report averages over 5000 Montecarlo repetitions. Black lines are mean prices, blue lines are ± 2 standard deviations around the mean. The bottom line reports the distribution of market distortion in the two markets over Montecarlo repetitions.

Consider first that the generating stochastic processes for fundamentals are weakly non-stationary by construction (with standard deviations increasing with \sqrt{t}), and that the variance of the random term for the fundamental value in the first market is the double of that for the second one. Unsurprisingly, both features are inherited by actual prices. In spite of this, the sample means of price volatility and kurtosis of returns ($\langle V \rangle$ and $\langle K \rangle$ in the upper part of Table 2, respectively) obtained by simply averaging across the price volatility and return kurtosis of the 5000 artificial time series are basically unaffected by differences in the statistical properties of the fundamentals.

The interesting part of the story emerges as we consider how the non-stationarity of market prices and fundamentals affect market efficiency, expressed in terms of excess volatility. A metric commonly used to measure it is a distortion index defined as follows:

$$D^i = \frac{1}{T} \sum_{t=1}^T |S_t^i - F_t^i|. \quad (7)$$

The index is bounded below by 0, while increasing values of D signal higher amounts of market inefficiency. A visual inspection of the bottom line of Figure 3 – where we plot the values of D obtained across the two markets in each of the 5000 Montecarlo repetitions – suggests that the distortion index is in both cases skewly distributed to the right, but also that the moments of the two distributions are quantitatively different. In fact, the mean, the standard deviation and especially the skewness of the distribution ($\langle D \rangle$, σ^D and Sk^D in the upper part of Table 2, respectively) are systematically higher for market 1, while a KS test rejects the null that the two distortion distributions were generated by a common probability density function at the 1% significance level. Both the average market inefficiency, as well as the probability to experience larger spells of excess volatility, are positively correlated to the instability of fundamentals.

Table 2. Key statistics for returns in the two markets, as traders operate under autarky and openness, respectively. Figures in chevrons are averages over 5000 Montecarlo repetitions.

		<i>Market 1</i>	<i>Market 2</i>
Autarky	$\langle V \rangle$	0.0176	0.0177
	$\langle K \rangle$	6.6768	6.6898
	$\langle D \rangle$	0.1396	0.1256
	σ^D	0.0279	0.0272
	Sk^D	1.1261	0.9930
Openness	$\langle V \rangle$	0.0132	0.0130
	$\langle K \rangle$	8.4448	8.5553
	$\langle D \rangle$	0.1390	0.1143
	σ^D	0.0223	0.0216
	Sk^D	0.9628	0.9926

It turns out that limiting the comparison between fundamentally heterogeneous markets to the phenomenological properties of market prices – typically, the price volatility and the leptokurtosis of returns – might misleadingly return the impression that structural differences in the frequency of news arrival and the speed with which

these are incorporated into the present value of subsequent dividends do not matter in driving market performances (Westerhoff, 2010). Indeed, the underlying dynamics of fundamentals, which is strictly related to the effectiveness with which traders collect and process pieces of information to form a consensus on the right valuation of stocks, impinges on their ability to keep the market price at its fair value. Markets characterized by a structurally higher volatility of fundamentals are therefore structurally more inefficient, given that in this case the excess volatility caused by the destabilizing speculative activity put forth by chartist traders is magnified. Since the rationale for a non-distortive FTT is that of restraining market inefficiency, policymakers interested in setting tax rates according to an optimal taxation principle should seriously take this issue into account.

What happens if the markets are open? In order to answer this question, we allow the traders to move freely across the two fundamentally heterogeneous markets. Montecarlo simulations show that in this case the average volatility of prices decreases in both jurisdictions if compared to the autarky experiment – a finding in line with the empirical evidence in Bekaert and Harvey (1997) – while the average kurtosis of returns increases steadily (bottom part of Table 2). The openness of markets is thus associated to a generalized stronger incidence of extreme returns. This comes with a better performance in discovering the right price in market 2. However, the average of the distortion index in the fundamentally more volatile market 1 remains basically unaffected. Although the skewness turns out to be equalized across the two distortion distributions, movements towards a closer integration of financial markets and broader opportunities of diversification imply an enlargement in the asymmetry of cross-market efficient price discovery.

