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Input versus output taxation in an experimental international economy ☆

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A B S T R A C T

This paper presents the results of a policy oriented macroeconomic experiment involving an 'international' economy with a relatively small 'home' country and a large 'foreign' country. It compares the economic performance of two alternative tax systems: a wage tax system and a sales-tax-*cum*-labor-subsidy system. The two systems are applied to the small country, while the wage tax system always obtains in the large country. The main result is that the sales tax system outperforms the wage tax system, using standard economic indicators. Moreover, it turns out that under the sales tax system economic activities appear to be moving toward the 'better' of two theoretical equilibria. It is argued that producers' reluctance to incur costs up-front while being uncertain about product prices can explain these results. Several pieces of evidence are provided to support this claim. The results strongly suggest that behavioral aspects should be taken into account also in applied macroeconomic models.

1. Introduction

> *Time usually elapses* (…) *between the incurring of costs by the producer* (*with the consumer in view*) *and the purchase of the output by the ultimate consumer. Meanwhile the entrepreneur* (…) *has to form the best expectations he can as to what the consumers will be prepared to pay when he is ready to supply them* (…).
>
> John Maynard Keynes (1970 [1936], Chapter 5: Expectation as Determining Output and Employment, p. 46)

A major economic issue concerns the effects of taxation on the behavior of individual consumers and producers and the performance of markets. In this context, a longstanding problem in public finance relates to the pros and cons of taxing inputs, e.g. labor and capital, versus the taxation of outputs, like sales or value added. One potentially highly relevant factor in this respect is that production takes time, a fact emphasized by Keynes in the preceding quote. At the time when producers have to make their input decisions, generally, the precise market conditions prevailing at the time consumers buy their products are unknown. Thus, when deciding on labor and capital employment producers, typically, face uncertainty about the real returns from these decisions. A similar problem holds for consumers when they have to allocate

☆ This paper uses data generated by a research project commissioned by the Dutch Ministry of Social Affairs and Employment, see van Winden et al. (1999).
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time between labor and leisure, because the real return on their labor will depend on the development of consumer prices over the period covered by the wage contract.

Several studies have argued that taking this uncertainty into account is important from a behavioral explanatory and optimal policy point of view. For example, Eaton and Rosen (1980) show that if consumers are uncertain about the real wage, an expected income-compensated increase in the wage tax may induce them to supply more labor. Moreover, lump-sum taxation is no longer necessarily efficient, because the wage tax insures the consumer against random real wage income movements. Regarding producers, a number of theoretical partial equilibrium studies have focused on the effects of output price uncertainty on the input and supply decisions of firms. Results show that output price uncertainty generally reduces factor demand and production level of risk-averse competitive firms (Sandmo, 1971; Batra and Ullah, 1974; Hartman, 1975, 1976; Holthausen, 1976, Ghosal, 1995).[1]

The policy relevance of this topic can be illustrated by referring to the puzzle of European unemployment (Blanchard and Katz, 1997). A large piece of this puzzle seems related to the strong reliance on wage taxation in financing the welfare state, and the focus on supply side conditions in employment policies. Indeed, several scholars have pointed at the pernicious effects of wage taxation in this respect, with rising tax rates and unemployment leading to a vicious circle (Snower, 2000). In a previous macroeconomic experiment we have found clear evidence of such a vicious circle in the dynamic interaction of a wage tax and unemployment (Riedl and van Winden, 2007). Moreover, and more importantly for the present context, a sales risk for producers due to price uncertainty on output markets appeared to cause a downward pressure on factor employment, which was exacerbated for labor by the wage tax. These findings and the above mentioned research suggest that shifting taxation from inputs to outputs may have a positive effect on production and employment because the government then effectively shares the sales risk faced by producers.

From an optimal taxation and general equilibrium perspective, however, it seems not at all clear whether such a shift in taxation will do any good, in particular in a small open economy. Taxation of outputs implies an implicit tax on the mobile factor capital and the conventional wisdom in the literature on optimal taxation in open economies is that taxing such a factor should be avoided. For example, based on the seminal work of Diamond and Mirrlees (1971), Razin and Sadka (1991) have shown that a small open economy should not tax mobile capital (at the source). Bovenberg (1994, p. 284) argued that "(…) small and open economies should not tax highly mobile factors (…)".[2]

On the other hand, theoretical reasoning does not always provide unambiguous answers, even in a frictionless perfectly competitive world. A well-known result from general equilibrium theory is that, generically, equilibrium predictions are not unique. In case of multiple equilibria, however, no clear forecasts concerning policy reforms can be made. Moreover, experimental evidence has shown that in a variety of circumstances the neglect of behavioral aspects may lead to wrong predictions and, consequently, misleading policy prescriptions. A main motivation of this paper is, therefore, to shed some light on the thorny issue of whether a tax on immobile labor or a sales tax – implicitly taxing mobile capital – leads to a better economic performance of a small open economy. In fact, in the framework we will be using theoretically multiple equilibria arise and as it will turn out behavioral factors play a crucial role in explaining the convergence dynamics of important economic indicators.

For our investigation we use data from an experimental study pitting a wage tax system against a sales tax system as alternative means to finance unemployment benefits, commissioned by the Dutch Ministry of Social Affairs and Employment.[3] The investigation was supervised by a steering committee of internationally renowned Dutch economists (in the fields of public economics, labor economics, experimental economics, and applied general equilibrium modeling).[4] Being a policy-oriented study, the experimental design was required to show some parallelism with the Dutch economy. The steering committee had to approve the design of the experiment and assist the project.

Part of the data used here was analyzed in Riedl and van Winden (2007), where we focused on the impact of a wage tax system in an experimental environment of a closed economy and an open economy. The main innovation of the present study is the comparison of the wage tax system with a sales tax system, using the same environment of an open economy with a relatively small 'home country' and a large 'foreign country'.[5] In a sense, conducting this study meant exploring the boundaries of the research method of laboratory experimentation. In our view, the results show that also in the area of policy related macroeconomic research experiments are a useful complementary research tool, next to theoretical and field empirical analysis. Compared to field econometric studies an important advantage is that it is possible to empirically

[1] Loss aversion, as in prospect theory (Kahneman and Tversky, 1979), would make this effect only stronger. Another strand of literature addresses the impact of (macroeconomic) uncertainty on investment, typically showing a negative effect (Aizenman and Marion, 1993; Brunetti and Weder, 1998; Guiso and Parigi, 1999).

[2] Many relatively small countries nevertheless tax capital implicitly or explicitly. A large body of the literature tries to square this empirical fact with the theory of optimal taxation either by discussing legal details (e.g. Gordon, 1992), allowing for frictions and market imperfections (e.g. Richter and Schneider, 2001; Koskela and Schöb, 2002) or by taking a global view of capital taxation (Braulke and Corneo, 2004).

[3] See, van Winden et al. (1999).

[4] For economically intuitive reasons, backed by the above mentioned theoretical results from optimal taxation theory, the members of the committee had the general opinion that the sales tax system would lead to capital flight, more unemployment, and a substantial welfare loss in a relatively small open economy, like The Netherlands. In addition, it was feared that a shift in economic activity would take place from the relatively capital intensive 'exposed sector' (producing tradeable goods) toward the more labor intensive 'sheltered sector'. The more so, because high tax rates were foreseen due to a labor subsidy that was incorporated in the alternative sales tax system.

[5] Akerlof (2002) discusses some experiments and Ricciuti (2008) and Duffy (2008a, 2008b) survey the experimental evidence concerning macroeconomic issues.

analyze the economic consequences of a *complete* implementation of a new tax system. With the additional virtue of being able to do so in a controlled way. Furthermore, an experiment offers the opportunity to generate (and if necessary replicate) the micro-level data of interest and avoids the noise field data are unavoidably exposed to.[6] In addition, no specific behavioral assumptions are needed, nor a restriction to a partial equilibrium framework as in the theoretical studies referred to above. Moreover, since theory generically predicts multiple equilibria, experiments can provide information on their relative attractiveness in practice; an issue that will also prominently show up in our study.[7]

In the baseline treatment of the experiment, in both the home country and the foreign country, a wage tax finances unemployment benefits. In the alternative treatment, the wage tax system is substituted by a sales tax system, in the home country only. Moreover, for each employed unit of labor the producer receives a subsidy equal to the unemployment benefit. The theoretical general equilibrium predictions turn out to be unique for the wage tax system. For the alternative sales-tax-*cum*-labor-subsidy system, however, we obtain two stable general equilibria implying two quite distinct sets of theoretical predictions concerning the economic performance indicators of this system. One set of predictions supports the economically intuitive hypothesis of capital flight from the small to the large country with very negative economic effects in the small country. In the second equilibrium, however, almost no capital flight occurs and employment, production, and consumption are even higher than under the benchmark system. The experiment allows us to investigate whether economic activities are attracted to one of these equilibria.

Our main finding is that, the alternative sales-tax-*cum*-labor-subsidy system performs significantly better than the wage tax system, with respect to all considered economic performance indicators. To explain this, we present theoretical arguments and empirical evidence in support of the claim that producers' aversion toward incurring costs up-front, while facing output price uncertainty, plays a crucial role. Our results, which corroborate and extend the findings of Riedl and van Winden (2007), point at the relevance of this hitherto underexposed behavioral regularity for economic model building as well as policy advising. Therefore, our study fits well into a still small but gradually growing stream of 'design' studies which involve the economist as 'engineer' (Roth, 2002).

The organization of the rest of the paper is as follows. Section 2 presents the experimental design and procedures, as well as the theoretical predictions. The experimental results are given in Section 3. In Section 4 we propose a behavioral explanation for our main findings, while additional supportive evidence is provided. Section 5 concludes.

