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Securities Transaction Taxes: Macroeconomic Implications in a General-Equilibrium Model*

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Abstract

This paper studies the impact of a securities transaction tax (STT) on financial trading, stock prices and real economic variables in a closed-economy dynamic stochastic general-equilibrium model featuring financial frictions. The model incorporates channels by which 'noise trading' affects real economic volatility. Firms' investment expenditure is related to the value of their outstanding shares. The model is calibrated to stylised facts of financial trading and firms' financing. The simulations suggest distortive effects of the STT on real variables similar to those of corporate income taxation. At the same time, the STT reduces economic volatility, but this stabilisation gain is quantitatively modest.

JEL classification: E22, E44, E62

Keywords: capital costs, financial markets, noise trading, securities transaction tax

1 Introduction

The banking and financial crisis of recent years has been followed by calls (yet, less action) to reform the financial regulation in order to prevent the replay of events and improve the resilience of the financial sector. Given the massive costs that bank rescues have inflicted on taxpayers, the demand to make the financial sector contribute to the financing of crisis-intervention costs has also gained political voice and support (IMF, 2010). The political debate suggests financial sector taxation as a toolbox to mitigate structural problems and recover (some of) the budgetary costs of the bank rescue. In contrast to the

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public discussion, however, there is little public finance literature on financial sector taxation, its regulatory merits and drawbacks, and its potential to generate government revenue. Furthermore, the existing empirical work looks fairly inconclusive. Consequently, the governments that have taken action have been largely unguided by academic research (Keen, 2011).

Against this background, we aim at contributing to this literature and provide an analysis of the securities transaction tax (STT) in a dynamic stochastic general-equilibrium (DSGE) model. The main questions our model specification addresses are: (1) What is the STT's long-term impact on financing costs, investment and economic activity? (2) Does the STT succeed in reducing (non-fundamental) volatility of asset prices and real economic variables?

The model we use to address these questions is an RBC model featuring two types of financial frictions. First, we incorporate short-term financial trade and allow for the presence of not fully rational traders, so-called 'noise traders' whose trading behaviour is a source of economic fluctuations in the model. Second, we introduce a financing constraint which links firms' investment spending to their outstanding share value. The structure of the model allows imposing a tax on securities transactions (STT). We calibrate our model to match some stylised facts about financial markets and firms' financing.

While the adverse impact on the financing costs for companies' real investment is generally seen as the major potential drawback of an STT, the reduction of non-fundamental volatility is usually regarded to be its principal regulatory merit. The model-based analysis in this paper makes an attempt to quantify both effects and their macroeconomic implications. The exercise also discusses the parameters that shape their relative importance.

The contribution and novelty of discussing the STT in a DSGE framework is the emphasis on the STT's macroeconomic impact and the exposition of relevant transmission channels. The approach contrasts with partial equilibrium approaches (e.g. Kupiec, 1996; Song and Zhang, 2005) that exclude feedback effects accross different markets and over time and conjecture the imapct of STTs on the real economy off-model.

The main results are that a transaction tax generating tax revenue of 0.1% of GDP would (1) increases capital costs by 4-5 basis points, implying a long-term 0.4% decline in the capital stock and a 0.2% decline in real GDP, and (2) reduce the volatility of physical investment and output by 4% and 1% respectively.

Section 2 of the paper reviews STT debate, listing the main arguments for and against STTs to place our analysis in context. Section 3 develops a DSGE model with noise trading and STT as the paper's analytical framework. Section 4 presents the parameterisation of the model. Section 5 presents the scenarios and simulation results and compares them to related findings in the literature. Section 6 summarises and concludes.

2 The STT debate

The paper contributes to the still inconclusive debate on the merits and drawbacks of STTs. Matheson (2011) and Schulmeister et al. (2008) give a comprehensive survey of the debate; Hemmelgarn and Nicodeme (2010) and Schwert and Seguin (1993) provide a concise list of pros and cons. This section provides a brief review of the key arguments to locate the contribution of our analysis.

2.1 Asset price volatility

Advocates of the STT have traditionally focused on the instrument's ability to curb short-term speculative trading in financial markets by raising the cost of financial transactions. The idea is that speculative trading rests on non-fundamental information ("noise"). Curbing short-term trade could in this view reduce asset mispricing and market volatility by reducing noise trading as well as the related waste of resources (from the society's perspective) in the financial sector (e.g., Stiglitz, 1989; Summers and Summers, 1989).

The volatility-reduction argument rests on the assumption that an STT corrects inefficiencies instead of adding an additional distortion, or, at least, that the corrective effect dominates distorting ones. Market volatility decreases if the tax succeeds in curbing non-fundamental trades. But critics argue that the trade-reducing impact of STTs could backfire. The tax may eventually increase asset price volatility in the market, because the trade volume reduction increases the impact of individual transactions on asset prices and price volatility (e.g., Habermeier and Kirilenko, 2003). In general, individual transactions cause larger price fluctuation in thinner markets.

Additionally, STTs cannot discriminate between fundamental-based and non-fundamental trades and may therefore weaken financial market adjustment and resilience. Restricting short-term trades by increasing the trading costs may result in a build-up of larger imbalances and increasing costs of risk hedging. Since all transactions are taxed at equal rates and independent of their risk profile, the STT may not reduce risk-taking and fragility in the financial sector (Keen, 2011). The tax should target trading risk rather than the trading frequency in order to make a contribution to financial market stability.

Moreover, there are many practical problems with introducing a general STT in the open economy. New financial instruments may be designed to avoid taxation and would further increase the opacity of the financial sector. Internationally integrated markets add the dimension of tax avoidance by cross-border transactions. To cope with the practical problems, the tax would have to be imposed on the broadest possible base and internationally coordinated. What consitutes the "broadest possible base" is likely to change with STT introduction, requiring dynamic adjustment. The success of an encompassing implementation is far from certain.

Limiting the STT to spot transactions that are easier to track, such as standard account transactions, or stock and bond purchases and sales, instead of including derivative trading is likely to limit the problem of tax avoidance, but skews the tax burden towards households and firms that have little to do with high-frequency trading and the associated volatility of asset prices.

STTs are already more than a hypothetical tool. Variants of STTs have been implemented in several countries (see IMF, 2010; Matheson, 2011; Schulmeister et al., 2008; Summers and Summers, 1989), and attempts have been made to quantify their impact on market volatility. While the empirical evidence is scarce, see Matheson (2011) and Schulmeister et al. (2008) for comprehensive surveys, it provides no robust support for a market-stabilising effect of the STT. Hau (2006), e.g., finds that increasing transaction costs has increased the stock price volatility in the French stock market. More precisely, he finds that 20% higher transaction costs have led to 30% increase in the hourly volatility of individual stock prices. Hau concludes that higher transactions costs and STTs in particular should be regarded as volatility increasing. For the United States, Jones and Seguin (1997) report a positive effect of transaction cost reduction on trade volumes for NYSE listed shares, which has reduced the volatility of share prices. Baltagi et al. (2006) study the Chinese case and find that the stamp tax has reduced trade volumes and increased market volatility. According to their results, an increase in the tax rate from 0.3 to 0.5% has increased transaction costs by one third and reduced trading volumes by one third. The results in Baltagi et al. (2006) also suggest negative effects of the STT on stock market efficiency, as markets take more time to absorb external shocks. Hence, the short-term trading that the STT is meant to eliminate is not empirically proven to be detrimental to price recovery.

