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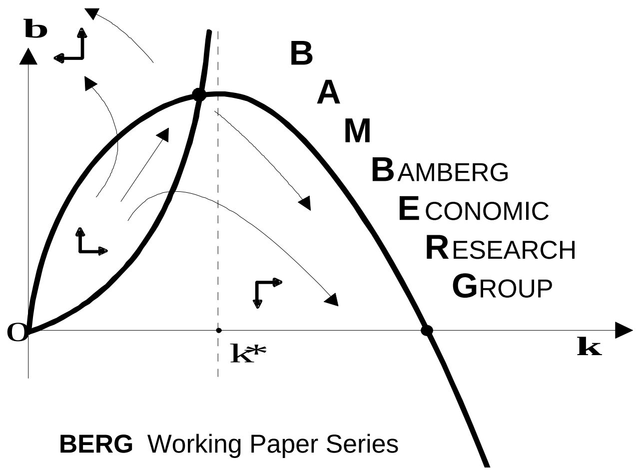

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Stability and welfare effects of profit taxes

within an evolutionary market interaction model*

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Abstract

We develop a partial equilibrium model in which firms can locate in two separate regions. A firm's decision where to locate in a given period depends on the regions' relative profitability. If firms react strongly to the regions' relative profitability, their market switching behavior generates unstable dynamics. If the goal of policy makers is to stabilize these dynamics they can do so by introducing profit taxes that reduce the regions' relative profitability. While stability can already be obtained by imposing profit taxes in one of the two regions, total welfare is maximized if policy makers coordinate their tax setting behavior across regions. However, policy makers only interested in welfare in their own region may have the incentive to decrease their profit tax below this level, thereby attracting more firms and increasing tax revenues, at the cost of instability in both regions.

Keywords

Market interactions; evolutionary dynamics; profit taxes;
policy coordination; welfare effects; stability analysis.

JEL classification

D83; E30; H20.

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1 Introduction

We develop a partial equilibrium model in which firms each period have the choice to locate in one of two separate regions, labeled region A and region B, and sell their products in that region. A firm's decision in which region to locate in a given period depends on the regions' relative profitability. Since firms only have a limited understanding of their economic environment, they try to identify the regions' relative profitability from their own past experience and by observing the past success of other firms. If firms react only weakly to the regions' relative past profitability, the model's dynamics is stable and global welfare is maximized. Welfare reducing fluctuations are set in motion, though, if firms react strongly to the regions' relative past profitability. The firms' location then leads to price and quantity fluctuations which are harmful for consumer surplus and firms' profits. Against this background, we explore whether policy makers are able to stabilize markets by imposing profit taxes. Moreover, we analyze the welfare effects of such tax policies in order to investigate whether it is optimal for policy makers to indeed stabilize markets.

Surprisingly, we find that market stability can already be established if a sufficiently high profit tax is implemented in one of the two regions. However, global welfare is only maximized if policy makers of region A and region B coordinate their tax setting behavior. The explanation for this may be summarized as follows. Policy makers are able to stabilize the dynamics in both cases since profit taxes manage to reduce the regions' relative past profitability and thereby slow down the firms' market switching behavior. The disadvantage of unilaterally imposed profit taxes is that they distort the optimal distribution of firms across markets with firms relocating to the region with lower taxes. The advantage of a bilateral tax policy is that it allows for a reduction in the regions' relative past profitability in such a way that the optimal distribution of firms remains preserved. However, policy makers may have an incentive to deviate from a coordinated tax policy. Starting from a situation in which globally optimal profit taxes are implemented in both regions, policy makers in one of the regions may try to improve local welfare by reducing profit taxes in their region. While this may compromise stability, the low-tax region attracts firms from the high-tax region which may outweigh the cost it suffers from instability.

Our paper is part of a recent stream of literature which investigates the dynamics of market interactions and policy tools to control them. Dieci and Westerhoff (2009, 2010) develop interacting cobweb market models and find that such systems tend to be more prone to instability than isolated cobweb markets. Since their cobweb approach entails a supply-response lag, the properties of their models depend on a four-dimensional nonlinear map. The dynamics of our model depend on a one-dimensional nonlinear map which enables us to offer an in-depth stability and welfare analysis. Brock and Hommes (1997) consider a single cobweb market in which firms switch between stabilizing and destabilizing expectation rules. One of their seminal insights is that endogenous dynamics may emerge if firms react strongly to the expectation rules' past performance differentials. Schmitt and Westerhoff (2015, 2016) show that policy makers have the opportunity to stabilize such dynamics by imposing profit taxes. Here we show that the basic mechanism at work within these models may carry over to frameworks with multiple regions.

Tuinstra et al. (2014) develop a cobweb-type model with two regions to study the stability and welfare effects of trade barriers. Firms from one of the two regions can offer their products in both regions, while firms from the other region have a cost disadvantage which forces them to supply their products only in their own market. As it turns out, free trade may lead to price and quantity fluctuations and thereby hamper welfare. Moreover, trade barriers, modeled in the form of import tariffs, may stabilize such dynamics and thus have – contrary to conventional wisdom – positive welfare effects. A similar result is demonstrated by Commendatore and Kubin (2009): while increasing labor and product market flexibility may increase employment, a deregulated economy may be subject to welfare-reducing fluctuations. Schmitt et al. (2017) consider a model in which firms have the opportunity to enter a competitive market and make an uncertain profit or to obtain a constant profit from a safe outside option. We extend that model by endogenizing the safe outside option, i.e. we allow firms to switch between two risky markets. While the main goal of Schmitt et al. (2017) is to show that profit taxes may give rise to unexpected dynamic phenomena such as hysteresis effects, our focus is on stability and welfare effects of profit taxes.

Our paper is also related to another stream of literature that models market interactions using a New Economic Geography perspective. The models by Agliari et al. (2011, 2014) and Commendatore et al. (2014, 2015) reveal that market interactions between multiple economic regions may lead to complex endogenous dynamics. These papers furthermore demonstrate that policy makers have tools to stabilize the fluctuations of these markets, such as increasing trade costs. Particularly relevant is Commendatore et al. (2008). They show that a small increase in the difference in taxes (or subsidies) between regions may lead to radical changes in both the dynamics and the spatial distribution of manufacturers in the Footloose Entrepreneurs model. The beauty of these contributions lies in their elaborate modeling of the economic environments of different regions. Unfortunately, the analysis of these models may be quite cumbersome. Our simple model may be regarded as a helpful complementary model to understand the basic destabilizing forces of market interactions and to identify key stability and welfare effects of profit taxes. We proceed as follows. In Section 2, we propose our model. In Sections 3 and 4, we analyze the stability properties of our model, and the welfare effects of profit taxes, respectively. In Section 5, we conclude our paper.

2 A simple market interaction model

We consider a partial equilibrium model with two regions, A and B. In both regions the same homogenous commodity is produced by firms that may relocate between the regions, and consumed by immobile households that do not migrate between the regions. Both regions are characterized by perfect competition, i.e. all firms are price takers. Once firms have selected their regions, the perfectly competitive market equilibrium emerges instantaneously.

The commodity demand $Q_t^{D,A}$ in region A follows from households in that region maximizing their quasi-linear utility function $U_t^A = Q_t^{D,A} - 0.5(Q_t^{D,A})^2 + Y_t^{D,A}$ subject to their budget constraint $M^A = P_t^A Q_t^{D,A} + Y_t^{D,A}$. Here P_t^A is the price of the commodity, M^A is the representative household's income and $Y_t^{D,A}$ is the consumption of a composite commodity with a price of 1, representing expenditures on all of the other commodities. For high enough M^A, $M^A > P_t^A(1-P_t^A)$, the optimal commodity demand is $Q_t^{D,A} = 1 - P_t^A$. The optimal demand for the composite commodity then is given by $Y_t^{D,A} = M^A - P_t^A(1-P_t^A)$. In a similar way we can derive the commodity demand in region B as $Q_t^{D,B} = 1 - P_t^B$.