2. Experimental design

In the following, the wage tax system is denoted as the *WT-system* and the alternative sales-tax-*cum*-labor-subsidy system as the *STLS-system*.

2.1. Economic environment

The economic environment builds on Riedl and van Winden (2007) but introduces the novel STLS-system with sales taxes and a labor subsidy which is compared to a pure wage tax system. Here we restrict ourselves to a short description of the environment and relegate details to the Supplementary materials accompanying this paper.

In view of the desired parallelism with a relatively small open economy, we consider an 'international' economy with consumers and producers in two 'countries', a relatively small country s, the home country, and a large country l, the foreign country. Consumers are endowed with $\overline{K}$ units of capital (K) and $\overline{L}$ units of labor (L) that they can sell to producers in a capital and a labor market. Consumers derive utility from 'leisure', i.e. unsold units of labor ($\overline{L}-L$), and the consumption of two private goods: X and Y, via a Cobb–Douglas type utility function. In addition to factor payments, the consumption budget is determined by an unemployment benefit for each unsold unit of labor.

Commodities X and Y are produced in separate sectors. Producers need capital and labor as inputs, which are transformed to outputs via *CES* production technologies exhibiting slightly decreasing returns to scale and allowing for different factor intensities and elasticities of substitution in the two production sectors.[8] The production of good X is relatively capital intensive, while the production of Y is relatively labor intensive. Profits are determined by the difference between sales revenue and the costs of inputs. The former may involve sales taxes and the latter wage taxes or labor subsidies, depending on the prevailing tax system. Tax revenues are used for financing unemployment benefits and/or labor subsidies (see the next subsection).

Both the capital market and the market for X are international (exposed), while the markets for labor and good Y are local (sheltered). Consequently, the total number of input and output markets equals six.

All inputs and outputs are traded in computerized multiple units double auction markets. Trading takes place in a number of trading periods. Each trading period is split into a first phase with only the input markets open, and a second

[6] In empirical studies of taxation this is a notorious problem which, for example, manifests itself in widely diverging estimates of tax rate elasticities (see e.g. Sørensen, 1997).

[7] In a policy related study as this external validity may be an issue. We discuss this in the Conclusions (Section 5).

[8] The actually implemented factor intensities and substitution elasticities resemble estimates for the Dutch economy. The choice of slightly decreasing returns to scale is motivated by an empirical and a methodological consideration. Firstly, there is empirical evidence suggesting that this is a realistic feature of economies (see Basu and Fernald, 1997). Secondly, it allows experimental producers to make strictly positive profits, and hence monetary earnings, in the theoretical general equilibrium discussed below.

Table 1
The implemented tax systems.

	WT-system	STLS-system	
	Both countries k	Small country s	Large country l
Unemployment benefit (w_0)	70	70	70
Labor subsidy (w_0)	0	70	0
Initial wage tax rate (τ_w^0)	0.3777	0	0.3777
Wage tax Adjustment rule (τ_w^{t+1})	$\tau_{wk}^{t+1} w_k^t L_k^t = w_0(\overline{L}_k - L_k^t)$		$\tau_{wl}^{t+1} w_k^t L_l^t = w_0(\overline{L}_l - L_l^t)$
Initial sales tax rate X (τ_x^0)	0	0.6521	0
Initial sales tax rate Y (τ_y^0)	0	0.7518	0
Sales taxes Adjustment rule ($\tau_x^{t+1}, \tau_y^{t+1}$)		$\tau_{xs}^{t+1} p_x^t X_s^t + \tau_{ys}^{t+1} p_{ys}^t Y_s^t = w_0 \overline{L}_s$; $\tau_{xs}^{t+1}/\tau_{ys}^{t+1} = \tau_{xs}^0/\tau_{ys}^0$	

Note: t denotes a trading period, L_k^t, $\overline{L}_k$, X_s, and Y_s denote aggregates in a country, superscripts ^{0} refer to initial values. The tax rates are derived from a theoretical benchmark model and empirical results. The value of w_o corresponds with a replacement rate of about 65%, resembling the Dutch situation, to the theoretical benchmark prediction of the WT-system (see Section 2.2). An upper bound of 0.90 was maintained for the tax rates because pilot studies showed that tax rates too close to 100% might have a strongly discouraging effect on trading.

phase with only the output markets open.[9] To facilitate trading, both consumers and producers are endowed with some fiat money at the beginning of the first phase of each period. In addition, consumers receive a transfer (unemployment benefit w_0) for each unit of labor that is unemployed at the end of this phase.

All taxes are levied on the producers. In the baseline treatment of the experiment the WT-system obtains in both countries. In this case a given tax rate (τ_{ws} in the small country, τ_{wl} in the large country) is applied to the wage of each unit of labor that is employed. In the treatment concerning the alternative tax system the WT-system again obtains in the large country, but now the STLS-system prevails in the small (home) country. Instead of paying a wage tax, producers in the small country now receive a fixed subsidy (equal to the unemployment benefit) for each unit of labor they employ, while paying a given tax rate (τ_{xs} in the X-sector, τ_{ys} in the Y-sector) on the sales price of their products.

Finally, it is noted that only one currency ('francs', with a fixed conversion rate to cash) is used in the lab economy. Since the focus of this study is not on issues of international finance we did not want to complicate the experiment by introducing multiple currencies.

Experimental subjects participate in a sequence of 16 trading periods. In a given treatment the first eight of these periods are identical with respect to the exogenous parameters. Except for the subjects' earnings nothing carries over from period to period. Consequently, each period can be seen as a repetition of the same static economy. In periods 9–16 tax rates are adjusted at the beginning of each new period such that a balanced budget would be obtained for the previous period, given the market outcomes of that period. The initial tax rates and the precise tax adjustment rules are shown in Table 1. This procedure guarantees a sufficient number of repetitions with a constant environment for making it possible to examine whether and at which level economic behavior stabilizes. The adjustment of the tax rates to the budget balance adds an important feature of realism and enables an analysis of the dynamic interaction between taxation, employment and other indicators of economic performance, while keeping everything else constant. It also allows to control for the potentially confounding effect that a relative good performance of a tax system is 'bought' by budget deficits.[10]

2.2. Theoretical general equilibrium predictions.

To get a theoretical benchmark prediction for our complex experimental economy, with its several interdependent markets and the double auction trading mechanism, we follow the procedure used in other studies of experimental markets employing a similar trading mechanism (Lian and Plott, 1998; Noussair et al., 1995, 1997; Quirmbach et al., 1996). We have calculated the numerical solution(s) of a competitive general equilibrium representation of the economy, equating supply and demand in the various markets under the additional condition of a balanced tax-transfer budget.[11]

Table 2 shows the predictions concerning consumer utility (U), quantities (K, L, X, Y), relative prices (r, w, p) and taxes (τ) separately for the international markets, the small country, and the large country. Generally, in our economy there exist two stable equilibria. The parameter values are chosen such that in the WT system the equilibria coincide, whereas for the

[9] There are two main reasons for using sequential instead of simultaneous markets. Firstly, in our view sequentiality of input and output markets is much more common in the field than simultaneous markets are. Note also that even simultaneous markets would exhibit some sequentiality, were it alone for the sequentiality that is inherent to the production process (cf. Keynes' view quoted in the beginning). Secondly, the sequentiality considerably reduces the complexity of the market environment for the subjects.

[10] Note that in the constant tax regime only the data from the WT-system where theoretical equilibrium tax rates have been implemented can be used for direct comparison with the theoretical benchmark (see also Section 3). In the variable tax regime all variables can freely move and any convergence is endogenous.

[11] The formal description of the economy can be found in the Supplementary materials.

Table 2
Theoretical general equilibrium predictions.

	WT-system	STLS-system			WT-system	STLS-system	
		Equilibrium 1	Equilibrium 2			Equilibrium 1	Equilibrium 2
	International						
K	240	240	240				
X	177	181	182				
r	0.0307	0.0295	0.0289				
p_x	0.1882	0.1807	0.1807				
	Small country				Large country		
U_{i_s}	106.7	110.3	89.0	U_{i_l}	216.2	216.4	218.3
K_s	30	28	11	K_l	210	212	229
L_s	28	33	18	L_l	197	199	213
X_s^c	22	25	17	X_l^c	155	156	165
X_s^p	22	25	14	X_l^p	155	156	168
Y_s	19	21	11	Y_l	132	133	140
w_s	0.1694	0.1971	0.1292	w_l	0.1694	0.1640	0.1743
p_{ys}	0.2211	0.2165	0.2747	p_{yl}	0.2211	0.2123	0.2121
τ_{ws}	0.3777			τ_{wl}	0.3777	0.3655	0.2769
τ_{xs}		0.4889	0.7835				
τ_{ys}		0.5414	0.8677				

Note: Equilibrium quantities are rounded to integers. Depicted prices are relative prices that are obtained by dividing nominal prices by the sum of all six nominal prices. The equilibrium tax rates guarantee a balanced budget in equilibrium. Superscript ^{c} (^{p}) indicates consumed (produced) quantities; when this distinction is not made consumed and produced quantities coincide in equilibrium.

STLS system there exist two equilibria that are quite different, in particular for the small country. Equilibrium 2 exhibits the serious negative economic consequences for the small country that economic intuition and the literature on optimal (capital) taxation in small open economies suggest (see e.g. Diamond and Mirrlees, 1971; Bovenberg, 1994). In contrast to the WT-system, where only labor is taxed, the STLS-system implicitly taxes capital thereby reducing the rents from capital in the small country. This induces the capital flight observed in equilibrium 2.