Partial-equilibrium models of financial markets with heterogenous agents and complex market structure obtain mixed results. While Westerhoff and Dieci (2006) find an STT imposition on all transactions to reduce price volatility accross markets, Mannaro et al. (2008) conclude that the STT increases asset price volatility by reducing trading values. Demay (2006) finds that the STT favours long-term investment over short-term speculation, but also punishes fundamental-based trading rules compared to trend extrapolation in exchange rate markets. Demay (2010) concludes that STTs increase asset mispricing beyond certain thresholds by reducing short-term trading in reaction to fundamantal changes. Pellizzari and Westerhoff (2009) stress the sensitivity of results with respect to the micro structure of financial markets. They contrast situations in which the STT increases price volatility by lower trading volumes with cases in which an STT effectively crowds out speculative trades. The experimental study by Hanke et al. (2010) finds the effects of a Tobin tax on exchange rates to depend on the existence of tax havens and on market size. The STT reduces short-term speculation, but market efficiency in taxed markets decreases when tax havens exist. A complementary paper by Kirchler et al. (2011) concludes that an encompasing Tobin tax in exchange rate markets has no impact on exchange rate volatility. Xu (2010) finds the effect of a Tobin tax on the exchange rate volatility introduced by noise traders to depend on the market structure (exogenous versus endogenous entry) and the interaction between the tax and other trading costs.

Finally, the banking and financial crisis of 2008 does not provide strong arguments for favouring a STT to tax the financial sector. Although the STT may reduced short-term trading and asset price volatility, a clear connection between short-term trading and long-run cycles of asset mispricing (bubbles) has not yet been established. Instead, the instruments that caused the distress and failure of financial institutions in the 2008 crisis did not belong to the set of frequently traded assets. The STT does not address leverage, maturity mismatch, currency mismatch and the underestimation of investment risk (e.g., Hemmelgarn and Nicodeme, 2011; Matheson, 2011).

2.2 Capital costs

The strongest objection against the STT is that it may harm rather than help real economic activity by reducing equity prices and increasing the capital costs for real investors. In an economy producing with decreasing marginal returns to physical capital, higher capital costs reduce the long-term capital stock, labour productivity and real output. The strength of the capital-cost effect would depend on the tax rate and the investment horizon of savers. A low tax rate and long-term focus should limit the impact on fundamental investment.[1]

The STT may affect capital costs and investment even if applied exclusively to the secondary market. Lower liquidity in the secondary market may increase the interest premium that investors charge to insure against the cost of premature disinvestment linked to a materialisation of investment risks or to an unforeseen tightening of the individual budget constraint. Similarly, financial constraints on real investment tighten if the STT reduces equity prices and the value of firms.

Broad-based STT application to all financial transactions could also affect the market structure in the real economy. IMF (2010) and Shackelford et al. (2010) argue that a broad STT imposition on business-to-business transactions supports economic concentration on goods and factor markets. Taxing business-to-business transactions instead of final values implies a cascading tax burden on the production by non-integrated firms, which provides incentives for the vertical integration of production lines.

The existing empirical evidence supports the view that a STT imposition reduces equity prices. Analysing the impact of the UK stamp duty, Bond et al. (2004) establish a positive impact of (announced) tax cuts on the relative price of more frequently traded shares. The empirical research does not address the effect on financing costs. Theoretically, lower stock values are likely to raise the firms' capital costs for equity and debt finance: The negative STT impact on stock prices reduces the capital raised by equity issuance at given trading frequencies. A falling firm value also reduces debt finance by tightening financial constraints and/or increasing the risk premium that lenders ask to compensate for the fall in the collateral value.

[1] From a general-equilibrium perspective, STT introduction may additionally allow reducing other taxes on capital and complementary factors that increase the costs of capital (e.g., Summers and Summers, 1989).

2.3 Tax revenue

Besides the idea that the tax could substantially dampen excessive trading, the second principal argument in favour of the STT is its potential to generate substantial tax revenue, which would help governments to cope with the budgetary costs and repercussions of the financial and economic crisis. To ensure substantial revenue and limit tax avoidance, the revenue-oriented imposition of STTs should favour broad tax bases, so that substantial revenue can be collected at low rates. As illustrated in the previous section for the example of cascading effects on non-integrated firms, broadening the tax base does not necessarily reduce the implied economic distortions. Granting exceptions, on the other hand, would give rise to strategies of tax avoidance (e.g., IMF, 2010).

More fundamentally, the STT illustrates once more the trade-off between the corrective effects of taxations and the collectable tax revenue, a trade-off that derives from the endogeneity of the tax base. To the extent the tax succeeds in dampening excessive trading the base, the collected STT revenue declines. At the end, the tax may be levied predominantly on fundamental-driven transactions. The tax revenue is highest, on the other hand, if the tax has little dampening impact on speculative trading.[2]

An additional concern relates to the STT's overall impact on the governemnt budget balance and government debt. How should government bonds and related derivatives be treated? Existing proposals exempt government debt from the STT to avoid an increase in financing costs for the government, which could decrease or even offset the positive impact of additional tax revenues. The exclusion of public debt would give an advantage to the government and distort financial investment towards the public sector. Depending on the size of the premium one may wonder whether cheaper debt could invite overborrowing and fiscal profligacy. Exempting public debt derivatives like default insurance from the STT would, on the other hand, exclude a category of assets that some observers think has aggravated the euro area's problems ("speculation against governments").

The subsequent sections of the paper relate to all three aspects, without addressing the entire set of problems, objections and caveats. The modelling and the simulations focus on: (1) the STT's impact on capital costs and real economic activity; and (2) the STT's impact on non-fundamental ("speculative") trading and associated asset price volatility. Focusing on the taxation of corporate equity transactions, the model excludes financial derivatives. Furthermore, we do not address technical problems (e.g., transparency of transactions, tax collection) and questions of tax avoidance or evasion in internationally integrated financial markets.

[2] Summers and Summers (1989) argue in this line that an STT with little impact on financial markets would raise tax revenue and fiscal space and allow reducing more distortionary taxes. In this scenario the STT would be a more efficient revenue source than alternative taxes. If a substantial part of the tax incidence fell on asset holders (instead of real wages), the STT would also be highly progressive.

3 Model description

To study the impact of STTs on the economy, the paper incorporates financial frictions in an otherwise standard closed-economy RBC model. Financial frictions are introduced along two dimensions:

Firstly, we introduce a sector of financial traders engaged in short-term trading of securities. Financial traders borrow from households, invest in stocks, receive returns on the investment, pay back the outstanding loans and consume the rest. A fraction of the traders are "noise traders" in the sense of De Long et al. (1990) and Shleifer and Summers (1990). Noise traders have noisy expectations about stock returns that may deviate from rational expectations based on economic fundamentals. Non-fundamental "noise shocks" that capture changes in the noise traders' beliefs increase the volatility of asset prices and trading.

Secondly, firms' borrowing for investment in physical capital is restricted by what we call a financial constraint. In particular, we assume that a firm's investment in physical capital cannot exceed a given fraction of the firm's stock value. Such a constraint would, e.g., occur if banks treat the stock value as indicator for a firm's economic conditions, so that the amount of loans they are willing to provide for real investment depends on the stock market valuation of the firm. If new investment by the firm is (partly) credit-financed, the investment will be limited by the valuation of firm's stocks. Another link might be the information value of stock prices for decisions by the firm's management. In our paper we do not model the bank sector explicitly. The financing constraint is a shortcut to capture the link between the stock value and the financing of firms. This link link between firm value and investment has been established empirically (see, e.g., Baker et al., 2003; Barro, 1990; Bond et al., 2011; Chen et al., 2007; Fazzari et al., 1988; Morck et al., 1990).

The model assumes that households have a long-term investment horizon and own a fixed share of total equity. The equity owned by households is not publicly traded and accounts for a larger part of total equity. This is meant to reflect the European model of corporate finance, where a relatively limited part of investment is funded by the public issuance of stocks. Noise and fundamental traders, in contrast, have short (2-period) planning horizons, which emphasises the short-term return orientation of their transactions. The traders borrow in the credit market from non-trader households at risk-free rates and invest in publicly-traded stocks. In the following period, they earn the returns on their risky investment and pay back their debt including the (risk-free) interest.