We consider a fixed number N of identical firms and assume that half of the firms are owned by the households from region A while the other half are owned by the households from region B. For simplicity, we normalize the total number of firms to $N = 1$. The firms' aggregate supply in region A can be written as $Q_t^{S,A} = n_t q_t^{S,A}$, where n_t denotes the number of firms located in A and $q_t^{S,A}$ the supply of a single firm active in this region. It takes one period for firms to relocate and we assume trade costs are sufficient to deter firms located in one region to supply their product in the other region. Policy makers in region A may impose a proportional tax on the profits of firms located in their region, given by the tax rate $0 \le \tau^A < 1$, which is their only control parameter. A firm located in region A faces a quadratic cost function $C_t^A = 0.5(q_t^{S,A})^2$ but has no fixed costs. Therefore its profits $\pi_t^A = (1-\tau^A)(P_t^A q_t^{S,A} - 0.5(q_t^{S,A})^2)$ are always positive. The optimal, profit-maximizing, supply of a single firm is $q_t^{S,A} = P_t^A$, i.e. a firm's supply is solely determined by the current commodity price. Market clearing in region A implies $Q_t^{D,A} = Q_t^{S,A}$.

The number of active firms in region B is given by $(1-n_t)$. The supply in region B can therefore be expressed as $Q_t^{S,B} = (1-n_t)q_t^{S,B}$, where $q_t^{S,B} = P_t^B$ denotes the optimal supply of a single profit-maximizing firm in region B. Again, market equilibrium implies $Q_t^{D,B} = Q_t^{S,B}$. Note that the setup of our model is symmetric, except that policy makers in region B may impose a different profit tax rate, given by $0 \leq \tau^B < 1$, than those in region A.[1]

The profitability of the two regions is unknown to firms when determining where to locate and depends on the location decisions that are simultaneously taken by all other firms. If firms are perfectly rational they may coordinate on the equilibrium where the allocation of firms over the two regions is such that profits of all firms are the same. No firm can then earn a higher profit by relocating to the other region, and this equilibrium allocation will be maintained forever. However, even in our highly stylized model, this requires solving a complex coordination problem on the part of the firms, which becomes even more demanding if the equilibrium is sometimes disrupted by exogenous shocks, such as a change in demand or costs. Moreover, out of equilibrium it is very difficult for an individual firm to determine the optimal choice of region, since this requires predicting the location decisions of all other firms. We therefore take a behavioral approach and assume firms compare their own past profit experience with those of other firms and may choose to imitate the latter. The well-known replicator dynamics, originally introduced in evolutionary biology by Taylor and Jonker (1978), also see Hofbauer and Sigmund (1988), can be derived from such an imitation process (see e.g. Gale et al. 1995 and Schlag 1998).

[1] We could introduce additional asymmetries, for example by assuming that demand is different in the two regions, with the demand functions having different intercepts (see e.g. Tuinstra et al. 2014). As long as this asymmetry is not too large and at the steady state a positive number of firms will locate in each region, the qualitative predictions of our model remain intact. We focus on symmetric demand functions because then the only asymmetry in the model, if any, comes from differentiated profit taxes, implying that asymmetries in the outcomes of the model can unambiguously be attributed to the differences in profit taxes.

In this paper, we use the exponential replicator dynamics, as introduced by Hofbauer and Weibull (1996).[2] Accordingly, the number of firms locating in region A becomes $n_t = \frac{n_{t-1}\exp[\beta\pi^A_{t-1}]}{n_{t-1}\exp[\beta\pi^A_{t-1}] + (1-n_{t-1})\exp[\beta\pi^B_{t-1}]} = \frac{n_{t-1}}{n_{t-1} + (1-n_{t-1})\exp[\beta(\pi^B_{t-1} - \pi^A_{t-1})]}$. Note first that the higher the past realized profit of a firm in region A, the more firms will locate there. Parameter $\beta > 0$ reflects the firms' intensity of choice and indicates how sensitive the mass of firms is in selecting the more profitable region. An increase in the firms' intensity of choice implies that more firms enter the region that has produced higher profits in the recent past. Second, imitation leads to some persistence in the behavior of firms: a very high (low) fraction of firms located in region A in period $t-1$ tends to lead to a high (low) fraction of firms located in region A in period t, even if the profitability of region A is below (above) the profitability of region B.

Straightforward computations reveal that the model's law of motion is given by

$$n_t = f(n_{t-1}) = \frac{n_{t-1}}{n_{t-1} + (1-n_{t-1})\exp\left[0.5\beta\left(\frac{1-\tau^B}{(2-n_{t-1})^2} - \frac{1-\tau^A}{(1+n_{t-1})^2}\right)\right]}. \quad (1)$$

Despite involving market interactions between two regions, the dynamics of our model only stem from a one-dimensional nonlinear map with three parameters: the firms' intensity of choice and the two profit tax rates set by the policy makers of regions A and B. Note that the difference in profits, $\pi^B_t - \pi^A_t$, is increasing in n_t. Moreover, if the difference in taxes is large enough this profit difference will be positive (negative) for every value of $n_t \in (0,1)$ and all firms will locate in

[2] An advantage of the replicator dynamics over other evolutionary models, such as the discrete choice model pioneered by Brock and Hommes (1997), is that the economic equilibrium of the model (the value of n_t for which profits in the different regions are equal) coincides with the fixed point of the replicator dynamics. The exponential replicator dynamics has the added advantage that it is still valid if profits become negative and that it has a parameter, β, which controls for the sensitivity with respect to profit differentials (i.e. the strength of the imitation process). Dindo and Tuinstra (2011) derive the exponential replicator dynamics from a model of imitation. Other economic applications of exponential replicator dynamics include, amongst others, Kopel et al. (2014), Tuinstra et al. (2014), Bischi et al. (2015) and Schmitt et al. (2017).

the same region. Such a scenario is of limited economic interest. Moreover, policy makers of the region without any firms will have a strong incentive to attract firms by lowering the tax rate. In the remainder of this paper we therefore restrict our attention to tax rates τ^A and τ^B such that, if all firms are located in region A, it is profitable for an individual firm to relocate to region B, and vice versa. From the profit functions it follows that this requires

$$\frac{1}{4} < \frac{1-\tau^A}{1-\tau^B} < 4\,. \tag{2}$$

3 The steady state equilibrium and its stability properties

We start with an analysis of the steady states of the model and their stability properties, which is summarized by the following result.

Proposition. *Assume the tax rates satisfy condition (2). Then the economic model (1) has three steady states,* $\bar{n}_1 = 0$, $\bar{n}_3 = 1$ *and* $\bar{n}_2 = \frac{1}{\tau^A - \tau^B}\left(2\tau^A + \tau^B - 3\left(1 - \sqrt{(1-\tau^A)(1-\tau^B)}\right)\right) \in (0,1)$. *Steady states* $\bar{n}_1$ *and* $\bar{n}_3$ *are unstable for all values of* $\beta > 0$. *The inner steady state* $\bar{n}_2$ *is locally stable for*

$$\beta < \beta^* = 2\left[\bar{n}_2(1-\bar{n}_2)\frac{\partial\left(\pi^B - \pi^A\right)}{\partial n}\right]^{-1}, \tag{3}$$

where $\frac{\partial(\pi^B - \pi^A)}{\partial n} = \frac{1-\tau^B}{(2-\bar{n}_2)^3} + \frac{1-\tau^A}{(1+\bar{n}_2)^3}$.

Proof. The three steady states can be found by solving $f(\bar{n}) = \bar{n}$ for $\bar{n}$. For local asymptotic stability of steady state $\bar{n}$ we need to determine $f'(\bar{n})$, see Gandolfo (2009). A straightforward calculation reveals that $f'(\bar{n}_1) = \exp(\beta(\pi^A - \pi^B)) > 1$ and $f'(\bar{n}_3) = \exp(\beta(\pi^B - \pi^A)) > 1$, where the inequalities follow from the fact that $\pi^A > \pi^B$ at $\bar{n}_1 = 0$ and $\pi^B > \pi^A$ at $\bar{n}_3 = 1$. Furthermore, $f'(\bar{n}_2) = 1 - \beta\bar{n}_2(1-\bar{n}_2)\frac{\partial(\pi^B - \pi^A)}{\partial n} < 1$, implying that $|f'(\bar{n})| < 1$ is equivalent with (2).■

From an economic perspective, the outer steady states $\bar{n}_1$ and $\bar{n}_3$ imply that either all firms leave or enter region A. As long as condition (2) holds, these steady states will be unstable. The inner steady state $\bar{n}_2$ is economically more interesting and equalizes profitability between the two regions.