Yet, implicitly taxing capital and labor broadens the tax basis, which has potentially positive efficiency effects. In particular, since the production process exhibits decreasing returns to scale allowing tax shifting to an immobile third factor, an effect akin to the tax shifting effect known in the literature on the 'double dividend' of environmental taxes (e.g. de Mooij and Bovenberg, 1998). This potentially beneficial tax shifting offers a rationale for equilibrium 1 in the STLS-system. Indeed, this equilibrium shows a higher utility level, substantial positive employment effects, little capital flight, and an increase in the production in both sectors.

Importantly, the property that for the small country in the STLS system one equilibrium is 'better' and one is 'worse' than the equilibrium in the WT system is not a coincidence. We have conducted numerical comparative statics analyses with respect to the level of unemployment benefit (and employment subsidy) and the returns-to-scale parameter (for details see van Winden et al., 1999). For a wide range of benefit and subsidy levels, these calculations show that in terms of utility the better equilibrium in the STLS system is always better than the equilibrium in the WT system. At the same time, the bad equilibrium in the STLS system is always worse than the equilibrium in the WT system. The same holds when changing the returns-to-scale parameter. Of course, numerical simulations are not a proof that the properties of the equilibria always hold but they give confidence that they are not too fragile.

The existence of two quite distinct general equilibria for the alternative STLS-system makes the experimental investigation particularly interesting. In addition to the comparison of the two alternative tax-transfer systems we can also investigate whether actual behavior converges to one of the equilibria, if it converges at all. This is of special interest because the multiplicity of equilibria leaves the economies with a coordination problem and the theoretical prediction ambiguous.

In order to avoid a potential bias of the experimental results in favor of the alternative tax system, and because the experiment was also policy oriented, it was decided not to implement the initial tax rates for the STLS-system from one of the two equilibria of the theoretical model. Instead, these were determined such that *on impact* the producers of X and Y would have to bear the same tax burden as *empirically* observed (in the laboratory) under the WT-system.[12] It turned out

[12] More precisely, the initial wage tax rate τ_w^0 which *ceteris paribus* balances actual average tax revenue with actual average unemployment expenditure in the periods 6–8 of the WT-system (denoted by A) is derived from: $\tau_w^0 w_s^A L_s^A = w_0(\overline{L}_s - L_s^A)$. The initial tax rates of the STLS-system (τ_x^0 and τ_y^0)

that these empirically based tax rates (τ_{xs} and τ_{ys}) were in a close neighborhood of the theoretical tax rates in the 'bad' equilibrium 2 prediction.

3. Experimental results

In the following we empirically analyze the performance of the WT- and the STLS-system in comparison to the theoretical predictions and also compare the two tax systems with each other. We will examine quantities and relative prices in the individual markets, as well as the policy relevant performance indicators earnings (as a proxy of aggregate welfare), labor employment, net capital export, shift toward labor intensive production, real GDP, and the budget surplus. While reporting results for both countries, our main focus will be on the performance of the small country.

3.1. Constant tax regime

Here we present the results for the constant tax regime (periods 1–8), where the tax rates are set at the level of the theoretical predictions shown in Table 2. Figs. 1 and 2 illustrate the development of quantities (panels (a)) and relative prices (panels (b)), averaged over sessions, for the WT-system and the STLS-system. In this subsection we restrict our discussion to the left-hand part of each figure (the first eight periods). The figures show an orderly development, as is also observed in other multiple markets experiments. Of particular interest are the following observations. Fig. 1(a) shows that, with only one exception, all quantities start below the equilibrium levels of the general equilibrium prediction (straight lines in the figures). Most of these variables, however, exhibit some convergence toward these levels. Regarding the development of prices, Fig. 1(b) exhibits no clear picture concerning the starting levels of the output prices, but shows that two of the three input prices (r and w_l) clearly start (and seem to stay) below the theoretically predicted levels.

This general impression is confirmed by a convergence analysis based on the following estimation model, that we will also use in the sequel (see Noussair et al., 1995)[13]:

$$y_{it} = a_{11}D_{A1}(1/t)+a_{12}D_{A2}(1/t)+a_{13}D_{A3}(1/t)+a_2D_A(t-1)/t+u_{it}$$

where y stands for the particular outcome focused at (quantity, price; with average outcomes per period and session as units of observation), i denotes the experimental session, t the trading period in the session, D_{Ai} a dummy variable for session i of the WT-system which is equal to 1 for i and 0 otherwise, and u the error term. Note that the coefficients a_{1i} indicate session specific starting values and a_2 the asymptotic value of y in the WT-system ($D_A = 1$ when the WT-system is effective).

Following Noussair et al. (1995) and Lian and Plott (1998) we apply two measures of convergence in assessing whether a variable converges to the predicted value: 'strong convergence' which is rather demanding and the less demanding notion of 'weak convergence'. We say that a variable is strongly converging if the estimated asymptotic value (a_2) is statistically not significantly different from the theoretically predicted level. We speak of weak convergence if a majority of the starting values of the data, measured by (a_{1i}), is further apart from the theoretically predicted level than the estimated asymptotic value. Although, clearly weaker than the notion of strong convergence, this definition still captures some movement toward the theoretically predicted level.

The regression results for the constant wage tax regime are based on Riedl and van Winden (2007). For completeness we summarize the main insights here. For statistical details the reader is referred to the Supplementary materials.

Result 1. *With constant taxes and the WT-system obtaining in both countries, a majority of the variables* (10 *out of 18*) *exhibits at least weak convergence toward the theoretical general equilibrium levels. The quantity and input price variables are typically converging from below, while the output prices are typically converging from above.*

Furthermore, though most asymptotic values are statistically significantly different from the predicted levels, the differences are mostly small in economic terms. Given the complexity of the laboratory economy we find this a remarkable result. In particular, in view of the fact that the theoretical general equilibrium model is a very stylized representation of the economy neglecting, most noticeable, individual price adjustment behavior (Fisher, 1970, 1972).

We have also run convergence regressions for the economic performance indicators unemployment rate, real GDP, consumer earnings,[14] net capital export, and labor intensity in the Y-sector. The results of these regressions corroborate the above findings. In both countries, all five performance indicators are weakly converging to the theoretically predicted equilibrium values. In both

(*footnote continued*)
then follow from: $\tau^0_x p^A_x X^A_s - w_0 L^A_{xs} = \tau^0_w w^A_s L^A_{xs}$ and $\tau^0_y p^A_{ys} Y^A_s - w_0 L^A_{ys} = \tau^0_w w^A_s L^A_{ys}$. When the tax rates are adjusted, in periods 9–16, the ratio of the tax rates is kept the same.

[13] Here and in the sequel we have also applied the convergence analysis proposed by Duffy (2008b). The results of this alternative approach corroborate the qualitative results of the approach used here. Generally, variables that are found (not) to converge using the reported regression analysis are also found (not) to converge using the regression analysis of Duffy (2008b). The detailed results of the alternative regression analysis can be found in the Supplementary materials accompanying this paper.

[14] Consumer earnings are the relevant earnings to compare with the theoretical predictions in the constant wage-tax regime. In the theoretical model profits are distributed to the consumers. In the experiment the theoretical amounts have been seeded with the consumers as their *Cash* (see, Supplementary materials, Table S.1). For results also taking producer earnings into account, see Footnotes 16 and 18.

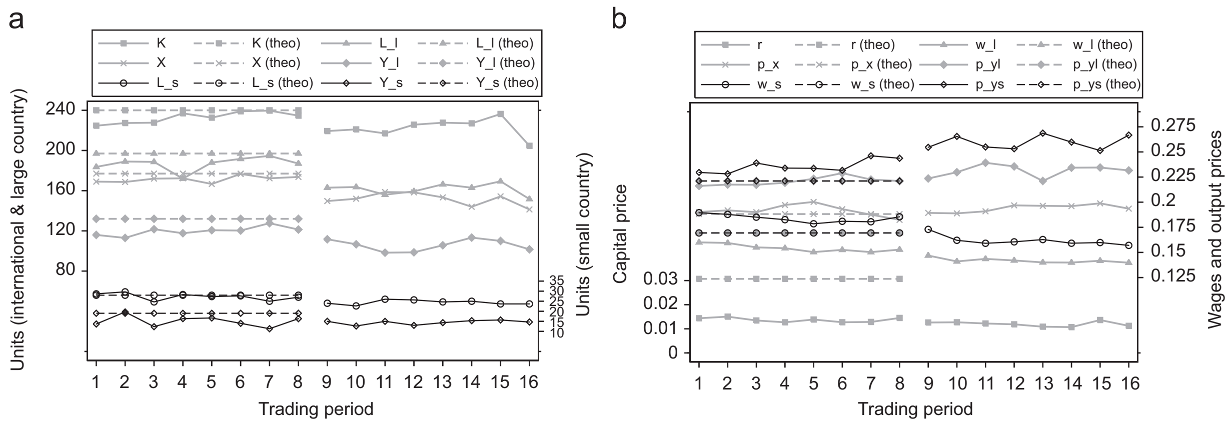

Fig. 1. Quantities and prices under the WT-system. (a) Quantities, (b) relative prices.