Short-term trading generates transaction costs by using limited resources such as time and effort. Imposing "wasted" transaction costs captures aggregate inefficiencies or the ressource use of short-term trading. The model introduces a tax (STT) on the short-term transactions to analyze its potentially corrective role.

The model determines the stock value of firms as the expected discounted flow of future dividends. The value increases with positive noise shock and declines in response to transaction costs and the STT. Falling stock prices increase the costs and/or reduce the ability for firms to raise capital through equity issuance, debt issuance or bank credit. The before-tax return on investment that financial investors require increases. With falling marginal returns to capital, the introduction of an STT translates into equilibria with lower capital stock and lower labour productivity.

Contrary to previous analyses, this paper integrates noise trading and the STT in a general-equilibrium model that links financial and real sector variables. Previous theoretical models to analyse financial sector taxation have adopted a partial equilibrium view of financial markets (e.g., Kupiec, 1996; Song and Zhang, 2005) and conjectured the impact on the real economy outside the model. Focusing on general equilibrium effects and the interaction between financial and real sectors, the structure of financial markets and trading is kept simple in our model. We distinguish two types of traders, but assume an atomistic market structure. Although the consequences of one group's behaviour affect the other type of traders, the atomistic market structure excludes strategic interaction. Consequently, our focus is different from heterogeneous-agent, partial-equilibrium models of the financial market (e.g., Demary, 2006; Demary, 2010; Mannaro et al., 2008; Hanke et al., 2010; Kirchler et al., 2011; Pellizzari and Westerhoff, 2009; Westerhoff and Dieci, 2005) in which the impact of STT imposition on asset prices and transaction volatilities is found to depend on the market structure.

As further simplification, we use a closed-economy framework and assume the STT to be effectively implementable and enforceable. The analysis abstracts from the challenge of tax evasion in internationally integrated financial markets. Alternatively, the setup can be interpreted as representing the world economy under globally unified transaction taxation.

The model focuses on corporate equity and excludes other classes of risky assets. In particular, the model excludes derivatives, which are not easily incorporated in a general-equilibrium framework, despite the fact that derivatives account for a large share of transactions in real-world financial markets today.

To align sequences of financial and real investment decisions, and despite the quantitative importance of high-frequency asset trading, we impose homogenous time intervals for financial trading and decisions on real economic variables. In line with standard practice in business-cycle models, the time interval corresponds to quarters of years. The following subsections describe the details of the model structure.

3.1 Households

The household sector consists of two types of households. A fraction s_l are the standard infinitely-lived households. These households consume, work and own a fixed fraction of firms' equity on which they earn dividends. The variables relating to the infinitely-lived households are indexed by the superscript l. The remaining fraction $1 - s_l$ are short-horizon financial traders. These traders borrow from the infinitely-lived households at the risk-free interest rate and invest the funds they have borrowed into stocks. Traders borrow and invest in period t. In the subsequent period $t + 1$, they receive dividends on their asset holdings and sell the assets. The traders use the proceeds from dividends and the selling of assets to settle their debt with the infinitely-lived households and then consume the remaining income. The variables relating to the traders are indexed by the superscript T. All variables in the model are defined in per capita terms.

The group of traders consists of two different sub-groups. The fraction s_n of trader households are so-called 'noise traders', indexed by the superscript N. Noise traders have noisy expectations about the future share return in the sense that their expectations may deviate from rational expectations by a noise shock. The share $1 - s_n$ of traders forms rational expectations about the stock return given the model structure and the occurence of shocks. These traders are labelled as informed traders by the superscipt I.

3.1.1 Infinitely-lived households

The infinitely-lived households l maximise welfare:

$$\max_{C_t^l, L_t, B_t^l} E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^l - \frac{\omega}{1+\kappa} L_t^{1+\kappa} \right) \tag{1}$$

subject to the budget constraint:

$$C_t^l + B_t^l + P_t^{shll} a_t^l = \left(1 - \tau^l\right) W_t L_t + R_{t-1} B_{t-1}^l + \left(P_t^{shll} + DIV_t\right) a_{t-1}^l - T_t^{ls} \tag{2}$$

where C_t^l is consumption, B_t^l are holdings of risk-free assets and a_t^l holdings of corporate equity. The equity held by the infinitely-lived households is not publicly-traded and constitutes a fixed proportion θ of total equity (traded and non-traded) in the economy. The value of assets that are never traded, a_t^l, is unaffected by the STT. They may be considered to proxy not only for private equity but also for investement financed by credit, which is also not subject to the STT. The value of a unit of the non-traded assets is P_t^{shll}. They bring dividend DIV_t per asset unit that is paid in period t. R_{t-1} is the gross interest rate on the risk-free asset fixed in $t-1$ and paid in t, L_t is per-capita hours worked, W_t is the nominal wage, τ^l is the labour income tax rate, and T_t^{ls} are lump-sum taxes.

The infinitely-lived households' first order condition (FOC) for optimal consumption, labour supply and financial investment are:

$$\omega L_t^{\kappa} C_t^l = \left(1 - \tau^l\right) W_t \tag{3}$$

$$\lambda_t^l = 1/C_t^l \tag{4}$$

$$\lambda_t^l = \beta R_t E_t \lambda_{t+1}^l \tag{5}$$

$$1 = \beta E_t \left[\frac{\lambda_{t+1}^l}{\lambda_t^l} \left(\frac{P_{t+1}^{shll} + DIV_{t+1}}{P_t^{shll}} \right) \right] \tag{6}$$

Equation (6) is the FOC with respect to the stock holding of the infinitely-lived households. It is the usual Euler equation, which stipulates that the household in equilibrium should be indifferent between consuming one additional unit of consumption today and investing this consumption unit into equity at price P_t^{shll} per unit of equity, selling this unit of equity next period at price P_{t+1}^{shll}, and consuming the proceeds plus the dividend DIV_{t+1} that additionally accrues. Since the amount of the households equity holdings a_t^l does not enter the Euler equation, it can be regarded as determining the value P_t^{shll} of the non-traded equity.

3.1.2 Short-lived traders

Each trader household exists for two periods only. The traders borrow from infinitely-lived households and invest the funds into publicly-traded corporate stocks. The profit from this financial investment is consumed. The amount of borrowing and investment derives from the maximisation of traders' utility:

$$\max_{C_t^{T,j}, a_t^{T,j}} \beta E_t^j \log C_{t+1}^{T,j} \tag{7}$$

subject to the traders' budget constraint:

$$\begin{aligned} E_t^j C_{t+1}^{T,j} &= \bar{w} + E_t^j \left(P_{t+1}^{sh} + DIV_{t+1} \right) a_t^{T,j} - R_t P_t^{sh} a_t^{T,j} \\ &\quad - \frac{c + \tau^{STT}}{2} P_t^{sh} \left(a_t^{T,j} \right)^2 \end{aligned} \tag{8}$$

where $j = I, N$ denotes the groups of informed traders and noise traders, respectively. In analogy to the non-trader households, $C_{t+1}^{T,j}$ is traders' consumption and $a_t^{T,j}$ their asset holding. The variable P_t^{sh} denotes the price of traded stocks $1 - \theta$. In period t, traders borrow the amount of $P_t^{sh} a_t^{T,j}$ from the non-trader households and invest these funds in stocks. In period $t + 1$, the traders receive the return on the investment $\left(P_{t+1}^{sh} + DIV_{t+1} \right) a_t^{T,j}$ net of transaction cost (c), STT (τ^{STT}) payments and a lump-sum tax $T_t^{ls,T}$. The traders return the borrowed funds plus interest to the non-trader households ($R_t P_t^{sh} a_t^{T,j}$) and consume the remaining profit plus the fix endowment $\bar{w}$.

The endowment $\bar{w}$ is added to the budget constraint (8) to exclude the occurence of negative values for trader consumption and does not affect any other result.