If tax rates are equal, $\tau^A = \tau^B$, the model is fully symmetric and in the inner steady state firms are split evenly between regions, as the following corollary to our proposition establishes.

Corollary. *For* $\tau^A = \tau^B = \tau \geq 0$ *the inner steady state is* $\bar{n}_2 = 0.5$ *and the local stability condition (3) reduces to* $\beta(1-\tau) < 13.5$.

In absence of profit taxes, $\tau^A = \tau^B = 0$, the inner steady state is therefore given by $\bar{n}_2 = 0.5$. Prices, aggregate quantities and profits will be equal across regions as well and given by $\bar{P}_2^A = \bar{P}_2^B = 2/3$, $\bar{Q}_2^{D,A} = \bar{Q}_2^{D,B} = 1/3$ and $\bar{\pi}_2^A = \bar{\pi}_2^B = 2/9$, respectively.[3] This equilibrium is locally asymptotically stable if $\beta < 13.5$. Since the slope of the map becomes steeper than -1 at the inner steady state as β exceeds 13.5, we can furthermore conclude that the model's primary bifurcation is a period-doubling bifurcation (this is also confirmed by numerical evidence presented in Section 4).

One advantage of our model is that it allows us to depict the effects of an increase in the intensity of choice, thereby enabling us to get a clear economic understanding of the origins of market instability. Panel (a) of Figure 1 depicts the shape of map (1) for three different values of the intensity of choice, assuming that $\tau^A = \tau^B = 0$. The black line results for $\beta = 6.75$, the red line for $\beta = 13.5$, and the green line for $\beta = 27$. The model's steady states are located where the map

[3] If we impose an additional asymmetry, for example by changing the intercept of the demand function in region A from 1 to *a*, at the steady state the firms will allocate over the regions in such a way that prices and profits in the two regions are equal (provided 0.5<*a*<2, for other values of *a* at the steady state all firms will locate in one of the regions). In particular, an increase in *a* above 1 would lead to an increase in the solid (black, red and green) curves in the right hand panels of Figure 1, increasing the steady state fraction of firms located in region A but not qualitatively changing the dynamics of the model.

intersects the 45-degree line. Obviously, the slope of the map at the inner steady state increases with β. As the intensity of choice exceeds 13.5, the slope of the map at the inner steady state becomes steeper than -1 and $\bar{n}_2$ becomes unstable.

***** Figure 1 about here *****

Panel (b) of Figure 1 depicts the profits a firm can make in region A (solid line) and in region B (dashed line) for an increasing number of firms located in region A. Recall that the profitability of region A and region B is independent of the firms' intensity of choice (the red and green lines for $\beta = 13.5$ and $\beta = 27$ thus collapse with the black lines for $\beta = 6.75$) and that both markets are equally profitable at the inner steady state. Out of equilibrium, however, the profitability of region A deviates from the profitability of region B. This is important since the firms' market entry and exit behavior crucially depends on the regions' relative past profitability. In particular, the higher the firms' intensity of choice, the stronger firms react to the regions' relative past profitability. It is exactly this reason why the slope of the map at the inner steady state becomes steeper as β increases, turning the model's inner steady state eventually unstable.

In the remainder of this section we investigate whether policy makers are able to stabilize the markets by imposing profit taxes on the firms located in their region. In Section 4 we will subsequently investigate whether, if possible, it is actually optimal for the policy makers to stabilize the markets. Let us first consider the case in which policy makers impose equal tax rates across regions, i.e. $0 < \tau^A = \tau^B = \tau < 1$. From the corollary we find that the local asymptotic stability condition of the inner steady state now reads $\beta(1-\tau) < 13.5$.

It is important to note that policy makers do not alter the model's inner steady state if they impose equal tax rates across regions. By imposing profit taxes, however, policy makers are able to stabilize markets. In particular, any destabilizing increase in the firms' intensity of choice can be offset by an appropriate increase in profit taxes. For example, if the firms' intensity of choice doubles from 13.5 to 27, policy makers can restore stability by setting $\tau = 0.5$. Panel (c) of Figure 1 presents the map's shape for increasing profit tax rates, assuming that $\beta = 27$, and illustrates this result. The black line represents the case $\tau = 0$, while the red and green lines are drawn for $\tau = 0.5$ and $\tau = 0.75$, respectively. Clearly, panel (a) and panel (c) of Figure 1 are mirror images: the change of the map observed in panel (a), caused by an increase in the firms' intensity of choice, is completely reversed in panel (c), due to an increase in the profit tax rate.

Which economic forces are driving this result? Panel (d) of Figure 1 shows how an increase in the profit tax rate affects the profitability of regions A and B. As can be seen, an increase in the profit tax rate diminishes the profitability of the two regions. But what is really important is that an increase in the profit tax rate also decreases the regions' relative past profitability. Since the firms' market entry and exit behavior depends on the regions' relative past profitability, an increase in the profit tax rate stabilizes the dynamics by reducing the regions' relative past profitability. With respect to the discussion of the remaining two tax cases, we stress that the model's inner steady state depends neither on β nor on τ. These parameters only affect the derivative of the map at $\overline{n}_2 = 0.5$, but not the location of the model's inner steady state.

Let us now turn to the case in which profit taxes are only imposed in one of the two regions. For concreteness, we assume that policy makers of region A impose a profit tax in their region but that there are no profit taxes in region B, i.e. $\tau^B = 0$. Condition (2) then requires $0 < \tau^A < 0.75$, and from the proposition we find that the inner steady state for this specification is $\overline{n}_2 = 2 - 3(1 - \sqrt{1 - \tau^A}) / \tau^A$. Since the inner steady state's local asymptotic stability condition $\beta < \beta^*$ only depends upon τ^A, we can depict the location of the model's inner steady state and the condition for its local asymptotical stability. The black line in panel (a) of Figure 2 shows the location of the model's inner steady state if policy makers increase $\tau = \tau^A = \tau^B$ between 0 and 1.

As discussed above, $\bar{n}_2$ is always given by 0.5 if policy makers tax both regions equally. The blue line represents $\bar{n}_2 = 2 - 3(1 - \sqrt{1 - \tau^A}) / \tau^A$ for $0 < \tau^A < 0.75$ and $\tau^B = 0$. Obviously, the number of firms located in region A decreases with τ^A. For $\tau^A \to 0$, half of the firms are located in region A while for $\tau^A \to 0.75$, no firms enter region A. The black line and the blue line in panel (b) of Figure 2 depict the corresponding local stability conditions of the model's inner steady state for these two scenarios. As can be seen, policy makers in region A are able to stabilize the dynamics by imposing a sufficiently high profit tax in their region. Moreover, a comparison of the respective stability conditions indicates that the critical value of the intensity of choice which just barely ensures stability is larger for $\tau^A < 0.579$ if profit taxes are bilaterally imposed while it is larger for $\tau^A > 0.579$ if profit taxes are unilaterally imposed.