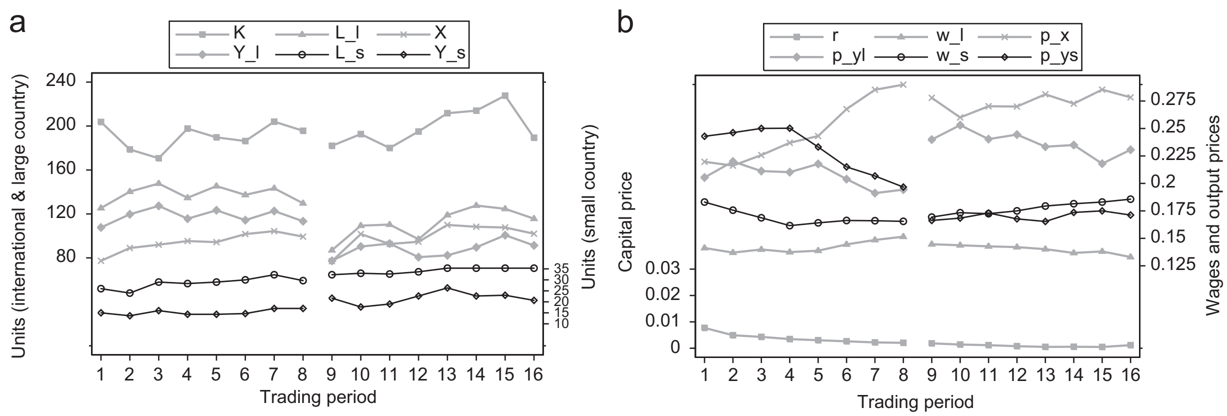

Fig. 2. Quantities and prices under the STLS-system. (a) Quantities, (b) relative prices.

countries the unemployment rate exhibits even strong convergence (from above) as does real GDP (from below) in the small country and the *Y*-production intensity in the large country. There is, however, a caveat to this result. As will be demonstrated below, this rather positive result does not come for free, because it is associated with relatively large budget deficits.

We now turn to a comparison of the two tax systems in the constant tax regime. Comparing Fig. 1(a) with Fig. 2(a) shows that economic activity starts at a lower level in the experimental sessions with the STLS-system. This holds for the employment of both input factors and is accompanied by lower input prices. In particular, output of the exposed sector *X* is affected, while its product price p_x exhibits a clear upward thrust. To put this outcome into perspective, one has to recognize that in these periods the small country is facing substantial sales taxes, with a tax rate of 65% and 75% on the price of *X* and *Y*. Recall that these tax rates are not taken from a theoretical model but determined such that *on impact* the producers of *X* and *Y* would have to bear the same tax burden as observed under the WT-system. Thus, the initial economic circumstances are not particularly favorable for a comparatively good performance of the alternative tax system.

Our primary research questions concern the small country. Therefore, in the following we mainly, but not exclusively, focus on the economic performance regarding the small country under the two different tax regimes. Figs. 3–5 illustrate the development of the unemployment rate, the budget surplus, and real GDP, for both tax systems (and both countries). Initially, the unemployment rate in the small country is at a higher level when the STLS-system is effective. However, in spite of the high sales taxes, there is a clear tendency for the unemployment rate to decline over time (Fig. 3). This stays in clear contrast to the development of the unemployment rate under the WT-system (and the development in the large country, where a wage tax is applied in both treatments). Under the STLS-system declining unemployment appears to have a beneficial effect on the budget surplus of the small country, which substantially increases over time (see Fig. 4). Wage taxes, on the other hand, are systematically accompanied by budget deficits; this holds for the baseline treatment (WT-system, small and large country) as well as the alternative treatment (large country with wage tax system). A similar picture emerges from the development of real GDP (see Fig. 5). Whereas economic activity strongly increases in the small country when the sales tax applies, it shows no clear development, neither in the small country nor in the large country, when the wage tax system is effective.

Result 2. *By the end of the constant tax regime, most economic performance indicators show a significant improvement for the small country under the STLS-system compared to the WT-system. Only consumer earnings unadjusted for the budget surplus are*

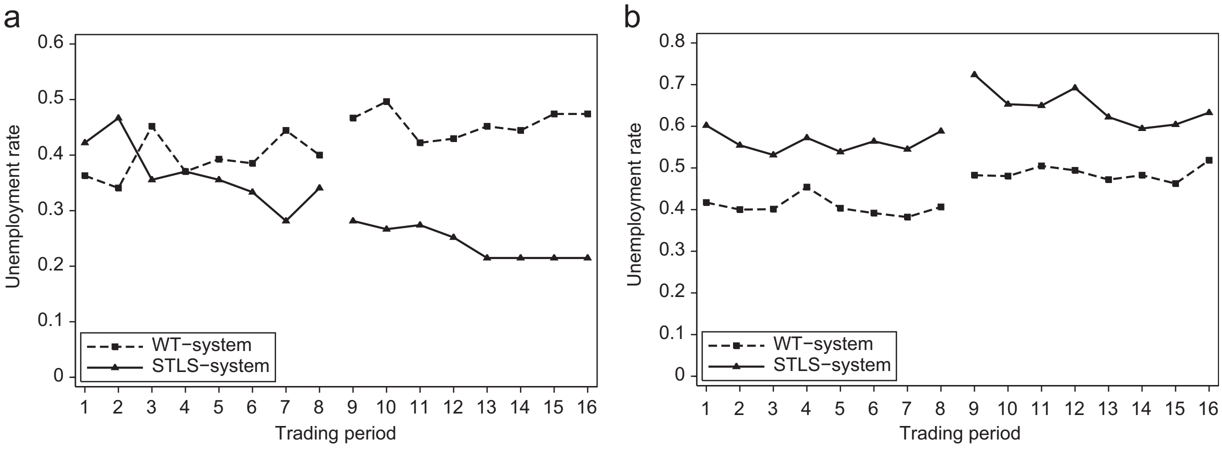

Fig. 3. Unemployment rates under the two tax systems. (a) Small country, (b) large country.

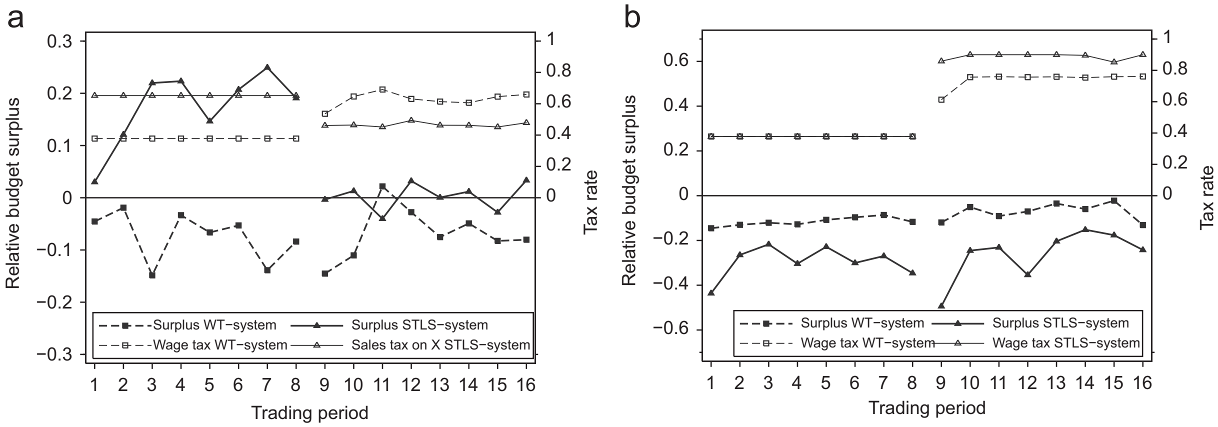

Fig. 4. Budget surplus and tax rates under the two tax systems. (a) Small country, (b) large country.

significantly lower under the STLS-system. In the large country, where in both treatments the wage tax is applied to finance unemployment benefits, no such development is observed.

These observations are statistically supported by a convergence analysis using an extension of the estimation model presented above.[15] Table 3 gives the results. Whereas the asymptotic estimates for the large country (b_2 versus a_2) still show the negative effects of the relatively adverse start in economic activity in these sessions, the outcomes for the small country are quite different. Compared to the WT-system, we see that in the STLS-system consumer earnings net of budget surplus (consumer earnings 2) are statistically and economically significantly larger. Together with the significantly worse performance of the WT-system in terms of budget surplus this also indicates that its slightly better performance regarding uncorrected consumer earnings (consumer earnings 1) comes at the cost of large budget deficits.[16] Real GDP also shows a statistically significant better outcome under the STLS-system than under the WT-system. The remaining two variables, shift in production toward the labor intensive sector Y and net capital export, are not significantly different for the two tax systems.

Note that these outcomes contradict the discussed intuitive hypothesis that the STLS-system will perform worse than the WT-system.

[15] The estimation model now becomes

$$y_{it} = a_{11}D_{A1}(1/t)+a_{12}D_{A2}(1/t)+a_{13}D_{A3}(1/t)+a_2D_A(t-1)/t$$
$$+b_{11}D_{B1}(1/t)+b_{12}D_{B2}(1/t)+b_{13}D_{B3}(1/t)+b_2D_B(t-1)/t+u_{it},$$

where D_{Bi} is a dummy variable representing session i of the STLS-system (equal to 1 for i, 0 otherwise); $D_B=1$ for sessions where the STLS-system applies in the small country, zero otherwise. The coefficients b_{1i} denote the session specific starting values and b_2 the asymptotic value of y in the STLS-system.

[16] Adding producer profits to consumer earnings mainly improves the outcomes for the STLS-system relative to the WT-system. When taking the budget balance not into account the WT-system does economically better ($a_2=220.4$) than the STLS-system ($b_2=81.4$) but standard errors also increase leading to only a marginally significant difference ($p=0.069$). When taking the budget balance into account the STLS-system generates statistically and economically significantly higher earnings ($a_2=13.9$, $b_2=561.5$, $p=0.000$).