To our knowledge, this finding has so far been largely neglected. A huge literature has rightly pointed out that a move towards a greater integration of financial markets implies that assets with identical risk should command the same expected return regardless of location as frictions to capital movements are gradually removed. We argue that this insight should be complemented with a focus on the impact of integration on excess volatility, which represents a signature of the market inefficiency originating from mispricing. Our result suggests that unless the integration process involves a higher synchronization in the evolution of fundamentals, the gain in efficiency stemming from the opening of domestic asset markets to foreign investors is larger for jurisdictions in which the incorporation of news on fundamentals is smoother and the macroeconomic environment is more stable, that is for more *fundamentally* stable markets.

Moving from these results, the next Section is devoted to explore whether the circumstance that financial markets might be characterized by heterogeneous processes as regards their fundamental dynamics bears some consequences when the issue of regulating them through the imposition of taxes is taken into account.

4. Taxation

The open market framework analyzed at the end of Section 3 is now employed to assess the effectiveness of levying FTTs. We do this in several steps. First, we evaluate the

effects of taxing one market at a time. In addition to exploring what happens to the price dynamics in the taxed market and the spillover effects on the untaxed one, we focus on the trading volume and market price efficiency. We will argue that the social welfare impact of a tax on financial transactions should be correctly measured along these two margins, instead of being exclusively associated to a reduction in volatility. Second, we consider the case of a coordinated application of FTTs on both markets. Finally, we look for optimal tax rates, where optimality is expressed in terms of the minimum amount of excess volatility associated to the trading patterns of the market participants over and above the incorporation of fundamental news.

For ease of comparison, we consider a representative simulation run and fix the seed of random variables as the tax rates are varied. The benchmark situation without taxation is represented in Figure 4. All the stylized facts regarding price dynamics recalled above are confirmed. A simple visual inspection of the time series for the two actual prices and their returns, as well as the sample autocorrelation functions for returns and absolute returns, does not suggest the presence of any significant difference, although the fundamentals behave quite dissimilarly. In both cases, market outcomes are characterized by a boom-and-bust dynamics, cluster volatility, uncorrelated returns and absolute returns that display a significant positive auto-correlation for many lags.