***** Figure 2 about here *****

The panels in the third line of Figure 1 help us to understand this puzzling observation. Panel (e) of Figure 1 presents the shape of the map for increasing values of τ^A, assuming that $\beta = 27$ and $\tau^B = 0$. To have a benchmark, the black line represents the case in which also region A abstains from implementing profit tax, i.e. $\tau^A = 0$, while the red line and the green line illustrate the cases of $\tau^A = 0.5$ and $\tau^A = 0.75$, respectively. As can be seen, a unilaterally imposed profit tax makes the model's map asymmetric and thereby influences the location of the model's inner steady state. Panel (f) of Figure 1 depicts the corresponding profits a firm can make in region A and in region B. If policy makers impose profit taxes in region A, the profitability of region A decreases. Since firms split across regions such that the (after-tax) steady-state profits are equal in both regions, the steady-state profits of firms in region B are also affected if profit taxes are imposed in region A. Although this is somewhat difficult to see, an isolated imposition of profit taxes in region A stabilizes the dynamics via two channels. First, it reduces the regions' relative past profitability – and this has a stabilizing effect, as already discussed. Second, it drives firms out of region A. Since firms try to learn about the regions' relative profitability by observing the success of other firms, the location of the model's inner steady state matters for stability. The more the inner steady state approaches one of the outer steady states (here $\bar{n}_1 = 0$), the more persistent and thus more stable the dynamics becomes. In part, this also explains why for $\tau^A > 0.579$ lower unilateral than bilateral tax rates are needed to stabilize the dynamics.

Finally, let us explore the case in which policy makers impose different profit taxes across regions, i.e. $0 < \tau^A < 1$, $0 < \tau^B < 1$ and $\tau^A \neq \tau^B$. For ease of exposition, we assume in the following that the tax rate imposed in region B is below 75 percent, implying that for $\tau^A = 0$ the model's inner steady state always exists. The steady states are given in the proposition, provided condition (2) is satisfied, i.e. $0 < \tau^A < 0.75 + 0.25\tau^B$.

Since the model's inner steady state and the right-hand side of its local asymptotic stability condition only depend on two parameters, we can again – by treating τ^B as a location parameter – conveniently display our results. The green line in panel (a) of Figure 2 depicts the location of the model's inner steady state for increasing values of $0 < \tau^A < 0.825$, assuming that $\tau^B = 0.3$. As to be expected, the number of firms located in region A decreases with τ^A. Moreover, for $\tau^A < 0.3$ we have $\bar{n}_2 > 0.5$ while for $\tau^A > 0.3$ we have $\bar{n}_2 < 0.5$. The green line in panel (b) of Figure 2 presents the stability condition for this steady state. As long as τ^B is not too high, the behavior of the model (and the economic interpretation) is similar to the case in which profit taxes are only imposed in region A.

However, the picture changes if τ^B is set to a higher value. The red line in panel (a) of Figure 2 shows the location of $\bar{n}_2$ for increasing values of $0 < \tau^A < 0.9125$, assuming that

$\tau^B = 0.65$. As to be expected, $\bar{n}_2$ increase with τ^B. The red line in panel (b) of Figure 2 reveals that an increase in the profit tax rate in region A has a non-trivial and, again at least at first sight, surprising effect on the stability of the model's inner steady state. For a certain range of values of the intensity of choice, roughly between 35 and 50, the inner steady state is stable for small values of τ^A, unstable for intermediate values of τ^A, and again stable for high values of τ^A.

Panels (g) and (h) of Figure 1, based on $\beta = 40$ and $\tau^B = 0.65$, help us to understand this intriguing result. The black, red and green lines originate from the setting $\tau^A = 0.01$, $\tau^A = 0.5$ and $\tau^A = 0.85$, respectively. The profitability of region A and thus the number of firms located in region A decreases as the tax rate in region A increases. The stability of the inner steady state is again influenced by two channels: the regions' relative past profitability and the location of the inner steady state. As the tax rate in region A increases from 1 to 50 percent, the regions' relative profitability is hardly affected. But since fewer firms are located in region A, the inner steady state becomes unstable. However, if the tax rate in region A increases from 50 percent to 85 percent, the regions' relative profitability decreases. This has a stabilizing effect on the dynamics. Moreover, the number of firms active in region A further declines, and this contributes to market stability (as discussed before).

4 Welfare effects of profit taxes

So far, our analysis reveals that policy makers have the opportunity to stabilize markets by imposing profit taxes. However, we have also seen that profit taxes may change the distribution of firms across markets. This raises some important questions, such as: what are the welfare effects of profit taxes? Is it optimal for policy makers to use profit taxes to stabilize markets? Within our model, a region's welfare consists of three components: consumer surplus, firms' profits and tax revenues. Starting from the standard definition of consumer surplus and using the fact that prices in region A can be expressed in terms of the number of firms located in this region, we can write region A's consumer surplus in period t as $CS_t^A = 0.5(1-P_t^A)^2 = 0.5(\frac{n_t}{1+n_t})^2$. For region B we obtain $CS_t^B = 0.5(1-P_t^B)^2 = 0.5(\frac{1-n_t}{2-n_t})^2$. The total profits of firms owned by households from region A depend on the profits these firms make in region A and in region B. Recall that the total number of firms is normalized to 1 and that half of all firms are owned by households from region A, while the other half are owned by households from region B. Moreover, the firms' total profits generated in region A and in region B are given by $n_t\pi_t^A$ and $(1-n_t)\pi_t^B$, respectively. In the following, we make the innocuous assumptions that half of the n_t firms active in region A and half of the $(1-n_t)$ firms active in region B are owned by households from region A. The total profits of firms owned by households from region A can be written as $TP_t^A = 0.5n_t\pi_t^A + 0.5(1-n_t)\pi_t^B = \frac{0.25n_t(1-\tau^A)}{(1+n_t)^2} + \frac{0.25(1-n_t)(1-\tau^B)}{(2-n_t)^2}$. The same is true for the total profits of firms owned by households from region B, that is $TP_t^B = 0.5n_t\pi_t^A + 0.5(1-n_t)\pi_t^B$ $= \frac{0.25n_t(1-\tau^A)}{(1+n_t)^2} + \frac{0.25(1-n_t)(1-\tau^B)}{(2-n_t)^2}$. The tax revenues policy makers of region A (region B) collect from firms located in region A (region B) amount to $TR_t^A = \frac{0.5n_t\tau^A}{(1+n_t)^2}$ ($TR_t^B = \frac{0.5(1-n_t)\tau^B}{(2-n_t)^2}$). The welfare in region A and in region B is represented by $W_t^A = CS_t^A + TP_t^A + TR_t^A$ and $W_t^B = CS_t^B + TP_t^B + TR_t^B$, respectively.[4]

[4] Entering the optimal demands $Q_t^{D,A} = 1-P_t^A$ and $Y_t^{D,A} = M^A - P_t^A(1-P_t^A)$ of consumers from region A in their utility function $U_t^A = Q_t^{D,A} - 0.5(Q_t^{D,A})^2 + Y_t^{D,A}$ yields the indirect utility function $V_t^A = M^A + 0.5(1-P_t^A)^2$. A change in utility between two prices, say $\tilde{P}_t^A$ and P_t^A, is given by $\tilde{V}_t^A - V_t^A = 0.5(1-\tilde{P}_t^A)^2 - 0.5(1-P_t^A)^2$ and equal to the difference in consumer surplus. Moreover, we assume that the tax revenues collected by the policy makers of region A go to the consumers of region A who receive additional utility equal to the tax revenue. This extra utility comes from

As it turns out, the sum of the welfare of region A and region B, i.e. global welfare, is independent of profit taxes. Straightforward computations reveal that $W_t = W_t^A + W_t^B = \frac{0.5 - n_t(n_t - 1)}{2 - n_t(n_t - 1)}$. Accordingly, the distribution of firms across regions which maximizes global welfare is given by $n_t = 0.5$, resulting in a global welfare level of $W_t = 1/3$. We will refer to $n_t = 0.5$ as the *optimal distribution of firms*. Due to the symmetry of the two regions, the local welfare levels are given by $W_t^A = W_t^B = 1/6$ for $n_t = 0.5$.

We are now able to derive a number of important policy insights. If policy makers do not impose profit taxes, the model's inner steady state is given by $\bar{n}_2 = 0.5$. As long as the firms' intensity of choice is below 13.5, the model's inner steady state is stable and global welfare is maximized. If firms' intensity of choice exceeds 13.5, endogenous dynamics kick in and global welfare decreases. However, policy makers can always stabilize the dynamics by imposing a uniform profit tax across markets. Since such a tax policy does not distort the optimal distribution of firms, policy makers can always achieve the best possible global welfare level.