The conceptual difference between transaction costs c and the STT is that the transaction cost consumes resources whereas the transaction tax transfers resources to the government budget. The transaction costs enter the resource constraint of the economy. They can be understood as the resource cost of trading in the sense of Summers and Summers (1989), i.e. the amount of labour, capital and skill absorbed by the financial system.

The real ex-post stock return for traders that liquidate their positions in period $t + 1$ can be defined as $R_{t+1}^{sh} \equiv \left(P_{t+1}^{sh} + DIV_{t+1} \right) / P_t^{sh}$. Informed traders have rational, i.e. model-consistent, expectations about the future return, i.e.

$E_t^I R_{t+1}^{sh} = E_t R_{t+1}^{sh}$. The noise traders' expectations deviate from rational expectations by a random noise shock:

$$E_t^N R_{t+1}^{sh} = E_t R_{t+1}^{sh} + \nu_t \tag{9}$$

with $\nu_t \sim N(\nu^*, \sigma_\nu)$. The traders' borrowing and investment decisions are determined by the FOCs:

$$E_t \frac{c + \tau^{STT}}{C_{t+1}^{T,I}} a_t^{T,I} = E_t \frac{R_{t+1}^{sh} - R_t}{C_{t+1}^{T,I}} \tag{10}$$

$$E_t^N \frac{c + \tau^{STT}}{C_{t+1}^{T,N}} a_t^{T,N} = E_t^N \frac{R_{t+1}^{sh} - R_t}{C_{t+1}^{T,N}} \tag{11}$$

Consumption by informed and noise traders in period t is given by:

$$\begin{aligned} C_t^{T,I} &= \bar{w} + \left(P_t^{sh} + DIV_t\right) a_{t-1}^{T,I} - R_{t-1} P_{t-1}^{sh} a_{t-1}^{T,I} \\ &\quad - \frac{c + \tau^{STT}}{2} P_{t-1}^{sh} \left(a_{t-1}^{T,I}\right)^2 \end{aligned} \tag{12}$$

$$\begin{aligned} C_t^{T,N} &= \bar{w} + \left(P_t^{sh} + DIV_t\right) a_{t-1}^{T,N} - R_{t-1} P_{t-1}^{sh} a_{t-1}^{T,N} \\ &\quad - \frac{c + \tau^{STT}}{2} P_{t-1}^{sh} \left(a_{t-1}^{T,N}\right)^2 \end{aligned} \tag{13}$$

Traders' total per-capita consumption is the weighted sum of per-capita consumption levels of informed and noise traders:

$$C_t^T = (1 - s_n) C_t^{T,I} + s_n C_t^{T,N} \tag{14}$$

Analogously, the total stock portfolio of traders is:

$$a_t^T = (1 - s_n) a_t^{T,I} + s_n a_t^{T,N} \tag{15}$$

in per-capita terms.

3.2 Firms

Firms choose employment, the capital stock (K_t) and investment (I_t) to maximise the discounted flow of expected future dividends. The future dividends are discounted by the stochastic discount factor of the infinitely-lived households who own the majority of the corporate equity. Formally, the optimisation problem of firms is:

$$\max_{L_t, K_t, I_t} \sum_{t=0}^{\infty} \beta \frac{\lambda_t^l}{\lambda_0^l} DIV_t \tag{16}$$

where λ_t^l is the Lagrange multiplier of the budget constraint of infinitely-lived households. Corporate dividends are the after-tax corporate income net of the wage bill, adjustment costs and investment expenditure:

$$DIV_t \equiv (1-\tau^c)(Y_t - W_t s_l L_t) + \tau^c \delta K_{t-1} - I_t \tag{17}$$

where τ^c is the corporate tax rate, δ is the depreciation rate of physical capital, and capital depreciation is tax-deductible.

The maximisation of dividends is subject to three constraints, namely the production technology:

$$Y_t = A_t (K_{t-1})^{1-\alpha} (s_l L_t)^{\alpha} \tag{18}$$

the law of motion for the capital stock:

$$K_t = (1-\delta) K_{t-1} + I_t \tag{19}$$

and a financing constraint for investment:

$$I_t \leqslant \phi \beta E_t \left[\frac{\lambda_{t+1}^l}{\lambda_t^l} \left(\theta P_{t+1}^{shll} + (1-\theta) P_{t+1}^{sh} \right) \right] \tag{20}$$

The financing constraint (20) states that the opportunity of raising funds for new investment by long-term borrowing from non-trader households or stock issuance is constrained by the current value of the firm as reflected in the equity value. The sensitivity of investment to the stock market performance is documented empirically in the literature (e.g., Baker et al., 2003; Barro, 1990; Chen et al., 2007; Fazzari et al., 1988; Morck et al., 1990). The investment constraint (20) is compatible with alternative hypotheses about the link between the stock market value and investment. E.g., banks could use the firm's stock value as signal of the firms economic health and make the volume and price of loans depend on the firm's valuation. If new investment by the firm is (partly) credit-financed, investment will be limited by the valuation of firm's stocks. The financing constraint is a mechanism/shortcut to capture the empirical link between stock value and investment in a stylized manner. Alternative hypotheses focus on the signaling value of equity prices for investment decisions (e.g., Bond et al., 2011, Chen et al., 2007, and Morck et al., 1990).

The equity value of the firm consists of two types of assets: value of publicly-traded stocks $(1-\theta) P_t^{sh}$ and of private equity θP_t^{shll}. Parameter θ governs the share of the long-term private equity holding in total equity. While firms may have a preference for financing by long-lived households, θ indicates an upper bound for the funds that these investors are able to offer. One explanation for why firms may have a prefererence for private equity is that this type of (owner) investors require lower returns, making financing cheaper. Yet, investors who set up a firm are likely to have limited financial resources and will need to turn to public offerings for additional capital. The value of θ should be relatively large in Europe, however, as European firms do not extensively rely on the stock exchange to raise capital to invest and more frequently rely on direct investment by owners (private equity) and loans.[3]

The maximisation of future dividends (17) under the constraints (18), (19) and (20) gives the FOCs for firm's labour demand, capital and investment :

$$\alpha \frac{Y_t}{s_l L_t} = W_t \tag{21}$$

$$Q_t = \beta E_t \frac{\lambda_{t+1}^l}{\lambda_t^l} \left[(1-\tau^c)(1-\alpha) \frac{Y_{t+1}}{K_t} + \tau^c \delta + (1-\delta) Q_{t+1} \right] \tag{22}$$

$$Q_t = 1 + \mu_t \tag{23}$$

where μ_t and Q_t are the Lagrange multipliers on the financing constraint and the capital accumulation equation respectively in terms of consumption utility.

3.3 Government

The government consumes an exogenous amount of goods (G_t) and receives tax income from wages, corporate income and financial transactions. Current government debt (B_t^G) is the sum of outstanding government debt, debt service and the primary deficit:

$$\begin{aligned} B_t^G / R_t &= B_{t-1}^G + G_t - \tau^l W_t s_l L_t - s_l T_t^{ls} - \tau^c (Y_t - W_t s_l L_t) \\ &\quad + \tau^c \delta K_{t-1} - (1-s_l) \frac{\tau^{STT}}{2} P_{t-1}^{sh} \left[(1-s_n) \left(a_{t-1}^{T,I} \right)^2 + s_n \left(a_{t-1}^{T,N} \right)^2 \right] \end{aligned} \tag{24}$$

Lump-sum taxes T_t^{ls} adjust endogenously to keep the government debt-to-GDP ratio, B_t^G/Y_t, constantly at its target level $\overline{BY}$. The use of lump-sum taxes to stabilise the debt-to-GDP ratio eliminates the income effect of the STT. Reducing distortive instead of lump-sum taxes to rebate the STT receipts would tend to improve the overall assessment of STT introduction in efficiency terms. The setup in this paper, which isolates the STT's distortionary effects without, at the same time, lowering other distortive taxes to reimburse the STT revenue, implies a rather critical assessment of STT-related inefficiencies.