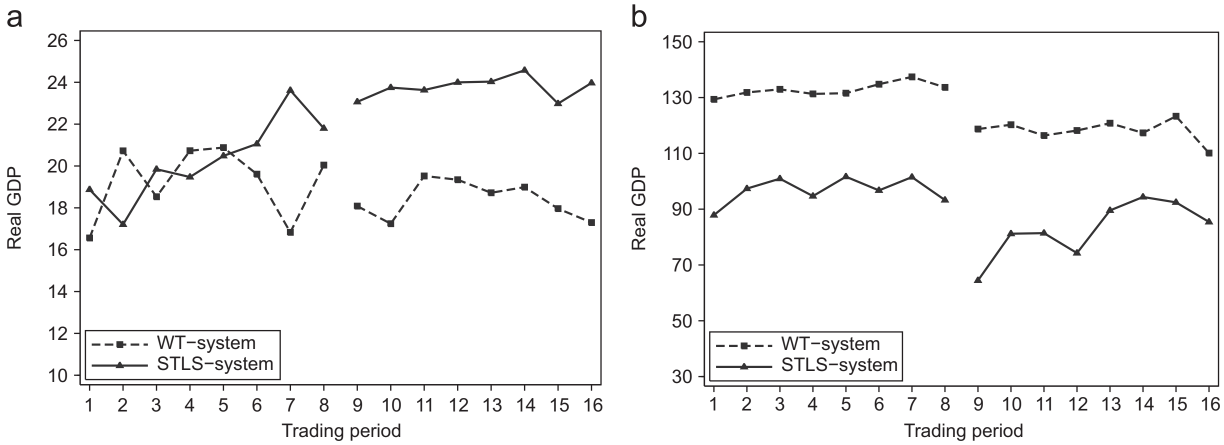

Fig. 5. Real GDP under the two tax systems. (a) Small country, (b) large country.

Table 3
Convergence regressions for constant tax regime: economic performance indicators compared between the tax systems.

Variable	a_{11}	a_{12}	a_{13}	b_{11}	b_{12}	b_{13}	a_2	b_2	p-value[a]	Wald's χ^2
	Small country									
Unemployment rate	0.3738	0.4479	0.2927	0.5547	0.6151	0.2683	0.4326	0.3134	0.001	2667.5
	(0.0552)	(0.0779)	(0.1017)	(0.0371)	(0.0357)	(0.0373)	(0.0317)	(0.0135)		
Budget surplus	−0.0927	−0.0895	−0.0070	0.0266	−0.0566	0.1056	−0.1409	0.2069	0.000	124.3
	(0.0676)	(0.0804)	(0.1129)	(0.0538)	(0.0923)	(0.0428)	(0.0345)	(0.0251)		
Real GDP	13.6	14.1	25.1	15.3	14.2	22.3	20.0	21.8	0.039	6392.5
	(2.02)	(1.99)	(1.54)	(1.44)	(1.84)	(1.22)	(0.68)	(0.56)		
Consumer earnings 1	84.0	88.0	107.1	67.4	18.7	104.6	98.4	87.3	0.013	17157.8
	(7.48)	(11.97)	(3.60)	(6.03)	(9.66)	(4.78)	(2.75)	(3.52)		
Consumer earnings 2	−13.9	−36.2	172.7	108.4	−25.4	331.5	−59.0	549.7	0.000	81.35
	(80.25)	(119.38)	(167.24)	(147.67)	(350.22)	(120.64)	(48.00)	(76.94)		
Net capital export	8.9	1.3	−16.8	2.8	0.4	−0.9	−8.1	−9.9	0.560	86.5
	(6.43)	(4.75)	(2.85)	(4.38)	(7.21)	(3.42)	(2.36)	(2.15)		
Y-production intensity	0.5018	0.5133	0.4011	0.5607	0.5293	0.4975	0.3625	0.3347	0.351	2061.5
	(0.0541)	(0.0527)	(0.0438)	(0.0510)	(0.0763)	(0.0522)	(0.0188)	(0.0231)		
	Large country									
Unemployment rate	0.4699	0.4429	0.3506	0.6928	0.6579	0.3653	0.4088	0.5206	0.000	6001.3
	(0.0385)	(0.0357)	(0.0451)	(0.0257)	(0.0905)	(0.0672)	(0.0167)	(0.0151)		
Budget surplus	−0.2724	−0.1578	−0.0425	−0.5536	−0.6708	−0.0388	−0.1174	−0.2175	0.000	1339.8
	(0.0467)	(0.0154)	(0.0539)	(0.0470)	(0.1587)	(0.0714)	(0.0108)	(0.0258)		
Real GDP	120.7	127.2	139.1	71.3	79.5	132.4	134.8	108.6	0.000	30313.3
	(8.16)	(2.31)	(6.01)	(5.25)	(18.67)	(10.87)	(1.64)	(3.26)		
Consumer earnings 1	197.3	207.6	214.6	176.9	177.4	197.8	208.9	197.2	0.001	136271.6
	(2.41)	(1.93)	(2.63)	(6.06)	(11.93)	(5.65)	(0.95)	(3.49)		
Consumer earnings 2	−1489.6	−1369.3	−219.5	−3865.3	−3344.2	−379.0	−843.3	−1926.2	0.000	1814.1
	(428.87)	(122.11)	(492.82)	(253.75)	(940.85)	(665.68)	(84.61)	(150.48)		
Net capital export	−8.9	−1.3	16.8	−2.8	−0.4	0.9	8.1	9.9	0.560	86.54
	(6.43)	(4.75)	(2.85)	(4.38)	(7.21)	(3.42)	(2.36)	(2.15)		
Y-production intensity	0.3606	0.5322	0.4025	0.5437	0.7096	0.6178	0.4416	0.6612	0.000	4060.7
	(0.0257)	(0.0352)	(0.0230)	(0.0493)	(0.0379)	(0.0371)	(0.0157)	(0.0178)		

Note: Superscript c (p) indicates units consumed (produced). Standard errors in parentheses; corrected for session specific heteroscedasticity and AR(1). 'Unemployment rate' is defined as the amount of unemployed units of labor relative to the total labor force (endowment) in the respective country; 'Budget surplus' denotes the nominal budget surplus relative to nominal GDP (defined as the total nominal value of the produced goods) in the respective country; the base 'year' for calculating 'Real GDP' is the first trading period in each session; 'Consumer earnings 1' denotes average earnings of a consumer in points ('utility'); 'Consumer earnings 2' are 'Consumer earnings 1' with the per capita budget surplus added; 'Net capital export' is the difference between total capital sold to the other country and total capital bought from the other country; 'Y-production intensity' denotes the total amount of goods produced in the Y-sector relative to the total amount of goods produced in the respective country.

[a] Tests the hypothesis that the asymptotic values a_2 and b_2 are equal; two-sided Wald tests.

3.2. Variable tax regime

Here we present the results of the trading periods where the tax rates adjusted to the budget surplus in the previous period. This will show the robustness of our findings obtained so far. In addition, we can examine the economic impact of changes of tax rates in the different tax systems. It also allows us to test for possible convergence of economic activity in the STLS-system and, hence, to explore whether economic activity coordinates on one of the two theoretical general equilibria.

On impact the adjustment of tax rates to the budget surplus in the previous trading period produces an economic shock under both systems. This can be observed from the development of the quantity variables shown in Figs. 1 and 2(a). From the former it can be seen that, under the WT-system, all traded quantities in both countries decrease from period 8 to period 9. Under the STLS-system, the quantities traded internationally and in the large country also decrease, but now the traded quantities of local goods in the small country (L_s and Y_s) increase when the tax rates begin to adjust (Fig. 2(a)).

In the last constant tax period all economies with wage taxation are confronted with substantial budget deficits, whereas large surpluses are generated under the sales tax system in the small country. Therefore, in the first period of the variable tax regime, tax rates increase in the former and decrease in the latter case (see Fig. 4). Figs. 3 and 5 illustrate that in the economies with wage taxation this triggers a clearly negative economic shock with increasing unemployment rates and decreasing real GDP. As a result, the budget balance does not improve in the transition period 9 (see Fig. 4). Thereafter, these economies seem to improve somewhat, showing some convergence toward a balanced budget and a full utilization of capital (see Fig. 2). However, unemployment stays at a high level, which has a negative effect on outputs, as manifested by the development of real GDP in Fig. 5.[17]

These developments in the economies where the wage tax system applies are in stark contrast to the economic development in the small country under the alternative tax system. First of all, the initial decline in the sales tax rates in period 9 produces positive economic effects. The unemployment rate drops significantly and real GDP clearly increases (see Figs. 3(a) and 5(a)). Note also the positive effect on the wage rate (w_s), and the negative effect on the price of the labor intensive good Y (p_{ys}), in contrast to the development under wage taxation (see Figs. 1(b) and 2(b)). Both effects are due to the substitution of the wage tax with a labor subsidy. Remarkably, under the STLS-system the budget immediately balances, and stays so over the remaining periods, with only small deviations. Furthermore, the unemployment rate and real GDP further improve in later periods, and show convergence toward a level that is substantially different from the level reached under the WT-system (Figs. 3(a) and 5(a)).

Table 4 presents the results of the convergence analysis comparing the performance of the two tax systems for the variable tax regime. These estimation results corroborate the above observations. Comparing the estimated asymptotic values a_2 and b_2, for the small country under the STLS-system, a significant decrease in the unemployment rate and net capital export together with a significant increase in real GDP can be observed. For the budget surplus, the labor intensity of production, and both of the consumer earnings measures, no statistically significant differences are found. Note, however, that under the STLS-system consumer earnings corrected for budget deficits (consumer earnings 2) converge to a value that is almost twice as large as under the WT-system. That this difference is statistically insignificant is due to the large standard errors under the WT-system.[18] The following result summarizes.