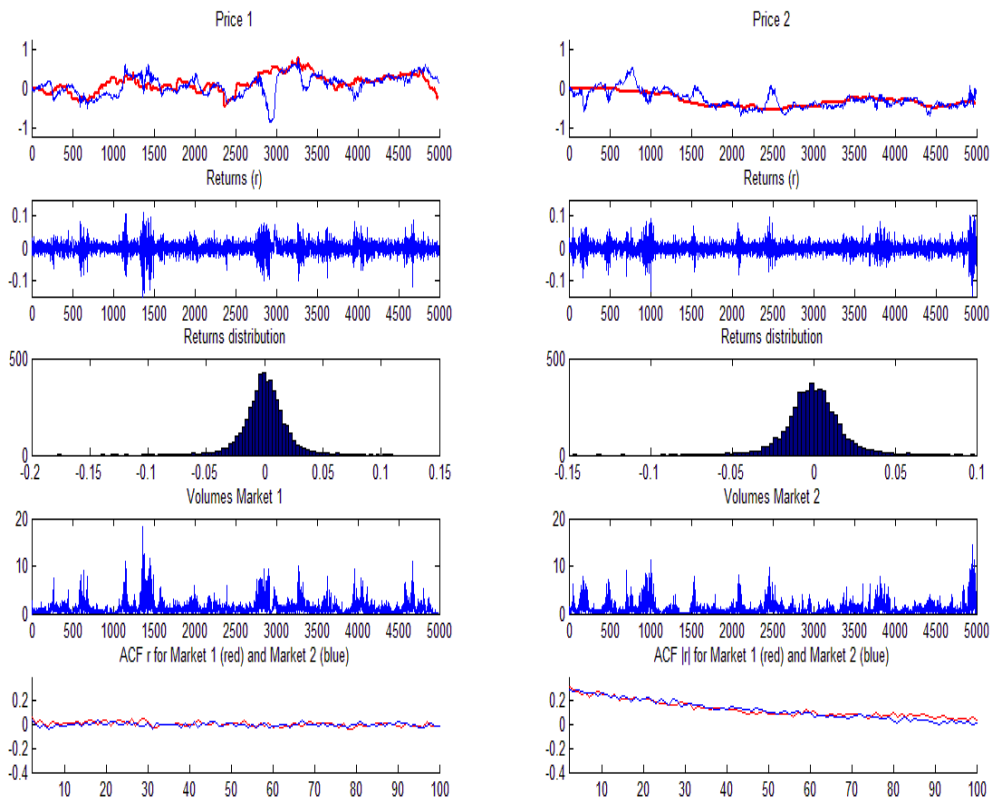


Figure 4. Numerical simulation of the open-market model with parameters as in Table 1 and no taxation.

The first column of Table 3 reports the time averages of daily trading volumes and the price distortion in the two interconnected markets over the simulated time series, while the cross-market sum of both indicators allows us to obtain a picture of the

performance at a systemic level. From here it appears clearly that traders are in fact operating in two heterogeneous markets. Pricing inefficiency is stronger in the most fundamentally volatile jurisdiction – where distortion exceeds that of market 2 by 27% – and this feature is echoed by transaction volumes, which are on average 32% higher.

Table 3. Trading volume and distortion for different choices of the tax rate.

	$\tau^1 = \tau^2 = 0$	$\tau^1 = 0.25\%; \tau^2 = 0$	$\tau^1 = 0; \tau^2 = 0.25\%$	$\tau^1 = \tau^2 = 0.25\%$
Volume Mkt 1	1.2742	0.2552	1.6595	0.4147
Volume Mkt 2	0.9617	1.4097	0.2277	0.4110
Volume Tot	2.2359	1.6650	1.8871	0.8257
D^1	0.1474	0.0734	0.1569	0.0597
D^2	0.1158	0.1259	0.0847	0.0563
D Tot	0.2632	0.1993	0.2416	0.1160

Both attributes lay at the root of the economic rationale of FTTs as a form of Pigouvian taxation aimed at discouraging activities which are deemed to have negative side effects (Stiglitz, 1989). The excess volatility stemming from the interplay between traders believing that the market price should be correctly anchored to its fundamental value and traders speculating on trends implies that the latter exert a negative externality on the former by breeding positive feedbacks. This in turn creates a wedge between private and social returns. From this point of view, therefore, the price distortion index (7) may be conceived as the proper social welfare criterion policymakers should employ in determining the optimal level of taxation, instead of aiming to reduce actual price volatility. Indeed, while the correct magnitude of volatility is a target very difficult to identify – given that it should be related to the unobservable risk tolerance of the traders – a better alignment between the market price and its fundamental value is socially valuable for two reasons that do not require the elicitation of individuals' preferences. First, more informative securities' prices provide a better alignment of the incentives of shareholders and managers, thus contributing to solve the typical problem of corporate governance for corporations. Second, when the market price reflects its fundamental the management of the firm can correctly assess its cost of capital, and use this piece of information as a guidance for planning the appropriate level of investment. The simple fact that both informational outputs of an efficient capital market are likely to be small in practice (Breshnan *et al.*, 1992) is irrelevant for the point in case. The maximization of the social welfare is achieved not by minimizing absolute volatility, but the volatility in excess of that implied by the dynamic evolution of the security's fundamental value.

Although the price distortion criterion has the additional advantage of being neutral with respect to the potential use of revenues, any consideration about optimality has also to take into account how the level of the tax rate impacts on the tax base, that is on the trading volume. Simply stated, levying an optimal tax that forces a market to remain steadily at its fundamental value by annihilating exchanges is basically useless. Notice that the rationale for this statement is different from the one usually put forth by the detractors of FTTs, who argue that the major adverse consequence of the tax is represented by the decrease of market liquidity associated to lower volumes. In fact, in our framework the two issues are detached, due to the presence of a market-maker who

provides infinite liquidity irrespective of the fraction of traders actively engaged in market activity (see eq. (1)). Deprived of the liquidity issue, the volume of trading can be seen as a way of quantifying other key economic functions served by a capital market, namely those of expanding the choice set of agents through exchanges, and to assist in the development of diverse methods of financing valuable projects by helping firms to raise equity capital (Schwartz *et al.*, 2015). The decision of a policymaker to levy a tax on financial transactions therefore implies to strike a balance between two different instances of efficiency, i.e. the one associated to efficient price discovery and the one related to the additional functions of resource allocation served by financial markets.