3.4 Aggregation and equilibrium

With the total number of stocks normalised to one, the per-capita stock portfolio of non-trader households is:

$$a_t^l = \theta / s_l \tag{25}$$

and the per-capita stock portfolio of traders is:

$$a_t^T = (1-\theta) / (1-s_l) \tag{26}$$

[3] It could be argued that the value of firms owned directly by households in form of private equity is not fully observed by loan providers and can therefore not be used (fully) to assess the firms' capacity of credit repayment. Publicly-owned equity should be given a higher weight in the financing constraint in this case. However, we do not make such distinction in this paper.

The non-traders' risk-free assets, which consist of government bonds and the funds lent to traders, equals:

$$B_t^l = \frac{1}{s_l}\left[\frac{B_t^G}{R_t} + (1-s_l)\, P_t^{sh} a_t^T\right] \tag{27}$$

Aggregate per-capita consumption is:

$$C_t = s_l C_t^l + (1-s_l)\, C_t^T \tag{28}$$

Total employment in per-capita terms is $s_l L_t$ as the trader households do not work.

Factor, financial and goods markets clear in equilibrium. The market clearing in the stock market implies:

$$a_t = s_l a_t^l + (1-s_l)\, a_t^T = 1 \tag{29}$$

Market clearing in the market for risk-free assets implies:

$$B_t^l = \frac{B_t^G + (1-s_l)\, P_t^{sh} a_t^T}{s_l} \tag{30}$$

Aggregate demand is the sum of private consumption, investment, government purchases and adjustment costs is aggregate demand. In equilibrium, aggregate demand minus the endowment $\bar{w}$ is equal to aggregate production Y_t:

$$Y_t = C_t + G_t + I_t + + (1-s_l)\,\frac{c}{2} P_{t-1}^{sh}\left[(1-s_n)\left(a_{t-1}^{T,I}\right)^2 + s_n\left(a_{t-1}^{T,N}\right)^2\right] - (1-s_l)\,\bar{w} \tag{31}$$

which can also be understood as the ressource constraint of the closed economy.

4 Parametrisation

The parameters for the real and financial sectors and the exogenous processes need to be quantified prior to simulations. The parametrisation is summarised in Table 1. Table 2 reports the steady-state ratios for key model variables as implied by the parameter choices.

4.1 Real economy

The parametrisation of the real economy part is standard in the RBC literature. The discount factor is set to $\beta = 0.99$, which implies an annualised steady-state risk-free interest rate of 4%. The long-lived households' weight of the disutility of labour is set to $\omega = 5$, which implies a steady-state employment of around 0.19 of households' time endowment. The elasticity of labour supply is set to $1/\kappa = 1$, which is standard in the DSGE literature, although upper-bound in microeconometric estimates of labour supply.

The labour share in the production function, which equals the steady-state wage share, is $\alpha = 0.64$. The depreciation rate of physical equals $\delta = 0.025$, which implies an average depreciation period of 2.5 years. Both values are standard in the literature. Together with the investment share of 23% of GDP, the depreciation rate implies a steady-state capital stock value of around 2.5 times GDP. Steady-state total factor productivity A is normalised to 1.

The steady-state shares and parameter values for the government sector correspond to EU average values. Government purchases account for circa 20% of GDP. The labour income tax rate is 40% and the corporate income tax rate 20%. The target level for public debt equals 50% of GDP.

4.2 Financial sector

Parameter choices for the financial sector are informed by data on trading volumes and the empirical literature on trading behaviour. In the benchmark calibration the share of stocks owned by non-trader households is set to $\theta = 0.8$ to match observed ratios of quarterly stock market turnover over the total value of outstanding corporate assets.

The share of noise traders is set to $s_n = 0.5$ in line with evidence on trading behaviour in (foreign-exchange) markets (e.g., Cheung et al., 2004; Menkhoff, 2001; Menkhoff and Taylor, 2007; Oberlechner, 2001). Based on surveys among market participants, these studies conclude that approximately 50% of trading in these markets at the quarterly horizon is based on non-fundamental as opposed to fundamental information. In the sensitivity analysis, we also consider alternative values, namely $\theta = 0.6$ and $\theta = 0.0$ as well as $s_n = 0.25$ and $s_n = 0.75$.

The benchmark calibration uses anSTT rate of 0.14%, which generates a steady-state tax revenue of around 0.1% of GDP. The effective tax rate of 0.14% is at the upper end of recent policy proposals (e.g., IMF 2010; Matheson, 2011; Schulmeister et al., 2008), although Summers and Summers (1989) suggest an STT rate of up to 0.5%.

4.3 Exogenous shocks

The simulations consider the response of the economy to fundamental and non-fundamental disturbances, namely technology (TFP) and noise shocks, in the presence of an STT. The focus on TFP shocks as real disturbances derives from the RBC literature's finding that TFP shocks are able to account for large parts of the observed volatility in real variables at business-cycle frequency. The TFP shocks is an AR(1) process with white-noise innovation ε_t^a:

$$\ln A_t = (1 - \rho_a) \ln \bar{A} + \rho \ln A_{t-1} + \varepsilon_t^a \tag{32}$$

In line with TFP estimates based on the Solow residual, the persistence of the TFP shock is $\rho_a = 0.95$ and the standard deviation of the stochastic innovation $\sigma_a = 0.0072$. The noise shock is white noise ε_t^ν:

$$\nu_t = \varepsilon_t^\nu \tag{33}$$

to capture eratic changes in noise traders' expectations and market sentiments.[4] The standard deviation of the innovation $\sigma_\nu = 0.0707$ is choosen to generate in the model a volatility of the return on stocks that is close to historic values of the stock return volatility in OECD countries (e.g., Kupiec, 1991). The stochastic innovations ε_t^a and ε_t^ν are assumed to be uncorrelated. TFP and noise shocks are applied together throughout the simulations.

Name	Symbol	Value
Discount factor	β	0.99
Elasticity of labour supply	κ^{-1}	1.00
Labour weight in utility	ω	5.00
Labour share in production	α	0.64
Capital depreciation rate	δ	0.025
Financing constraint	ϕ	0.025
Public debt-to-GDP target	$\overline{BY}$	0.50
Labour tax rate	τ^l	0.40
Capital tax rate	τ^c	0.20
STT rate	τ^{STT}	0.0014
Long-term share holding	θ	0.80
Share of noise traders	s_n	0.50
Trader endowment	ϖ	0.10
Tax rebate to traders	s^T	0.00
Financial transaction costs	c	0.01
Persistence of TFP shock	ρ_a	0.95
Steady-state TFP	$\overline{A}$	1.00
Steady-state noise	ν^*	0.00
Standard deviation of TFP shock	ε^a	0.0072
Standard deviation of noise shock	ε^ν	0.0707

Table 1: Model parameters

5 Results

5.1 STT in the benchmark model

This subsection presents simulation results that gauge the impact of an STT in the benchmark model with the parameterisation as described in the previous section. The STT rate is set to 0.14% to raise a tax revenue of 0.1% of GDP in the steady state.

The STT's impact on financial variables and economic aggregates is summarised in Table 3. Values in the first column ("mean") report the percentage

[4] Non-zero persistence of the noise shock would imply a systematic component in the respnse of noise traders to disturbances that should better be integrated in the traders' decision rules.

Steady-state ratio	Value
Y	1.00
$\frac{C}{Y}$	0.68
$\frac{I}{Y}$	0.23
$\frac{G}{Y}$	0.10
$\frac{B^G}{Y}$	0.50
$\frac{K}{Y}$	9.10
L	0.36

Table 2: Steady-state ratios

change in the steady-state level in response to the introduction of the STT. The second colum of results ("std/mean") shows the percentage change between the standard deviation of the variables with and without STT.