Result 3. *Under the variable tax regime, all economic performance indicators of the country where the STLS-system is applied further improve, relative to the WT-system as well as in absolute terms.*

Not surprisingly, for the large country, the outcomes are worse for the STLS-system sessions, because of the bad start. Note, however, that the asymptotic values a_2 and b_2, which are statistically significantly different for unemployment and consumer earnings uncorrected for the budget surplus, clearly show a movement toward each other. For both indicators the starting values are much further apart than the asymptotic values. Furthermore, the differences seem economically not significant. The budget surplus is clearly negative and virtually the same under both systems as are the consumer earnings net of the budget surplus. The significant difference in net capital export mirrors the result for the small country.

An important further issue concerns the economic effect of *changes* in the different tax rates under the two tax systems. Table 5 shows the results of a regression analysis with respect to the economic performance indicators: unemployment rate, capital employment, real GDP, consumer earnings, net capital flight, and Y-production intensity. In addition to the tax rates the number of the trading period is also included as an explanatory variable, to control for a time trend.[19]

Several observations are in order. First of all, the signs of all tax effects are in line with economic intuition. For both the wage tax and the sales tax it appears that tax hikes have a negative impact on economic activity and consumer earnings of the country directly involved. Higher taxes also encourage capital flight. Furthermore, changes of tax rates in the small country have no spill-over effects on the large country (the only exception being the effect of a wage tax change on capital

[17] Note, furthermore, that the gap between the values of the economic performance indicators in the large country narrows over the periods with variable tax rates. We will return to this when presenting the convergence analysis for the variable tax regime.

[18] Adding producer profits to consumer earnings significantly improves the outcomes for the STLS-system relative to the WT-system. This holds for both with and without adjusting for the budget balance ($a_2 = 196.3, b_2 = 611.6, p = 0.000$ and $a_2 = 236.4, b_2 = 581.8, p = 0.000$, respectively).

[19] Note that the tax rates are given at the beginning of each trading day and, hence, are exogenous to the investigated economic variables in that period.

Table 4
Convergence regressions for variable tax regime: economic performance indicators compared between the tax systems.

Variable	a_{11}	a_{12}	a_{13}	b_{11}	b_{12}	b_{13}	a_2	b_2	p-value[a]	Wald's χ^2
	Small country									
Unemployment rate	0.6647	0.5279	0.2076	0.3200	0.2726	0.2974	0.4807	0.2417	0.000	2818.1
	(0.0790)	(0.0155)	(0.0845)	(0.0592)	(0.0270)	(0.0411)	(0.0279)	(0.0151)		
Budget surplus	−0.3990	−0.0357	−0.0155	0.0151	−0.0295	0.0061	−0.0259	0.0038	0.210	30.1
	(0.0940)	(0.0349)	(0.0450)	(0.0119)	(0.0261)	(0.0177)	(0.0227)	(0.0067)		
Real GDP	15.1	16.1	26.1	21.3	24.1	22.4	18.9	22.8	0.000	8526.7
	(3.43)	(0.25)	(2.46)	(1.76)	(1.29)	(1.11)	(0.91)	(0.56)		
Consumer earnings 1	83.4	86.3	70.7	82.3	76.8	104.8	91.8	89.3	0.640	5030.7
	(4.41)	(5.00)	(10.25)	(8.10)	(11.90)	(10.82)	(2.32)	(4.83)		
Consumer earnings 2	−353.9	49.6	64.7	122.8	−1.1	114.0	64.2	104.6	0.230	447.5
	(108.24)	(47.05)	(73.52)	(22.09)	(64.71)	(34.69)	(30.73)	(13.86)		
Net capital export	2.0	5.0	−22.0	0.1	0.7	−23.9	−5.9	−20.1	0.000	550.9
	(7.48)	(1.48)	(7.16)	(6.47)	(3.80)	(3.05)	(1.04)	(1.57)		
Y-production intensity	0.3046	0.4229	0.4113	0.4361	0.5061	0.4846	0.4091	0.4204	0.709	11007.1
	(0.0471)	(0.0111)	(0.0296)	(0.0654)	(0.0970)	(0.0586)	(0.0107)	(0.0283)		
	Large country									
Unemployment rate	0.6007	0.5046	0.4126	0.6807	0.8258	0.6193	0.5244	0.5838	0.043	9030.9
	(0.0174)	(0.0676)	(0.0609)	(0.0706)	(0.0842)	(0.0222)	(0.0203)	(0.0213)		
Budget surplus	−0.3274	−0.0705	−0.0126	−0.3562	−0.7059	−0.3281	−0.1249	−0.1216	0.945	283.4
	(0.0435)	(0.0705)	(0.0609)	(0.1140)	4(0.1534)	(0.0470)	(0.0344)	(0.0339)		
Real GDP	96.3	117.6	133.3	73.5	48.3	85.1	110.5	98.8	0.053	5736.4
	(3.93)	(11.53)	(12.01)	(15.34)	(18.14)	(4.99)	(3.91)	(4.61)		
Consumer earnings 1	196.7	202.4	211.1	188.7	169.5	192.4	203.9	197.5	0.008	101716.7
	(2.16)	(6.74)	(3.35)	(3.19)	(8.90)	(3.88)	(1.51)	(1.91)		
Consumer earnings 2	−2343.8	−550.1	93.3	−2155.2	−4374.2	−1830.1	−750.2	−935.9	0.631	222.7
	(366.52)	(579.34)	(481.54)	(948.01)	(1154.18)	(323.99)	(282.92)	(264.15)		
Net capital export	−2.0	−5.0	22.0	−0.1	−0.7	23.9	5.9	20.1	0.000	550.9
	(7.48)	(1.48)	(7.16)	(6.47)	(3.80)	(3.05)	(1.04)	(1.574)		
Y-production intensity	0.4409	0.4735	0.4671	0.6344	0.6051	0.5444	0.4484	0.5411	0.002	32879.1
	(0.0122)	(0.0528)	(0.0107)	(0.0409)	(0.0860)	(0.0539)	(0.0071)	(0.0289)		

Note: Superscript c (p) indicates units consumed (produced). Standard errors in parentheses; corrected for session specific heteroscedasticity and AR(1). 'Unemployment rate' is defined as the amount of unemployed units of labor relative to the total labor force (endowment) in the respective country; 'Budget surplus' denotes the nominal budget surplus relative to nominal GDP (defined as the total nominal value of the produced goods) in the respective country; the base 'year' for calculating 'Real GDP' is the first trading period in each session; 'Consumer earnings 1' denotes average earnings of a consumer in points ('utility'); 'Consumer earnings 2' are 'Consumer earnings 1' with the per capita budget surplus added; 'Net capital export' is the difference between total capital sold to the other country and total capital bought from the other country; 'Y-production intensity' denotes the total amount of goods produced in the Y-sector relative to the total amount of goods produced in the respective country.

[a] Tests the hypothesis that the asymptotic values a_2 and b_2 are equal; two-sided Wald tests.

flight, which is due to the definition of this variable). An increase of the wage tax in the large country, however, has a statistically significantly negative effect on consumer earnings in the small country.

The regression results clearly show that a wage tax increase has strong adverse effects on the economic performance in the respective country. This is witnessed by the statistically and economically highly significant coefficients of the wage taxes τ_{ws} in the small country and τ_{wl} in the large country, in most regressions. Increasing the wage tax rate in a country substantially increases unemployment and capital flight and decreases real GDP and capital employment.

An increase of the sales tax rate in the small country also adversely affects unemployment and real GDP in a statistically significant way. What is striking, though, is that the magnitude of these effects is substantially smaller than the effects of a wage tax rate increase. For unemployment the coefficient is 0.4420 for the wage tax but only 0.1831 for the sales tax. Similarly, real GDP decreases by only 6.85 when the sales tax increases whereas the marginal decrease of this measure amounts to 11.95 for the wage tax. For capital employment, consumer earnings, net capital flight, and labor intensity of production, a change in the sales tax is not even significantly different from zero. The next result summarizes.

Result 4. *In the small country, compared to the wage tax, an increase in the sales tax appears to have a much smaller adverse economic impact.*

What remains to be discussed is whether under the STLS-system economic activities tend to coordinate on one of the two theoretical general equilibria presented in Table 2.[20]

[20] The equilibrium predictions in the variable tax regime are the same as in the constant tax regime in so far as in equilibrium there is a balanced budget, implying that there is no tax adjustment over periods necessary. Empirically, though, on impact (i.e. in trading period 9) the imposed taxes are out-of-equilibrium, budget surpluses are likely unbalanced and tax adjustment will occur. Therefore, in our convergence analysis we not only check the

Table 5
The effect of taxes on the performance of real economic variables.