Armed with these insights, the second and third columns of Table 3 provide an illustration of what happens when one market at a time is taxed (market 1 and market 2, respectively), while the other jurisdiction remains unaffected. As a reference, we assume that the public authority sets the tax rate at 25 basis points. As expected, it appears that the unilateral imposition of a FTT determines a substantial decrease of the trading volume in the taxed market. This comes with a significant enhancement of its price efficiency measured by the excess volatility over and above the dynamics of the fundamental. At the same time, however, the untaxed market is negatively affected, since its distortion increases. Measured in terms of the welfare criterion (7), the final result of a unilateral imposition is positive for the system as a whole, as the total distortion is in both cases lower if compared to the absence of taxation. It is also evident that the spillovers impinged upon the untaxed market by the migration of speculative activity from the taxed one are less damaging when the tax is levied on the more fundamentally volatile jurisdiction, if considered once again from a systemic perspective. In this case, the total amount of distortion decreases by 24% in comparison to the benchmark unregulated situation, while the gain of systemic efficiency when the opposite case applies is limited to 8%.

The trade-off in terms of spillovers between informational efficiency and the interference of FTTs on the other economic functions served by the stock market becomes apparent as we complete the picture by performing a comparison of trading volumes across the two experiments. Absent any consideration on liquidity, the externality exerted across borders through unilateral taxation is in this case positive, as soon as we concede that a higher volume of trading activity can be thought as a proxy of the ability of the stock market to offer a larger amount of real services. Notice that in the aggregate the burden in terms of wasted trading volumes is lower when the tax is levied on the jurisdiction with a less volatile fundamental.

The sign of the externalities generated by the unilateral imposition of a FTT we have just described are totally in line with the evidence reported in comparable computational studies (Westerhoff and Dieci, 2006; Mannaro *et al.*, 2008). If traders are allowed to move freely across structurally heterogeneity markets, however, which market is effectively taxed matters. The systemic informational efficiency is higher when the tax is levied on the more fundamentally volatile market. In turn, the loss in terms of volumes is lower when the opposite holds true. This opens the question of whether a multilateral agreement is not only feasible, but also desirable.

The fourth column of Table 3 then illustrates the case of a coordinated action, by assuming that both markets are taxed with a common tax rate of 25 basis points.

Coordination turns out to be beneficial for price discovery, as the aggregate distortion is the lowest of the four scenarios we are considering. Interestingly enough, the final outcome in terms of informational efficiency in both jurisdictions is now enhanced if compared to what would happen if a market were taxed unilaterally. In strategic terms, as soon as the two public authorities are interested in maximizing pricing efficiency, coordination represents for both of them a strictly dominating strategy. The result changes if the main objective is that of minimizing the loss of trading volume, however. In this case, the only equilibrium admitted by the game is the no-tax solution.

We argue that a proper ordering of the two possible welfare targets could make a coordination agreement incentive-compatible. If we assume that policymakers are primarily concerned with the avoidance of excess volatility, and only in subordination to this they aim to limit volume losses, the coordination equilibrium is not only self-enforcing in the first place, but it also allows to increase the domestic trading volume with respect to the case in which the FTT is levied irrespective of what decision is taken in the other jurisdiction. The general lesson one can take from this is that a careful craft of the institutional setting based on two pillars is fundamental in securing a coordinated approach in levying FTTs is desirable and feasible. First, the FTT should be applied only in markets whose microstructure is such that a proper amount of liquidity is guaranteed, for example through the presence of a market-maker. Second, the agreement is self-enforcing if the policy targets are articulated correctly. The primary welfare criterion should be that of enhancing the ability of financial markets to stay in line with fundamental values, that is to avoid excess volatility. Any other goal, such that of limiting the loss of trading volume, should be considered as a derivative.