Impact of STT on mean values and volatilities		
	Mean (%)	Std (%)
Output	-0.19	-0.99
Capital	-0.43	0.15
Investment	-0.42	-3.59
Consumption	-0.02	-3.25
Employment	-0.06	-8.28
Real wage	-0.14	-0.34
Share trade	-8.40	-12.25
Share price	-8.40	-1.74
	Mean (pp)	Std (%)
Return on shares	1.25	-8.61
Risk-free return	0.00	-7.59
Return on physical capital	0.04	-1.57
Transactions costs/GDP	-0.06	-2.61
STT revenues/GDP	0.09	

Note: The table compares scenarios without and with STT and reports the percentage (%) or percentage point (pp) changes in the mean and the standard deviation of the variables for identical shocks.

Table 3: STT effects in the benchmark model

The results in Table 3 illustrate two main effects from introducing an STT. First, the introduction of the STT leads to a reduction in the price of the traded equity and an increase in the pre-tax stock return in the long run (see the 'mean' column). The increase in the pre-tax return on capital required for investment increases the financing costs for firms. As a result, investment and the stock of productive capital decline by around 0.4%. Output, consumption and employment decline as well in the long run in response to the decline in the capital stock, lower labour productivity and falling income. Real GDP declines by 0.2% in the long term, which is sizable for an STT rate of 0.14%.

Second, the STT leads to a reduction in short-term trade and thereby dampens non-fundamental fluctuations in real aggregates. According to the results in Table 3, introducing an STT of 0.14% would reduce the normalised volatility of investment by circa 4% and the one of output by circa 1%.

The STT-related decline in the volatility of financial and real variables also applies to the response to TFP shocks only. The share value fluctuations in response to TFP shocks reflect changing expectations about the profitability of investment. Introducing an STT in this context dampens the adjustment of the capital stock, which also translates into lower volatility of investment, consumption and output. This volatility reduction is not unambigously positive from a welfare perspective, however, as the STT may constrain the adjustment of macroeconomic variables to TFP fluctuations. On the other hand, the economy does also includes additional frictions, such as distortionary labour/corporate taxes and the financing constraint of firms, that may amplify economic volatility in response to fundamental shocks. In other words, given that the economy without STT is not first best, taxing financial transactions may or may not be second best in such distorted environment.

In sum, the STT's effects in efficiency terms are mixed: (1) The tax introduces economic inefficiencies by increasing the cost of capital, (2) dampens fluctuations of real variables, whereby (3) lower volatility in response to fundamental TFP shocks may not be welfare-improving.

The results in Table 3 refer to a scenario in which STT revenues are compensated by lump-sum transfers to keep the debt-to-GDP ratio at its target level. The STT revenue is not used in this set-up to reduce other distortionary taxes. Assuming a lump-sum rebate allows to isolate the distortionary impact of the STT from other distortions. At the same time it paints a rather negative picture of the STT's impact on economic efficiency. An alternative scenario which lowers, e.g., labour or corporate tax rates instead of lump-sum taxes to rebate STT revenues would lead to a more favourable picture for overall economic efficiency.

5.2 Alternative assumptions about the financing of investment

A first robustness check varies the average investment horizon for investment in financial assets in the economy by varying the share of equity holdings by (non-trading) infinitely-lived households and short-lived traders respectively. Table 4 presents results for a setting in which the share of stocks owned by the long-lived households is reduced from $\theta = 0.8$ in the benchmark to $\theta = 0.6$. Table 5 presents results for an extreme opposite case, where non-trader households do not hold stocks, i.e. all stocks are owned by informed and noise trader ($\theta = 0$). As before, we consider an STT rate of 0.14%. All other parameters and the fundamantal and non-fundamental shocks are as before.

Impact of STT on mean values and volatilities		
	Mean (%)	Std (%)
Output	-0.24	-0.93
Capital	-0.49	0.06
Investment	-0.49	-1.52
Consumption	-0.02	-2.36
Employment	-0.08	-4.86
Real wage	-0.15	-0.18
Share trade	-5.23	-6.46
Share price	-5.23	-2.51
	Mean (pp)	Std (%)
Return on shares	1.32	-8.44
Risk-free return	0.00	-4.65
Return on physical capital	0.05	-1.67
Transactions costs/GDP	-0.10	-2.83
STT revenues/GDP	0.13	

Note: The table compares scenarios without and with STT and reports the percentage (%) or percentage point (pp) changes in the mean and the standard deviation of the variables for identical shocks.

Table 4: STT effects with stronger short-term investment

Impact of STT on mean values and volatilities		
	Mean (%)	Std (%)
Output	-1.14	-1.49
Capital	-3.25	-0.77
Investment	-3.26	3.37
Consumption	-0.88	-2.25
Employment	0.07	-1.95
Real wage	-1.21	-0.46
Share trade	-3.25	-2.66
Share price	-3.25	-2.15
	Mean (pp)	Std (%)
Return on shares	1.56	-4.45
Risk-free return	0.00	-1.98
Return on physical capital	2.24	-1.40
Transactions costs/GDP	-0.24	-1.97
STT revenues/GDP	0.31	

Note: The table compares scenarios without and with STT and reports the percentage (%) or percentage point (pp) changes in the mean and the standard deviation of the variables for identical shocks.

Table 5: STT effects without long-term stock investment

Varying the share of long-term versus short-term investment provides the following results: First, the tax revenue raised increases with falling θ, because higher short-term investment and trading volumes increase the tax base. Second, the STT's negative impact on mean levels of investment, wages, consumption and output that is associated with rising capital costs increases substantially when the share of long-term stock holding decreases as a decline in θ raises the share of equity subject to the STT.[5]

5.3 Alternative degrees of noise trading

A second robustness check concerns the importance of noise trading, keeping the STT rate constant. Based on empirical studies, the benchmark parameterisation assumes half of the traders to have noisy expectations. Table 6 and 7 report results for noise-trader shares of 25% ($s_n = 0.25$) and 75% ($s_n = 0.75$) respectively. Comparison of the tables shows the long-run behaviour ("mean") of macroeconomic and financial variables to be independent of the share of noise traders. The STT-related reduction in the volatility of financial and real variables (with the exception of employment) increases with the share of noise traders, because the relative importance of noise shocks for economic fluctuations increases with the share of noise traders. The stabilising impact of an STT reducing the transmission of noisy expectations into actual trade and real variables increases in this context.

5.4 The impact on the costs of capital

Absent empirical evidence on the impact of a broad-based STT, we have to rely on model comparison to assess the plausibility of our results. The plausibility check is particularly relevant with respect to the results for the cost of capital as the STT-related increase of the cost of capital is generally seen and used as the main argument against the tax.

For a robustness check across models we compare the cost-of-capital result of our benchmark model with a simpler model structure. The simpler general-equilibrium model has only one type of households, i.e. no separate traders, and no financing constraint on firms. In the simpler model, since all shares are held by households, it can be assumed that firms maximise the after-tax share value for households. This acts like a tax on dividends.

[5] One can also perform a similar exercise that keeps not the STT rate, but the STT revenue constant. In this case the effect on the real economy is very similar across different values of θ. The intuition is that when the share of assets owned by traders, $1-\theta$, increases, a smaller tax rate suffices to raise the same revenue. The fact that a larger tax base reduces the tax rate necessary to raise a certain tax revenue decreases the negative impact of the STT on real variables. On the other hand, an increase in $1-\theta$ subjects a larger share of equity in the economy to taxation , which increases the impact of a given tax rate on capital costs and trading volumes. The two effects are nearly offsetting in our model, which brings the aggregate effect of varying θ close to zero.