Variable	Unemployment rate	Capital employment	Real GDP	Consumer earnings 1	Net capital flight	*Y*-production intensity
	Small country					
τ_{ws}	0.4420***	−27.95***	−11.95***	−2.89	24.42***	−0.0879
	(0.0554)	(6.02)	(1.92)	(8.18)	(5.58)	(0.0521)
τ_{xs}	0.1831*	−8.87	−6.85***	−3.38	13.96	−0.0639
	(0.0728)	(7.10)	(2.03)	(13.22)	(7.95)	(0.0750)
τ_{wl}	−0.0342	3.82	−0.25	−22.21*	−2.55	0.0308
	(0.0425)	(5.70)	(1.32)	(9.74)	(5.95)	(0.0604)
Period	−0.01	1.11	−0.03	1.15*	−1.44***	0.0018
	(0.05)	(0.54)*	(0.14)	(0.56)	(0.38)	(0.0038)
Constant	0.26***	31.30***	26.72***	95.90***	−0.25	0.4136***
	(0.06)	(6.24)	(1.78)	(6.44)	(4.37)	(0.0430)
N	54	54	54	54	54	54
R^2	0.84	0.87	0.95	0.93	0.61	0.57
Wald's χ^2	106.2	25.5	42.1	16.6	48.0	5.1
	Large country					
τ_{ws}	0.0041	32.95	5.69	6.30	−24.42***	−0.0357
	(0.0528)	(18.29)	(11.31)	(5.00)	(5.58)	(0.0628)
τ_{xs}	0.1450	−26.03	−27.46	−8.61	−13.96	0.1964***
	(0.0808)	(25.40)	(17.35)	(8.40)	(7.95)	(0.0627)
τ_{wl}	0.2793***	−49.81*	−54.71***	−25.61***	2.55	0.0238
	(0.0583)	(20.27)	(12.76)	(5.39)	(5.95)	(0.0472)
Period	−0.0032	0.4667	0.4183	0.6010	1.44***	0.0005
	(0.0043)	(1.18)	(1.00)	(0.4271)	(0.38)	(0.0032)
Constant	0.3371***	203.58***	147.29***	210.60***	0.25	0.4485***
	(0.0487)	(13.06)	(11.39)	(38.46)	(4.37)	(0.0367)
N	54	54	54	54	54	54
R^2	0.95	0.93	0.93	0.99	0.61	0.88
Wald's χ^2	38.2	54.1	27.4	24.6	48.0	19.0

Note: *** significant at 0.1%, ** significant at 1%, and * significant at 5%. Standard errors in parentheses; corrected for session specific heteroscedasticity and AR(1). All estimates are based on periods 8–16. 'Unemployment rate' is defined as the amount of unemployed units of labor relative to the total labor force (endowment) in the respective country; 'Capital employment' denotes the total amount of capital employed in the respective country; 'Real GDP' is total value of produced goods in the respective country with the first trading period in each session as the base 'year'; 'Consumer earnings 1' denotes the average earning of a consumer in points ('utility'); 'Net capital flight' is the difference between total capital sold to the other country and total capital bought from the other country; '*Y*-production intensity' denotes the total amount of goods produced in the *Y*-sector relative to the total amount of goods produced in the respective country. Only one sales tax rate appears in the regressions because of the fixed ratio of the tax rates for the two production sectors.

To this end we performed a convergence analysis for periods 9 to 16 and compared the outcomes with the theoretical predictions. Table 6 presents the results. In the table, column 'equil. 1' shows the predictions of the 'favorable' general equilibrium and the column 'equil. 2' those of the 'unfavorable' one. For the international variables, which are mainly influenced by the large country, it holds that too little capital is employed and (accordingly) too little X produced. Both variables, however, exhibit weak convergence toward the equilibrium values which are virtually identical in the two general equilibria. On the other hand, the price of capital is too low and the price of commodity X appears to be too high. All this suggests that the equilibration process did not yet settle down on the international markets. A similar picture can be observed for the development of variables in the large country. There, capital and labor employment as well as the production and consumption of X weakly converge toward the equilibrium values from below. Concerning the local prices of labor and Y it can be observed that the former is too low and the latter to high compared to any of the equilibrium predictions. The budget surplus is weakly balancing from below but the tax rate τ_{wl} is much too high and far removed from any equilibrium value.

For the small country in which the alternative STLS-system applies the results are remarkably different. Three of the five real variables converge at least weakly to the favorable equilibrium (L_s, X_s^c, and Y_s). Capital K and the production level of the capital intensive commodity, X_s^p, even overshoot the prediction of the favorable equilibrium. The budget balance strongly converges to zero, while the sales taxes (weakly) converge to the tax rates predicted by the favorable general equilibrium. Also the wage rate weakly converges from below to the value predicted in the favorable equilibrium. Only the

(*footnote continued*)
dynamics of the quantity and price variables, but also of the budget surplus and the now endogenous tax rates. This analysis will inform us whether the economies endogenously coordinate on (or at least come close to) one of the static theoretical equilibria with a balanced budget.

Table 6
Convergence regressions for variable STLS regime: comparison with theoretical equilibrium predictions.

Variable	b_{11}	b_{12}	b_{13}	b_2	Equil. 1	p-value[a]	Equil. 2	p-value[a]	Wald's χ^2
	International								
K	188.4 (23.73)	131.6 (10.39)	201.7 (12.37)	209.3 (4.73)	240	0.000	240	0.000	5050.2
X	82.0 (21.0)	91.7 (21.4)	95.0 (12.3)	132.1 (7.86)	181	0.000	182	0.000	473.7
r	0.0036 (0.0003)	0.0010 (0.0003)	0.0011 (0.0006)	0.0006 (0.0002)	0.0295	0.000	0.0289	0.000	250.2
p_x	0.2313 (0.35)	0.3450 (0.97)	0.2191 (0.44)	0.2427 (0.32)	0.1807	0.000	0.1807	0.000	2624.9
	Small country								
K_s	29.8 (7.69)	36.6 (7.17)	50.4 (4.32)	51.1 (3.63)	28	0.000	11	0.000	451.1
L_s	30.6 (2.67)	32.7 (1,21)	31.6 (1.85)	34.1 (0.68)	33	0.098	18	0.000	5719.6
X_s^c	11.9 (2.76)	9.6 (5.42)	19.0 (4.30)	18.9 (1.63)	25	0.000	17	0.235	260.7
X_s^p	27.5 (4.03)	23.8 (5.55)	22.4 (2.21)	30.0 (1.44)	25	0.001	14	0.000	1038.2
Y_s	20.5 (4.13)	23.6 (4.01)	21.4 (3.32)	21.2 (1.60)	21	0.917	11	0.000	370.6
w_s	0.1566 (0.0144)	0.1099 (0.0178)	0.1998 (0.0235)	0.1647 (0.0128)	0.1971	0.011	0.1292	0.005	237.0
p_{ys}	0.2074 (0.0048)	0.0979 (0.0309)	0.1950 (0.0329)	0.1704 (0.0043)	0.2165	0.000	0.2747	0.000	13,928.1
τ_{pxs}	0.5442 (0.0143)	0.2985 (0.0286)	0.5239 (0.0264)	0.4681 (0.0099)	0.4889	0.035	0.7835	0.000	8102.9
sur_s	0.0151 (0.0119)	−0.0295 (0.0261)	0.0061 (0.0177)	0.0038 (0.0067)	0	0.568	0	0.568	8086.3
	Large country								
K_l	160.3 (17.84)	105.5 (13.77)	148.3 (17.14)	168.6 (5.96)	212	0.000	229	0.000	1809.9
L_l	100.6 (22.24)	54.9 (26.53)	119.9 (7.00)	131.1 (6.70)	199	0.000	213	0.000	1749.2
X_l^c	69.5 (14.26)	82.1 (18.60)	75.6 (10.86)	111.5 (6.42)	156	0.000	165	0.000	488.2
X_l^p	54.2 (19.98)	61.6 (18.53)	74.5 (11.68)	100.4 (7.51)	156	0.000	168	0.000	300.5
Y_l	100.4 (10.24)	32.9 (9.57)	99.7 (6.97)	92.3 (3.49)	133	0.000	140	0.000	1832.8
w_l	0.1451 (0.0037)	0.1533 (0.0052)	0.1538 (0.0065)	0.1446 (0.0032)	0.1640	0.000	0.1743	0.000	4289.4
p_{yl}	0.2380 (0.0069)	0.3103 (0.0217)	0.2313 (0.0183)	0.2512 (0.0111)	0.2123	0.000	0.2121	0.000	1934.6
τ_{wl}	0.8762 (0.0418)	0.8982 (0.0067)	0.8258 (0.0228)	0.8958 (0.0156)	0.3655	0.000	0.2769	0.000	141,093.6
sur_l	−0.3562 (0.1140)	−0.7059 (0.1534)	−0.3281 (0.0470)	−0.1216 (0.0339)	0	0.000	0	0.000	207.5

Note: For X superscript c (p) indicates units consumed (produced); for Y quantities produced are used as units of observation. Standard errors in parentheses; corrected for session specific heteroscedasticity and AR(1). Only the sales tax rate τ_{pxs} appears because of the exogenously fixed ratio of the tax rates for the two production sectors.

[a] Tests the hypothesis that the asymptotic value a_2 is equal to the theoretical prediction; two-sided Wald tests.

price of the local good Y does not show a clear pattern in the small country. The following result summarizes the main observations.

Result 5. *Under the variable tax regime, when the STLS-system obtains in the small country and the WT-system obtains in the large country, the international and large country real variables mostly weakly converge toward the equilibrium predictions, from below, while the input prices are too low and the output prices too high. In contrast, in the small country all variables (but one) are either converging toward the favorable equilibrium or do even better than this equilibrium predicts.*

Table 7
Fraction of cases where producers' marginal revenue product exceeds net input price.

	WT-system		STLS-system		WT-system		STLS-system	
	Labor	Capital	Labor	Capital	Labor	Capital	Labor	Capital
	Small country				Large country			
X-sector	0.479	0.646	0.750	0.958	0.615	0.802	0.865	0.979
	(0.695)	(0.003)	(0.000)	(0.000)	(0.016)	(0.000)	(0.000)	(0.000)
Y-sector	0.576	0.771	0.694	0.674	0.618	0.625	0.646	0.632
	(0.040)	(0.000)	(0.000)	(0.000)	(0.003)	(0.002)	(0.000)	(0.632)

Note: Based on average current period input and output prices and all periods; within parentheses the probability of obtaining values at least as extreme as observed when $p=0.5$; binomial test, one-sided; $n=96$.