The last issue to analyze is whether the coordination agreement entails an optimal choice of asymmetric tax bases, given that the two markets are characterized by fundamental heterogeneity. Optimality is here referred to systemic efficiency.

Table 4. Aggregate distortion for tax rates ranging from 0 to 50 basis points.

$\tau_2 \backslash \tau_1$	0%	0.05%	0.10%	0.15%	0.20%	0.25%	0.30%	0.35%	0.40%	0.45%	0.50%
0%	0.2632	0.2455	0.238	0.2364	0.2381	0.2416	0.246	0.2505	0.2548	0.259	0.2633
0.05%	0.2301	0.2097	0.2025	0.2007	0.202	0.2055	0.21	0.215	0.2201	0.2251	0.2294
0.10%	0.2062	0.1808	0.171	0.1675	0.1671	0.1687	0.1716	0.1754	0.1795	0.1841	0.1888
0.15%	0.1909	0.1522	0.1398	0.1348	0.135	0.1392	0.1431	0.1468	0.1507	0.1547	0.159
0.20%	0.1878	0.1464	0.1317	0.1244	0.1209	0.12	0.1206	0.1222	0.1244	0.1271	0.1301
0.25%	0.1993	0.1467	0.1304	0.122	0.1177	0.116	0.116	0.117	0.1187	0.1208	0.1234
0.30%	0.2023	0.149	0.1315	0.1224	0.1175	0.1153	0.1149	0.1156	0.1169	0.1188	0.121
0.35%	0.2061	0.1523	0.1337	0.124	0.1187	0.1161	0.1154	0.1158	0.1169	0.1185	0.1205
0.40%	0.2106	0.1562	0.1364	0.1262	0.1206	0.1177	0.1167	0.1169	0.1178	0.1192	0.121
0.45%	0.2161	0.1608	0.1395	0.1288	0.1228	0.1197	0.1185	0.1185	0.1192	0.1205	0.1222
0.50%	0.2229	0.1663	0.1432	0.1318	0.1255	0.1221	0.1207	0.1205	0.1211	0.1222	0.1237

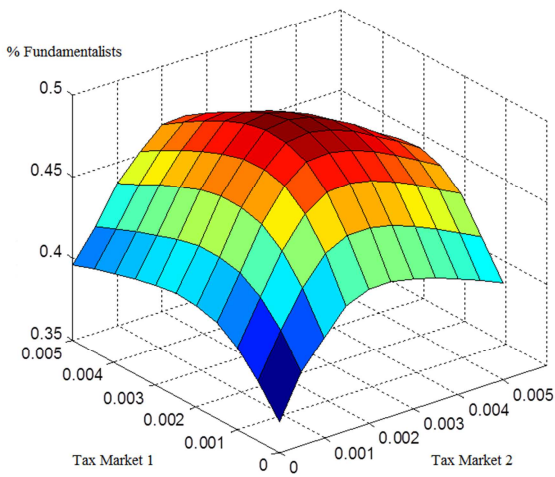
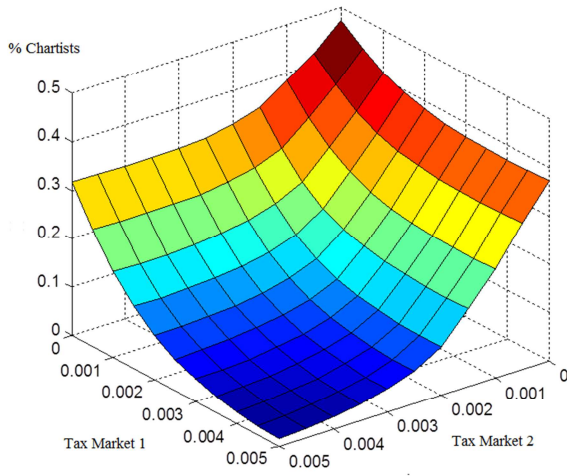
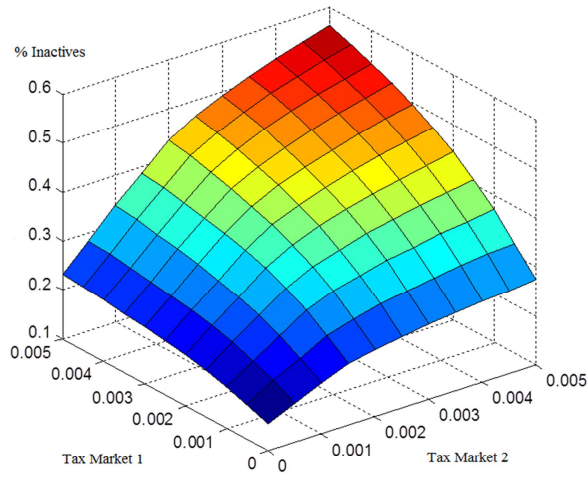