Impact of STT on mean values and volatilities		
	Mean (%)	Std (%)
Output	-0.19	-0.43
Capital	-0.43	0.15
Investment	-0.42	-1.96
Consumption	-0.02	-1.54
Employment	-0.06	-6.40
Real wage	-0.14	-0.03
Share trade	-8.42	-12.36
Share price	-8.40	-1.62
	Mean (pp)	Std (%)
Return on shares	1.25	-8.61
Risk-free return	0.00	-7.57
Return on physical capital	0.04	-0.47
Transactions costs/GDP	-0.06	-2.96
STT revenues/GDP	0.09	

Note: The table compares scenarios without and with STT and reports the percentage (%) or percentage point (pp) changes in the mean and the standard deviation of the variables for identical shocks.

Table 6: STT effects with lower share of noise traders

Impact of STT on mean values and volatilities		
	Mean (%)	Std (%)
Output	-0.19	-2.50
Capital	-0.43	0.05
Investment	-0.42	-4.51
Consumption	-0.02	-4.76
Employment	-0.06	-7.81
Real wage	-0.14	-0.49
Share trade	-8.40	-11.91
Share price	-8.40	-1.89
	Mean (pp)	Std (%)
Return on shares	1.25	-8.61
Risk-free return	0.00	-7.59
Return on physical capital	0.04	-2.84
Transactions costs/GDP	-0.06	-2.91
STT revenues/GDP	0.09	

Note: The table compares scenarios without and with STT and reports the percentage (%) or percentage point (pp) changes in the mean and the standard deviation of the variables for identical shocks.

Table 7: STT effects with higher share of noise traders

The STT's effect in this structure is to increase the compound discount factor, which discourages savings. Given a decline in savings, borrowing costs for firms will increase. For more details, the structure of the simpler model is attached in appendix B. Levying 0.1% of GDP tax revenue with an STT increases the cost of capital in the simpler model by annualised 4 basis points, while in the benchmark model the tax increases the cost of capital by 4-5 basis points.

The equation describing the cost of capital in the simpler model is identical to the formula used by Matheson (2011) to asses the impact of the STT in a partial-equilibrium framework, which captures the STT as a tax on dividends. Abstracting from the corporate income tax and from any source of financing alternative to shares, as does Matheson (2011), and hence considering the largest possible tax base, the tax rate that raises 0.1% of GDP tax revenue when paid once per quarter is 1 basis point. According to Matheson's (2011) formula, this rate of 1 basis point implies an annual increase in capital costs by 4 basis points, which is identical to what the simple general-equilibrium model suggests.

6 Conclusions

To the best of our knowledge, very little theoretical work has been done to assess the impact of an STT on the real economy. The existing papers that analyse STTs in the presence of non-fundamental volatility (noise trading) limit themselves to partial equilibrium analysis and tend to restrict focus to the financial market. Only Xu (2009) studies the impact of a transaction tax in a general-equilibrium framework with noise traders. Xu (2009) focuses on foreign-currency transactions, however, as opposed to the STT on stock trading in this paper, and does not include a capital-cost channel for the transmission of taxation to real economy variables.

Similarly, model-based (partial-equilibrium) assessments of the impact of an STT on equity prices and the cost of capital are scarce. Matheson (2011) uses a simple formula to assess the STT's effect on equity prices for given interest rates and dividends.

In constrast, our model integrates the STT in a coherent general-equilibrium framework with a financing constraint for firms as link between equity prices and firms' investment decisions. The approach captures the STT's long-run impact on equity prices and economic aggregates and creates a link between variations in after-tax stock returns and variations in the cost of capital. Discussing the STT in a general-equilibrium model allows to analyse the STT's macroeconomic impact, distinguish the relevant transmission channels and assess the robustness of results with respect to financial market and real economy characteristics. Contrary to partial-equilibrium models (e.g., Kupiec, 1996; Song and Zhang, 2005) the general-equilibrium approach captures feedback effects accross different markets and over time.

The main conclusions from simulations with the benchmark model are that a transaction tax generating tax revenue of 0.1% of GDP would (1) increase capital costs by 4-5 basis points, implying a long-term 0.4% decline in the capital stock and a 0.2% decline in real GDP, and (2) reduce the volatility of physical investment and output by 4% and 1% respectively. The estimate for the capital-cost effect are similar to results from a simpler general-equilibrium model that establishes the same link between the STT and capital costs as Matheson (2011). The capital-cost effect operates through the firms' financing constraint, where the value of equity constrains the possibility of physical investment.

Increasing the share of noise traders increases the volatility-dampening impact of the STT in our model and does not affect long-term levels of real and financial variables. As the STT targets short-term transactions, increasing the share of long-term equity holding dampens the negative impact of the tax on capital costs, investment and output levels at constant tax rates. Real effects are independent of the share of long-term equity holding if the STT is fixed in terms of tax revenue, however, because the effects of smaller tax bases and higher required tax rates offset each other in this case.

The STT dampens the fluctuation of financial and real variables in response to non-fundamental (here, noise) and fundamental (here, TFP) shocks. Given that the STT is introduced in a setting with additional frictions, hence the environment is not first best, the welfare effect of the STT-related dampening of the share price response to TFP shocks is not unambigous. In an environment with financial and/or real frictions, adding a distortionary tax can in principle be second best.

Due to the difficulties of modelling financial markets in DSGE models, several elements of the policy debate have not been adressed in this paper: First, the model assumes the STT to be effectively implementable and enforceable. It does not include a market for financial derivatives or a distinction between primary and secondary markets. Consequently, the model is silent about financial derivatives and their treatment. It is also silent about the impact of market structure in the financial sector on STT effects, which is the key theme of, e.g., Pellizzari and Westerhoff (2009) and Westerhoff and Dieci (2006). As it contains distinct assets (corporate equity, government bonds, loans), the model could, however, be used to assess spillover effects of selective versus uniform STT application across equity and debt markets.

Second, using a closed-economy model, which can also be understood as one-region global model, excludes tax avoidance through cross-border capital mobility. Addressing this issue in an open-economy framework would pose challenges beyond the current state of the art. Tax avoidance should, in general, reduce STT revenues and the impact of the tax on financial and real economic variables alike. At the same time, broad-based STT introduction might itself trigger non-trivial changes in the structure of financial markets (e.g., new financial products) with consequences that are difficult or impossible to project.

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A Equations in the simulated benchmark model

A.1 Households

$$\omega L_t^{\kappa} C_t^l = \left(1-\tau^l\right) W_t$$

$$\lambda_t^l = 1/C_t^l$$

$$\lambda_t^l = \beta R_t E_t \lambda_{t+1}^l$$

$$1 = \beta E_t \left[\frac{\lambda_{t+1}^l}{\lambda_t^l} \left(\frac{P_{t+1}^{shll} + DIV_{t+1}}{P_t^{shll}} \right) \right]$$

A.2 Financial traders

$$C_t^T = \left(1-s_n\right) C_t^{T,I} + s_n C_t^{T,N}$$

$$\lambda_t^T = s_n / C_t^{T,N} + \left(1-s_n\right) / C_t^{T,I}$$

$$a_t^T = \left(1-s_n\right) a_t^{T,I} + s_n a_t^{T,N}$$

$$E_t^N R_{t+1}^{sh} = E_t R_{t+1}^{sh} + \nu_t$$

$$E_t \frac{c+\tau^{STT}}{C_{t+1}^{T,I}} a_t^{T,I} = E_t \frac{R_{t+1}^{sh} - R_t}{C_{t+1}^{T,I}}$$

$$E_t^N \frac{c+\tau^{STT}}{C_{t+1}^{T,N}} a_t^{T,N} = E_t^N \frac{R_{t+1}^{sh} - R_t}{C_{t+1}^{T,N}}$$

$$\begin{aligned} C_t^{T,I} &= \bar{w} + \left(P_t^{sh} + DIV_t\right) a_{t-1}^{T,I} - R_{t-1} P_{t-1}^{sh} a_{t-1}^{T,I} \\ &\quad - \frac{c+\tau^{STT}}{2} P_{t-1}^{sh} \left(a_{t-1}^{T,I}\right)^2 \end{aligned}$$

$$\begin{aligned} C_t^{T,N} &= \bar{w} + \left(P_t^{sh} + DIV_t\right) a_{t-1}^{T,N} - R_{t-1} P_{t-1}^{sh} a_{t-1}^{T,N} \\ &\quad - \frac{c+\tau^{STT}}{2} P_{t-1}^{sh} \left(a_{t-1}^{T,N}\right)^2 \end{aligned}$$