4. A behavioral explanation and empirical support

The presented experimental results suggest that financing unemployment benefits via sales taxes, in combination with a subsidy for employment, leads to much better economic outcomes than using a wage tax, even in a relatively small open economy. In the following we present theoretical arguments and empirical support for the following claim, which offers an explanation of these observations.

Claim 1. *Uncertainty about product prices makes producers reluctant to incur production costs. This can explain the good economic performance of the sales-tax-cum-labor-subsidy system in comparison with the wage tax system. Instead of being confronted with a tax burden up-front on the input of labor, producers under the former system receive a labor subsidy and only have to pay taxes in proportion to their sales revenues, which effectively means risk sharing by the government.*

To substantiate this claim we offer four pieces of evidence, which extend the findings of Riedl and van Winden (2007) concerning the WT-system. *First*, recall from Result 1 that under the constant wage tax regime quantity and input price variables typically converge from below, whereas output prices seem to converge from above toward the competitive equilibrium levels of the theoretical general equilibrium model. Although this theoretical model does not capture all details of our complex lab economy, the result is suggestive of some downward pressure on the demand for inputs. Also, because these outcomes are accompanied by a budget deficit. A *second* piece of evidence in this respect is obtained by comparing the (after tax) marginal revenue product of labor and capital with the respective net input price. Table 7 shows the fraction of cases in which producers' marginal revenue product *exceeds* the input price, using average current prices.[21] Assuming random errors, profit maximization would be consistent with a fraction of 50%. The observed fractions are remarkably different from this benchmark, however.[22] Our next result summarizes the evidence.

Result 6. *Averaging over periods and tax systems, for about 70% of the cases producers' marginal revenue product of capital* (74%) *and labor* (65%) *exceeds the input price. With only one exception in each system, the excess is significant.*

This result provides further support for the view that, under both tax systems, producers are reluctant to buy inputs. In particular, because we have no evidence of a shortage of capital or labor.[23] As referred to in Riedl and van Winden (2007), Noussair et al. (1995) observe a similar phenomenon in an experiment concerning international trade. These authors conjecture that producers may require a compensation for the market risk they run, since they may not be able to sell outputs. A likely underlying reason for this behavior is some form of aversion toward risk or losses. Indeed, as discussed in the Introduction (Section 1), theoretical partial equilibrium models exist indicating that product price uncertainty reduces the factor demand of risk-averse competitive firms, and risk-averse behavior of firms appears to be a realistic assumption (see, e.g., Zhang, 1998; Stiglitz, 1999). Yet, empirical microeconomic studies of the consequences of market uncertainty for factor demand are scarce (see Ghosal (1995)). Important exceptions are Leahy and Whited (1996) and Guiso and Parigi (1999). Both of these studies find that investment is negatively affected by uncertainty.

Taking the standard deviation of transaction prices in the previous period as a measure of expected price uncertainty in the current period, we examine the correlation of this measure with the employment of capital and labor. Table 8 presents

[21] Similar results are obtained when the average product price of the previous period is used.

[22] Moreover, comparing the second half of the trading periods with the first half, there is no systematic decrease in the excess; see Supplementary materials).

[23] On the contrary, comparing actual labor supply with theoretical labor supply - using the benchmark model and actual prices - we find excess supply for a fraction of consumers that is significantly larger than 50% (on average, 94% for the WT-system and 73% for the STLS-system). Concerning capital, the relatively low capital price also points into the direction of an excess supply (see Figs. 1 and 2). We can also confidently reject that factor demand was restricted by binding nominal cash-in-advance constraints. In both systems and both countries the cash left over by producers when the factor markets closed was never below 16% of the initial cash in any trading period.

Table 8
Correlation of factor employment and output price uncertainty.

	WT-system	STLS-system		WT-system	STLS-system
L_{ys}	−0.0868	−0.3490	K_{ys}	−0.0056	−0.3390
	(0.5709)	(0.0188)		(0.9711)	(0.0227)
L_{yl}	−0.3198	−0.4796	K_{yl}	−0.3251	0.2455
	(0.0322)	(0.0009)		(0.0293)	(0.1041)
L_{xs}	−0.3195	−0.5016	K_{xs}	−0.3004	−0.6194
	(0.0324)	(0.0004)		(0.0450)	(0.0000)
L_{xl}	−0.2721	−0.6669	K_{xl}	0.0737	−0.5833
	(0.0706)	(0.0000)		(0.6304)	(0.0000)
L_x	−0.2828	−0.6565	K_x	−0.0523	−0.6567
	(0.0598)	(0.0000)		(0.7331)	(0.0000)

Note: Entries show Spearman's ρ between employment of the mentioned factor in period t and the standard deviation of the relevant nominal output price in period $t-1$; p-values in parentheses, two-sided tests.

the outcomes and shows a mostly significantly negative correlation for both tax systems. The next result summarizes this *third* piece of evidence for our claim.

Result 7. *In both tax systems, the demand for capital and labor is significantly negatively correlated with output price uncertainty.*

Studies into the causes of risk averse behavior provide additional support for our result of a negative effect of price uncertainty on factor demand. For example, Caplin and Leahy (2001) argue that conventional measures of risk aversion underestimate the effect of uncertainty on asset prices due to the neglected impact of anxiety.[24] In the context of sequential markets it is also important to note that people seem to treat delayed outcomes as being uncertain (see Keren and Roelofsma, 1995). Furthermore, it has been shown that already little perceived uncertainty can have substantial real behavioral effects (cf. Harless and Camerer, 1994; Loewenstein et al., 2001). Thus, it need not be surprising if we do not observe rapid convergence to competitive equilibrium levels in complex market environments. To improve theoretical predictions it seems important to take the so far neglected dynamic *behavioral* aspects of such market economies into account. A research direction which is strongly advocated by Akerlof (2002) and Akerlof and Shiller (2009).

Importantly, the overall output price uncertainty turns out to be similar under both tax systems. In fact, our measure of uncertainty shows some tendency to be larger under the STLS-system. Together with the above result and the relatively good performance of the economy under that system this corroborates the view that producers perceive the uncertainty differently under the WT- and the STLS-system. The fact that under the latter system the risk can be shared with the government seems to play an important role here.

For our *fourth* and final piece of evidence for our claim we return to Table 5. This table shows that increases in the sales tax have much weaker adverse economic effects than increases in the wage tax. This finding fits the view that producers are relatively more concerned with incurring certain costs up-front than with some uncertain costs that can be shared with the government in the future.[25]

5. Conclusion

Based on conventional economic indicators our experimental comparison of a wage tax system and an alternative sales tax system can only conclude in favor of the alternative. The main reason for this result seems to be producers' reluctance to incur production costs up-front when facing product price uncertainty. We present four pieces of experimental evidence in support of this claim. This evidence makes it understandable that the alternative tax system performs much better than the wage tax system. Instead of having to pay an input tax up-front, producers receive a labor subsidy while they only have to pay taxes in proportion to whatever the sales revenues turn out to be. The latter effectively means risk sharing by the government. Furthermore, our claim finds support from some theoretical models showing that risk-averse firms indeed employ fewer inputs.

A major aspect of our study is that it uses laboratory experiments for evaluating different tax regimes in a macroeconomic context. This and the potential policy relevance raises questions of external validity. Recently, a number of studies investigated if observations in the laboratory obtained with students carry over to outside-lab situations with non-student subjects. So far the results are mixed. For instance, Alevy et al. (2007) investigate the behavior of financial market professionals regarding information cascades and find that "professionals are less Bayesian than students"

[24] Experimental evidence of a negative impact of anxiety on risk taking is presented in Bosman and van Winden (2010).

[25] We have also looked at the correlation between tax rates and output price uncertainty (dispersion of output prices in the same period). In contrast with the positive correlations observed by Riedl and van Winden (2007) for the WT-system, we find a mixture of positive and negative correlations for the STLS-system.

(Alevy et al., 2007, p. 161) but report only little evidence for differences in cascade formation. Haigh and List (2005) investigate the difference in myopic loss aversion (MLA) between students and professional traders and find that "traders exhibit behavior consistent with MLA to a *greater* extent than students" (Haigh and List, 2005, p. 523, emphasis in original). This latter result is of particular interest for our study because it could indicate that the reluctance to trade we observe under the wage tax system may be even larger for professionals.

Our study can be seen as part of a still relatively small but the recently growing literature using experiments to investigate macroeconomic (policy) issues (see, e.g., Bernasconi and Kirchkamp, 2000; Duffy and Ochs, 2002, for surveys see Duffy, 2008b; Normann and Ricciuti, 2009). The research that is accumulating in this area is of interest from a scientific as well as policy perspective. On the policy side, the experimental findings are in agreement with Akerlof's view that macroeconomics should be behavioral, in the spirit of Keynes (Akerlof, 2002, p. 428; see also Akerlof and Shiller, 2009). On the scientific side, these findings may have a wider bearing on the theoretical modeling of how economic agents behave in complex dynamic market environments. As noted by Plott (2001): "as it turns out, the classical theories of price adjustment are incomplete" (p. 3), and "experiments teach us about theory and it is theory that we use when addressing complex and new problems. The progress builds in slow and in unexpected ways" (p. 27).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.euroecorev.2011.09.002.

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