Figure 5. Fractions of inactives, chartists and fundamentalists operating in both markets for different level of taxation. In the middle panel the two horizontal axes are inverted .

Table 4 reports the level of aggregate distortion as the tax rate in both jurisdictions is increased from 0 to 50 basis points. The surface we obtain is convex. Interestingly enough, the minimum level of distortion is reached for a symmetric solution corresponding to a tax rate of 30 basis points. This finding is in line with the insight advanced from the beginning by Tobin (1972; 1978), according to whom any feasible international arrangement aimed at imposing an effective FTT should envisage the use of a uniform tax rate. While the emphasis has been originally put on the desire to minimize the negative externalities associated to observed market volatilities, however, we argue that a uniform FTT represents an optimal solution even when the global coordination is correctly aimed at eliminating the volatility in excess, that is a measure of market inefficiency. This turns out to be true irrespective of the stage of development reached by the financial markets involved in the agreement.

The intuition for this result can be grasped by looking at the three panels of Figure 5, where we plot the average fractions of traders adopting alternative trading strategies on the two markets in correspondence of the different tax rates. To allow for an easier interpretation, the two horizontal axes of the chart in the middle panel are inverted. As the tax rate is increased the chartists exit the market in a monotonic fashion, signaling that the FTT curbs speculative activity by forcing trend-chaser agents to abstain from trading. The surface representing the average fraction of fundamentalists is concave, however. Thus, the global maximum level of efficiency in terms of minimized excess volatility is reached for an internationally-agreed uniform tax rate which maximizes the presence of fundamental activity.

5. Conclusions

FTTs are Pigouvian taxes. This implies that the use of such a policy option must be firmly grounded on an exact definition of the kind of externality it aims to offset. In this paper we start from recognizing that the existence of speculative activity in financial markets is not an evil in itself, arguing instead that the main reason to limit its presence is that of helping traders to trade at the securities' fundamental value. In other terms, the proper target for levying FTTs is the volatility in excess of the discounted stream of subsequent dividends, and not the observed one. Indeed, the price volatility measured in diverse markets might be similar even if the degree of market inefficiency varies substantially. The latter is in fact associated to the process driving the evolution of fundamental values, which is in turn related to the speed with which news are incorporated into estimates of fair prices, the risk-return profile typical of a given stage of development and macroeconomic volatility. Since all these factors vary substantially across countries, it seems interesting to ask whether this kind of cross-market heterogeneity plays any role in easing or hindering international agreements for a coordinated action.

In this paper we have extended a class of agent-based pricing models in which traders swing between different strategies as they trade in diverse markets sharing a common fundamental price, to a setting in which fundamentals vary according to jumping random processes characterized by different jump frequencies and volatilities. Our analysis has allowed us to draw two main conclusions. First, a global coordination

to tax financial markets is feasible, given that a multilateral imposition of a FTT is incentive-compatible as soon as the policy target is correctly set as the minimization of both domestic and systemic price distortions. Second, the optimal tax rate is uniform across jurisdictions even if markets are characterized by fundamental heterogeneity.

Given these results, future research should be devoted to validate the class of agent-based models discussed in this paper with real data, in order to provide punctual policy advising as regards the effective tax rate to be agreed upon by the governments involved in setting an international agreement to tax financial markets. From this point of view, several approaches can be fruitfully employed. In addition to the method of simulated moments proposed by Franke and Westerhoff (2016), a particularly promising approach is the gradient-based method suggested by Recchioni *et al.* (2015).

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