A.3 Firms

$$Y_t = A_t \left(K_{t-1}\right)^{1-\alpha} \left(s_l L_t\right)^{\alpha}$$

$$K_t = (1-\delta) K_{t-1} + I_t$$

$$DIV_t \equiv (1-\tau^c)(Y_t - W_t s_l L_t) + \tau^c \delta K_{t-1} - I_t$$

$$I_t = \phi \beta E_t \left[\frac{\lambda_{t+1}^l}{\lambda_t^l} \left(\theta P_{t+1}^{shll} + (1-\theta) P_{t+1}^{sh} \right) \right]$$

$$\alpha \frac{Y_t}{s_l L_t} = W_t$$

$$Q_t = \beta E_t \frac{\lambda_{t+1}^l}{\lambda_t^l} \left[(1-\tau^c)(1-\alpha) \frac{Y_{t+1}}{K_t} + \tau^c \delta + (1-\delta) Q_{t+1} \right]$$

$$Q_t = 1 + \mu_t$$

A.4 Government

$$\begin{aligned} B_t^G / R_t \quad = \quad & B_{t-1}^G + G_t - \tau^l W_t s_l L_t - s_l T_t^{ls} - \tau^c (Y_t - W_t s_l L_t) + \tau^c \delta K_{t-1} \\ & - (1-s_l) \frac{\tau^{STT}}{2} P_{t-1}^{sh} \left[(1-s_n) \left(a_{t-1}^{T,I} \right)^2 + s_n \left(a_{t-1}^{T,N} \right)^2 \right] \end{aligned}$$

$$T_t^{ls} = T_{t-1}^{ls} + \alpha^{Tls} \left(\frac{B_t^G}{Y_t} - \overline{BY} \right)$$

A.5 Aggregation and equilibrium

$$a_t^l = \theta / s_l$$

$$a_t^T = (1-\theta) / (1-s_l)$$

$$a_t = s_l a_t^l + (1-s_l) a_t^T = 1$$

$$B_t^l = \frac{1}{s_l} \left[\frac{B_t^G}{R_t} + (1-s_l) P_t^{sh} a_t^T \right]$$

$$C_t = s_l C_t^l + (1-s_l) C_t^T$$

$$B_t^l = \frac{B_t^G + (1-s_l) P_t^{sh} a_t^T}{s_l}$$

$$Y_t = C_t + G_t + I_t + (1-s_l) \frac{c}{2} P_{t-1}^{sh} \left[(1-s_n) \left(a_{t-1}^{T,I} \right)^2 + s_n \left(a_{t-1}^{T,N} \right)^2 \right] - (1-s_l) \bar{w}$$

A.6 Exogenous processes

$$\ln A_t = (1-\rho_a) \ln \bar{A} + \rho \ln A_{t-1} + \varepsilon_t^a$$

$$\nu_t = \varepsilon_t^{\nu}$$

B Simple general-equilibrium model

This appendix outlines the simple model udes for comparison in section 5.4. Unless stated otherwise, notation is as in the benchmark model.

B.1 Households

There is a representative household that maximises:

$$\max_{C_t, N_t, a_t} E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln C_t - \frac{\omega}{1+\kappa} L_t^{1+\kappa} \right]$$

subject to the budget constraint:

$$\begin{aligned} C_t + B_t + P_t^{sh} S_t &= W_t N_t + (1 + r_{t-1}) B_{t-1} \\ &+ \left(1 - \tau^{STT}\right) \left(P_t^{sh} + DIV_t\right) S_{t-1} - T_t^{ls} \end{aligned}$$

B.2 Firms

The firms maximise the present value of future dividend flows discounted at the stochastic discount factor $DF_{t,t+i}$ (to be defined below) of their owners:

$$\max_{K_{t+i}, N_{t+i}} E_t \sum_{i=0}^{\infty} DF_{t,t+i} \left[DIV_{t+i}(K_{t+i}, L_{t+i}) \right]$$

Dividends equal corporate income net of the wage bill, capital depreciation and investment:

$$DIV_t(K_t, L_t) \equiv (1 - \tau^c) (Y_t - W_t L_t) + \tau^c \delta K_t - I_t$$

Maximising the steam of dividends is subject to the constraints:

$$Y_t = A_t L_t^{\alpha} K_t^{1-\alpha}$$

$$K_t = (1 - \delta) K_{t-1} + I_t$$

which describe the production technology and capital accumulation.

B.3 Government

The government budget constraint is:

$$B_t^G = (1 + r_{t-1}) B_{t-1}^G + G_t - \tau^c (Y_t - W_t L_t - \delta K_{t-1}) - \tau^{STT} P_t^{sh} S_t - T_t^{ls}$$

B.4 Market clearing

In equilibrium, the transversality condition holds and all markets clear. For the goods market this implies:

$$Y_t = C_t + I_t + G_t$$

Equilibrium in the capital market implies equality between domestic savings and capital investment. The number of stocks defining firm ownership is kept constant at $S_t = 1$.

B.5 First order conditions

The households' FOC of the optimisation are:

$$\lambda_t = 1/C_t$$

$$\omega L_t^{\kappa} = W_t \lambda_t$$

$$1 = \beta \frac{\lambda_{t+1}}{\lambda_t} (1 + r_t)$$

$$P_t^{sh} = \beta \frac{\lambda_{t+1}}{\lambda_t} \left(1 - \tau^{STT}\right) \left(P_{t+1}^{sh} + DIV_{t+1}\right)$$

The iteration of the FOC for capital investment gives an expression for current share value as the discounted sum of future after-tax dividends:

$$P_t^{sh} = \sum_{i=1}^{\infty} \beta^i \frac{\lambda_{t+i}}{\lambda_t} \left(1 - \tau^{STT}\right)^i DIV_{t+i}$$

The firm maximises the after-tax share value of the owners, so that the stochastic discount factor can be defined as:

$$DF_{t,t+i} \equiv \beta^i \frac{\lambda_{t+1+i}}{\lambda_t} \left(1 - \tau^{STT}\right)^i$$

Optimisation of the share value gives FOCs for the optimal level of employment and capital:

$$\alpha \frac{Y_t}{L_t} = W_t$$

$$F'(K_t) \equiv (1 - \alpha) \frac{Y_t}{K_t}$$

$$F'(K_t) = \frac{1 + \tau^c \delta + \beta \frac{\lambda_{t+1}}{\lambda_t} \left(1 - \tau^{STT}\right) (1 - \delta)}{1 - \tau^c}$$

Hence, the STT directly enters the firms' FOC for investment.

In steady state $\overline{\lambda}$, so that the FOC for investment involving the cost of capital becomes:

$$F'(K) = \frac{1 - \tau^c \delta - \beta \left(1 - \tau^{STT}\right) (1 - \delta)}{1 - \tau^c}$$

Noting that in the steady state $\beta = 1/(1+r)$ and assuming $\tau^c = 0$ gives:

$$F'(K) = 1 - \frac{\left(1 - \tau^{STT}\right)(1-\delta)}{1+r}$$

which corresponds to the formula A.16 in Matheson (2011) with $\tau^{STT} = T/N$, where T is the tax rate and N is the lenght of the time interval. In our quarterly model, $N = 0.25$. Interest rates, discount rates and depreciation rates of our model also have to be annualised for a comparison with Matheson (2011).