Figure 3 illustrates the steady-state welfare effects of profit taxes. The black line in panel (a) of Figure 3 represents the global steady-state welfare level for $0 < \tau = \tau^A = \tau^B < 1$; the red line shows the steady-state welfare level of region A, which, in turn, is identical to the steady-state welfare level of region B. Obviously, the global and local steady-state welfare levels are independent of τ. Panel (b) of Figure 3 reveals how consumer surplus in region A (red line, small-sized dashing), firms' profits in region A (red line, medium-sized dashing) and tax revenues in region A (red line, large-sized dashing) react to an increase of a uniformly imposed profit tax. Of course, consumer surplus, firms' profits and tax revenues are equal across regions

consuming the composite commodity which is produced by the public sector at constant marginal costs equal to one. The same holds for region B.

for this model specification. As can be seen, consumer surplus in region A is constant and given by 1/18. For $\tau = 0$, firms' profits in region A amount to 2/18 and then linearly decrease in the profit tax rate. The reduction of firms' profits is equal to the increase in tax revenues, i.e. the sum of firms' profits and tax revenues is constant.

***** Figure 3 about here *****

Let us next consider the case where firms' profits are only taxed in region A. As discussed in the previous section, such a tax policy affects the model's inner steady state. The higher the tax rate in region A, the fewer firms are active in this region. Panel (c) of Figure 3 reveals that such a policy reduces global welfare by distorting the optimal distribution of firms. In particular, welfare in region A decreases significantly as τ^A increases, while region B moderately benefits from such a policy. Panel (d) illustrates who gains and who loses from this policy on a local level (the blue lines depict the situation in region B). By driving firms from region A to region B, an increase in τ^A decreases consumer surplus in region A and increases consumer surplus in region B. The profitability of firms is equal across regions and decreases with τ^A. Finally, tax revenues of region A first increase with τ^A and then decrease again. For $\tau^A = 0.75$, all firms have left region A. Consumer surplus and tax revenues in region A are then zero. Welfare of region A only remains positive since firms owned by households from region A make profits in region B. To sum up, while the imposition of a profit tax in region A may stabilize the dynamics, it is negative for global steady-state welfare and for region A's steady-state welfare. Nevertheless, below we show that the stabilizing role of a unilaterally imposed profit tax may be beneficial for region A.

Panel (e) portrays the global and local steady-state welfare effects for an increase in the profit tax rate in region A, assuming that region B imposes a rather high profit tax rate of 65 percent. It is clear from our analysis above that global welfare increases up to $\tau^A = \tau^B = 0.65$ and then decreases again. However, we also see that region A may improve its welfare by imposing a moderate profit tax rate (while region B always benefits if firms in region A are subject to higher profit taxes). Despite suffering from a lower consumer surplus and lower firms' profits, panel (f) of Figure 3 reveals that the reason why region A benefits from imposing a moderate profit tax rate is that it generates additional tax revenues.

We now study the out-of-equilibrium properties of our model. We start with contrasting the effects of an increase in the firms' intensity of choice versus an increase in a uniformly imposed profit tax in regions A and B. Panel (a) of Figure 4 presents a bifurcation diagram for the firms' intensity of choice, assuming that $\tau = \tau^A = \tau^B = 0$. Parameter β is varied between 0 and 27. As predicted by our analytical results, the model's inner steady state $\overline{n}_2 = 0.5$ turns unstable as β becomes larger than 13.5, giving rise to a period-two cycle with increasing amplitude. Panel (b) of Figure 4 shows a bifurcation diagram for profit taxes, assuming that $\beta = 27$. The profit tax rate τ is varied between 0 and 1 across regions. As can be seen, policy makers are able to decrease the amplitude of the period-two cycle by increasing profit taxes. By setting the profit tax rate above 50 percent, policy makers can fully stabilize the dynamics. Panel (c) of Figure 4 depicts the effect of an increase in the firms' intensity of choice on the average global welfare. Average welfare of regions A and B decreases once the dynamics becomes unstable. Panel (d) of Figure 4 reveals that policy makers are able to improve the average welfare of regions A and B by imposing a uniform profit tax rate. Average global welfare increases with higher profit tax rates and reaches its maximum possible value of 1/3 at $\tau = 0.5$.

***** Figure 4 about here *****

The evidence presented in panels (a) to (d) of Figure 4 has important policy implications. An increase in the firms' intensity of choice may compromise market stability and thereby reduce average global welfare. Fortunately, policy makers can always restore market stability and thus increase average global welfare by imposing uniform profit taxes in region A and region B. In particular, the highest average global welfare with the lowest possible tax rate is achieved where the model's inner steady state just becomes stable. The remaining panels of Figure 4 demonstrate that the average welfare losses due to an increase in β and the average welfare gains due to an increase in τ also manifest themselves on a local level. To check whether our policy insights also hold in the presence of exogenous noise, we add normally distributed random shocks with mean zero and standard deviation 0.015 to the model's law of motion. The outcome of this experiment, depicted in gray in Figure 4, reveals the robustness of our conclusions.

Figure 5 focuses on the case in which profit taxes are only imposed in one of the two regions. Panel (a) of Figure 5 shows a bifurcation diagram for $0 < \tau^A < 1$, assuming that $\beta = 20$ and $\tau^B = 0$. The other panels on the left side of Figure 5 portray the corresponding effects on average global welfare, average welfare in region A and average welfare in region B, respectively. In line with our analytical results, an increase in τ^A stabilizes the dynamics. Initially, the amplitude of the period-two cycle decreases. At $\tau^A = 0.408$, the model's inner steady state becomes stable. As τ^A increases further, the number of firms located in region A decreases. For $\tau^A \geq 0.75$, no firm is active in region A.

The above welfare analysis suggests that the imposition of profit taxes in region A is harmful for global welfare and for region A's welfare. But these results are only valid in a steady-state environment. The left panels of Figure 5 offer an example in which the out-of-equilibrium effects of a unilaterally imposed profit tax are positive. As it turns out, the highest achievable average global welfare and the highest achievable average welfare of region A coincide with the tax rate which just ensures stability. Since the distribution of firms across regions is not equal at $\tau^A = 0.408$, average global welfare remains below its highest possible value of 1/3. From a global perspective, this policy is not optimal. In addition, the average welfare of region A remains for all

τ^A below 1/6, while the average welfare of region B may become larger than 1/6. The right panels of Figure (5) repeat this experiment for $\beta = 50$. First of all, policy makers of region A now need to impose higher profit taxes to stabilize the dynamics. While panel (d) of Figure 5 indicates that average global welfare is again maximized for tax rates which just enable stable markets, panel (f) of Figure 5 makes clear that average welfare of region A is maximized for considerably lower values of τ^A. Once again, it should be noted that average global welfare and average welfare of region A remain for all τ^A below 1/3 and 1/6, respectively.

***** Figure 5 about here *****

Let us sum up, we can conclude that policy makers of one of the two regions can stabilize markets by unilaterally imposing profit taxes. The welfare effects of such a policy for region A depend on how many firms leave region A when they are subject to profit taxes. If a moderate tax level is sufficient to stabilize markets, policy makers of region A may improve average welfare in their region. This will be the case if firms' intensity of choice is not too high. If firms react strongly to the regions' relative past profitability, policy makers of region A have to impose rather high profit taxes. While this may stabilize the dynamics, the crowding out of firms has negative welfare effects for region A. Moreover, a unilaterally imposed profit tax may improve global welfare, but it is not able to bring about the maximal possible level of average global welfare. This can only be achieved by a coordinated tax policy.

Figure 6 is devoted to the case in which policy makers impose different profit taxes across regions. Panel (a) of Figure 6 shows a bifurcation diagram for an increase in the tax rate in region A, given $\beta = 37$ and $\tau^B = 0.65$. What we see here is an example of the nontrivial effect an increase in the tax rate in region A can have on market stability if the tax rate in region B is high: a small tax rate in region A generates stable dynamics, an intermediate tax rate in region A triggers unstable dynamics, and a high tax rate in region A causes again stable dynamics. The boundaries of the period-two cycle can be computed via stability condition (3). The period-two cycle starts at $\tau^A = 0.213$ and ends at $\tau^A = 0.615$. Note that an increase in τ^A also decreases the (average) number of firms active in region A. Panel (c) of Figure 6 reveals that average global welfare is maximized for $\tau^A = 0.65$, implying that half of the firms are located in region A. But panel (e) of Figure 6 demonstrates that this globally optimal tax policy may not be in the interest of region A's policy makers. Average welfare of region A is maximized at $\tau^A = 0.213$, coinciding with the inner steady state's first bifurcation point.

***** Figure 6 about here *****

The right panels of Figure 6 repeat this experiment for $\beta = 75$. Since firms now react more strongly to the regions' relative past profitability, the dynamics fluctuates more wildly than before and policy makers of region A need to impose a profit tax rate of 83.35 percent to stabilize the dynamics. While this policy maximizes average global welfare, given $\tau^B = 0.65$, as visible in panel (d) of Figure 6, it is not the optimal global tax policy. For $\beta = 75$, policy makers of regions A and B should impose a uniform profit tax rate of 82 percent. Furthermore, panel (f) of Figure 6 suggests that it is better for region A not to impose profit taxes. Although setting $\tau^A = 0$ triggers unstable dynamics, region A is better off since it attracts more firms. Finally, the properties of the deterministic dynamics depicted in Figure 6 are robust with respect to exogenous noise.

5 Conclusions

We present a partial equilibrium model in which firms can offer their products in two separate regions. The firms' decision whether to locate in a given trading period either in region A or in region B depends on the regions' relative past profitability. The higher a region's relative past profitability, the more firms it will attract. The dynamics of our model stem from a one-dimensional nonlinear map. In addition to two unstable outer steady states in which all firms locate either in region A or in region B, there is an inner steady state in which firms split evenly across regions. As long as firms react only weakly to the regions' relative past performance, the inner steady state is stable and global welfare is maximized. Welfare depressing endogenous dynamics emerge if firms react strongly to the regions' relative past performance. We use our model to study whether policy makers are able to stabilize these dynamics by imposing profit taxes and whether they can promote local and/or global welfare by doing so. One important insight is that policy makers can always maintain stable dynamics and maximize global welfare by coordinating their tax setting behavior. The advantage of a coordinated tax policy is that it does not distort the optimal distribution of firms across markets.

For political reasons, policy makers of one of the two regions, say region B, may not be able to implement profit taxes. Surprisingly, policy makers of region A can still achieve stable dynamics by imposing profit taxes in their own region. Unfortunately, a unilateral tax policy distorts the firms' optimal distribution across regions. Whether such a tax policy has positive or negative welfare effects depends on the trade-off between the optimal distribution of firms and market stability. Our analysis suggests that the chances that policy makers have to improve welfare depends on the tax rate they have to introduce to stabilize dynamics. If firms' intensity of choice is not too high, the beneficial stabilizing effect of a moderate tax rate may outweigh the welfare loss incurred by a non-optimal distribution of firms across regions. Our analysis further reveals that policy makers may have reasons to deviate from a coordinated tax policy. Suppose, for instance, that the profit tax rate that policy makers would need to impose to stabilize markets and to maximize global welfare is rather high. In such a situation, policy makers in one of the two regions may have an incentive to reduce profit taxes in their region: the welfare gain which arises from attracting more firms may outweigh the welfare loss which occurs from market instability.

We conclude by pointing out four avenues for future research. For simplicity, the model's two regions are symmetric. A first natural extension of our model could be to consider two asymmetric regions, e.g. by assuming that demand for the commodity is different in the two regions. Moreover, our model highlights market interaction from a supply side. A second natural extension could be to add market interactions arising from the demand side. To keep our welfare analysis as simple as possible, we assume that the public sector offers a composite commodity at a price equal to its marginal costs. A third natural extension of our model could be to endogenize this background part of our model, i.e. to develop a general equilibrium model. Finally, profit taxes are exogenously fixed in our model. A fourth natural extension could be to allow policy makers to endogenously adjust profit taxes. To improve our understanding of the stability and welfare effects of profit taxes, we have refrained from these extensions so far.

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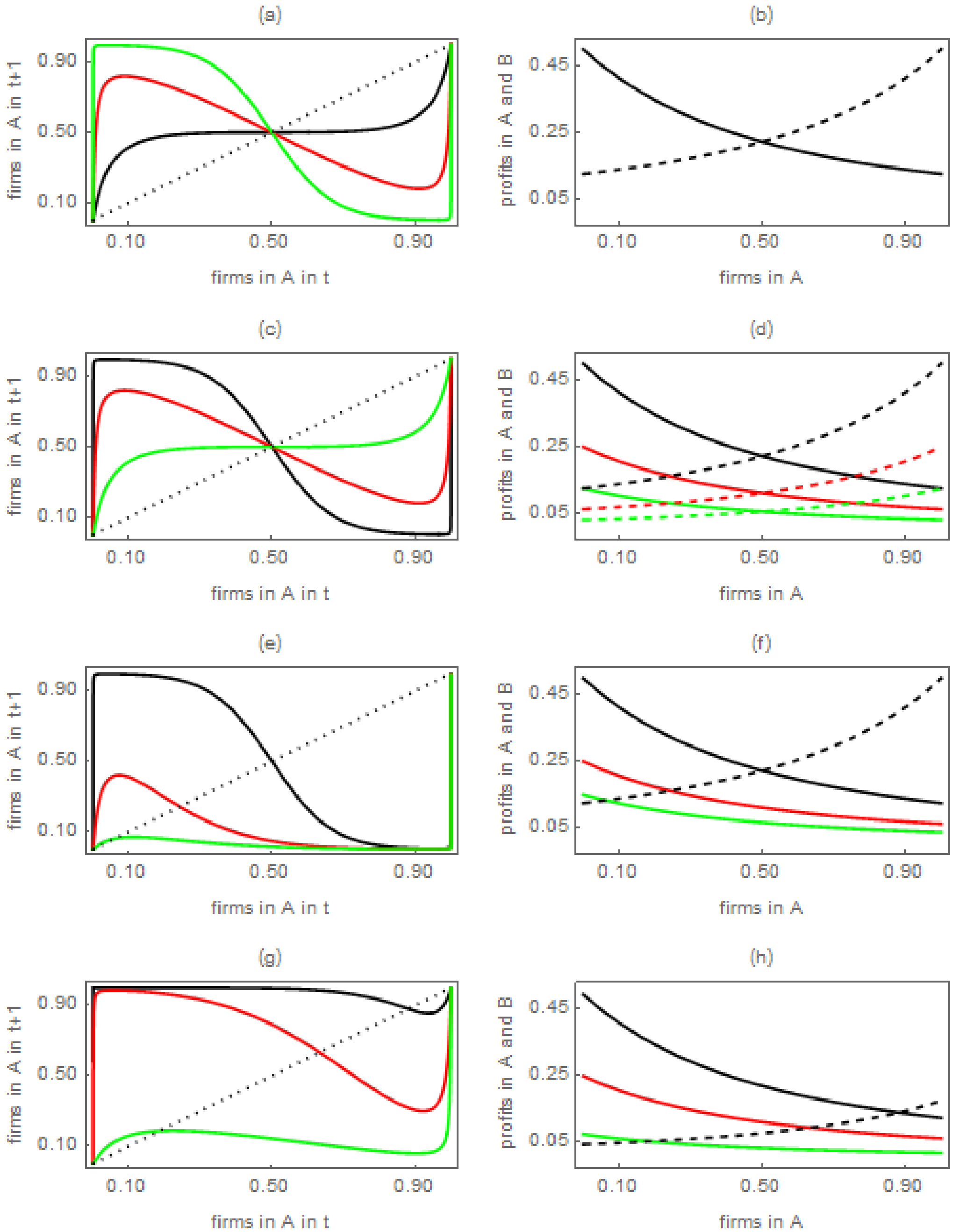

Figure 1: Shape of the model's map and profitability of region A and region B. The left panels show the shape of map (1) for different parameter combinations while the right panels show the corresponding profits a firm can make in region A (solid lines) and in region B (dashed lines). First line of panels: $\tau^A = \tau^B = 0$ and $\beta = 6.75$ (black lines), $\beta = 13.5$ (red lines) and $\beta = 27$ (green lines). Second line of panels: $\beta = 27$ and $\tau^A = \tau^B = 0$ (black lines), $\tau^A = \tau^B = 0.5$ (red lines) and $\tau^A = \tau^B = 0.75$ (green lines). Third line of panels: $\beta = 27$, $\tau^B = 0$ and $\tau^A = 0$ (black lines), $\tau^A = 0.5$ (red lines) and $\tau^A = 0.75$ (green lines). Fourth line of panels: $\beta = 40$, $\tau^B = 0.65$ and $\tau^A = 0.01$ (black lines), $\tau^A = 0.5$ (red lines) and $\tau^A = 0.85$ (green lines).

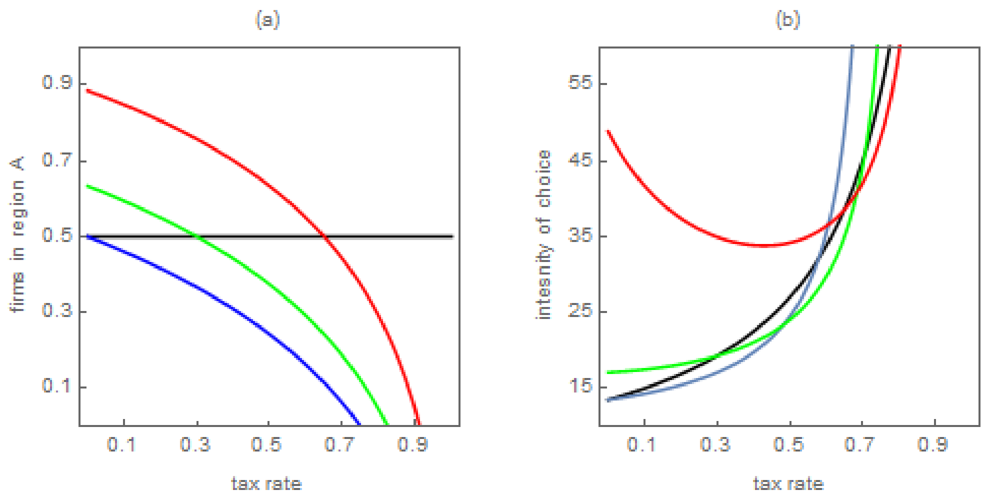

Figure 2: Location and stability domain of the model's inner steady state. Panel (a) shows the location of the inner steady state for different model specifications. Black line: $0 < \tau^A = \tau^B = \tau < 1$. Blue line: $0 < \tau^A < 0.75$ and $\tau^B = 0$. Green line: $0 < \tau^A < 0.825$ and $\tau^B = 0.3$. Red line: $0 < \tau^A < 0.9125$ and $\tau^B = 0.65$. Panel (b) depicts the corresponding local asymptotic stability conditions for these steady states. In the absence of profit taxes, local asymptotic stability of the model's inner steady state requires that $\beta < 13.5$.

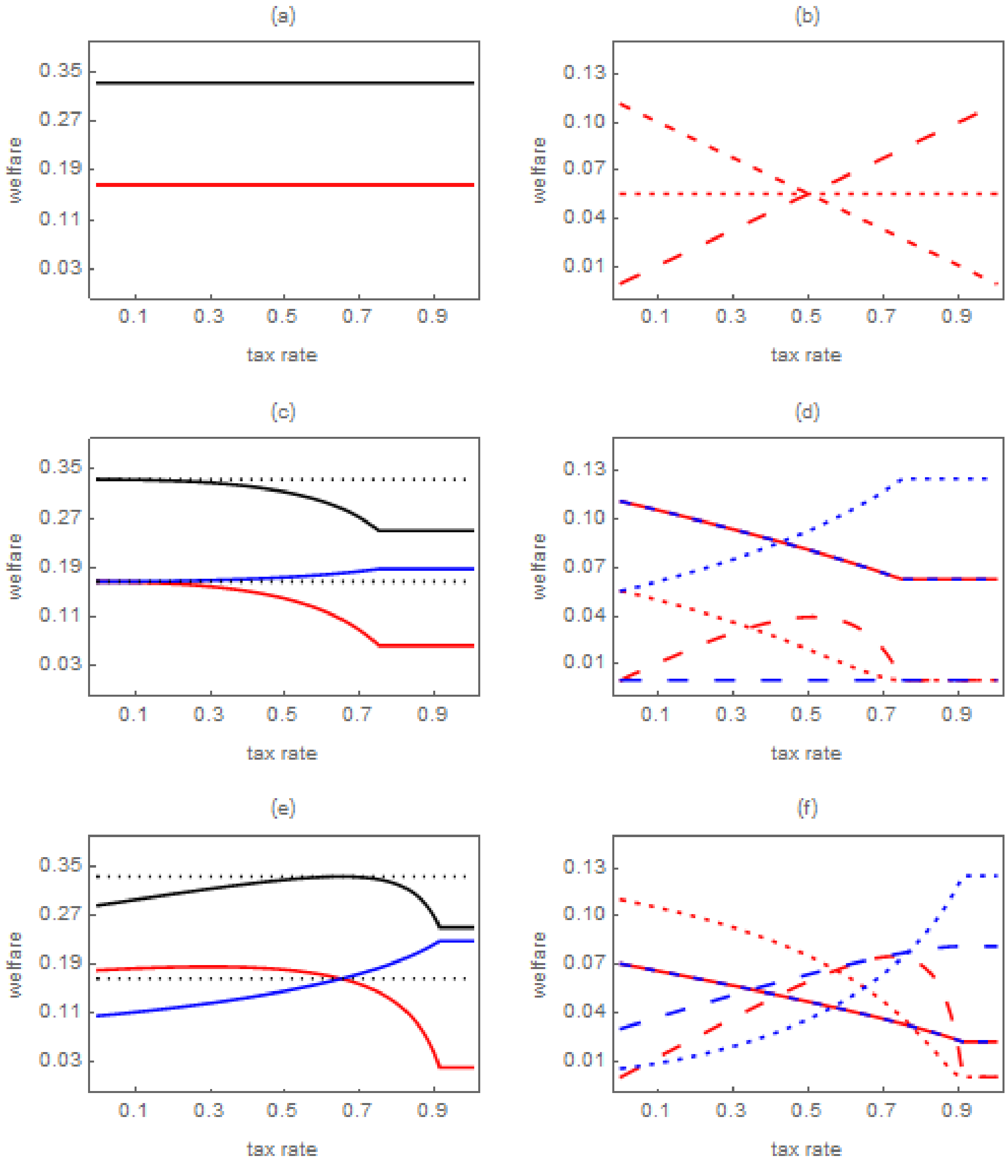

Figure 3: Steady-state welfare effects of profit taxes. The left panels show the global welfare (black line), welfare in region A (red line) and welfare in region B (blue line). The right panels show consumer surplus (small dashing), firms' profits (medium dashing) and tax revenues (large dashing) in region A (red) and region B (blue). First line of panels: $0 < \tau^A = \tau^B < 1$. Second line of panels: $0 < \tau^A < 1$ and $\tau^B = 0$. Third line of panels: $0 < \tau^A < 1$ and $\tau^B = 0.65$.

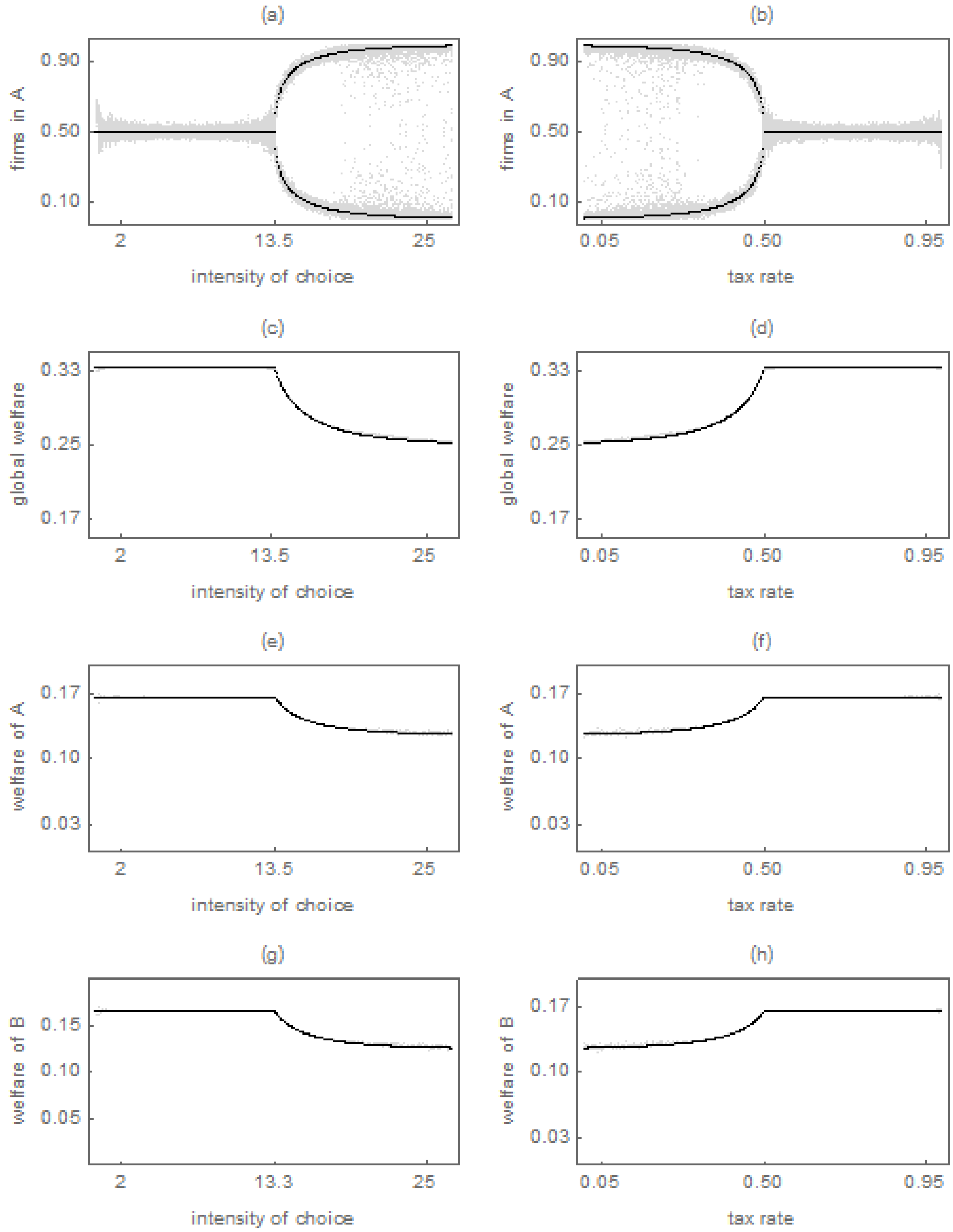

Figure 4: Intensity of choice versus uniform profit taxes. The left panels depict in black the effects of an increase in the intensity of choice on the number of firms active in region A, on the average global welfare, on the average welfare in region A and on the average welfare in region B, respectively, assuming that $\tau^A = \tau^B = 0$. The right panels show the same for a uniform increase in the tax rate across regions, assuming that $\beta = 27$. The impact of additive normal distributed noise with mean zero and standard deviation 0.015 on these quantities is illustrated in gray.

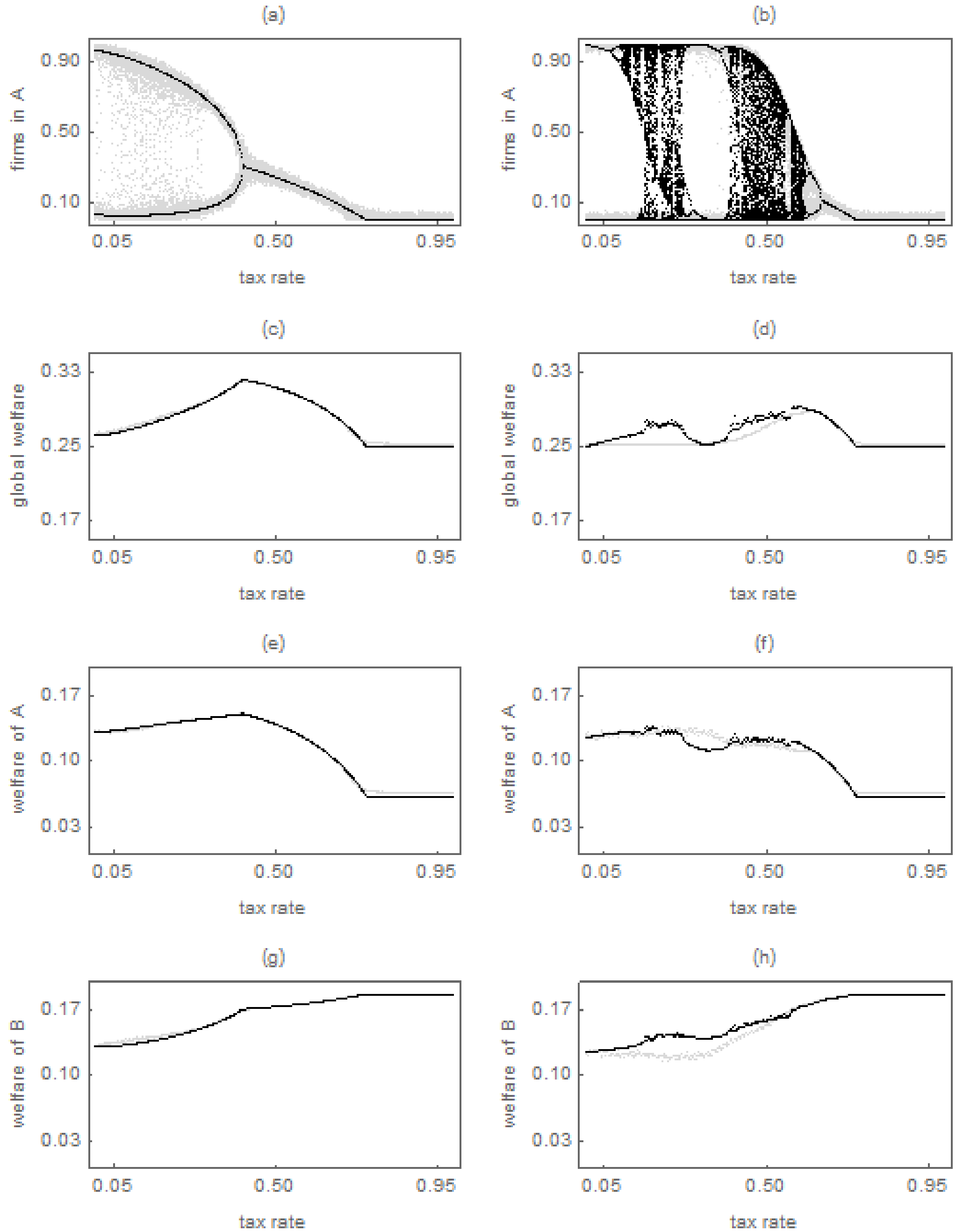

Figure 5: Imposition of profit taxes in region A. The left panels depict in black the effects of an increase in the tax rate in region A on the number of firms active in region A, on the average global welfare, on the average welfare in region A and on the average welfare in region B, respectively, assuming that $\beta = 20$ and $\tau^B = 0$. The right panels show the same for $\beta = 50$. The impact of additive normal distributed noise with mean zero and standard deviation 0.015 on these quantities is illustrated in gray.

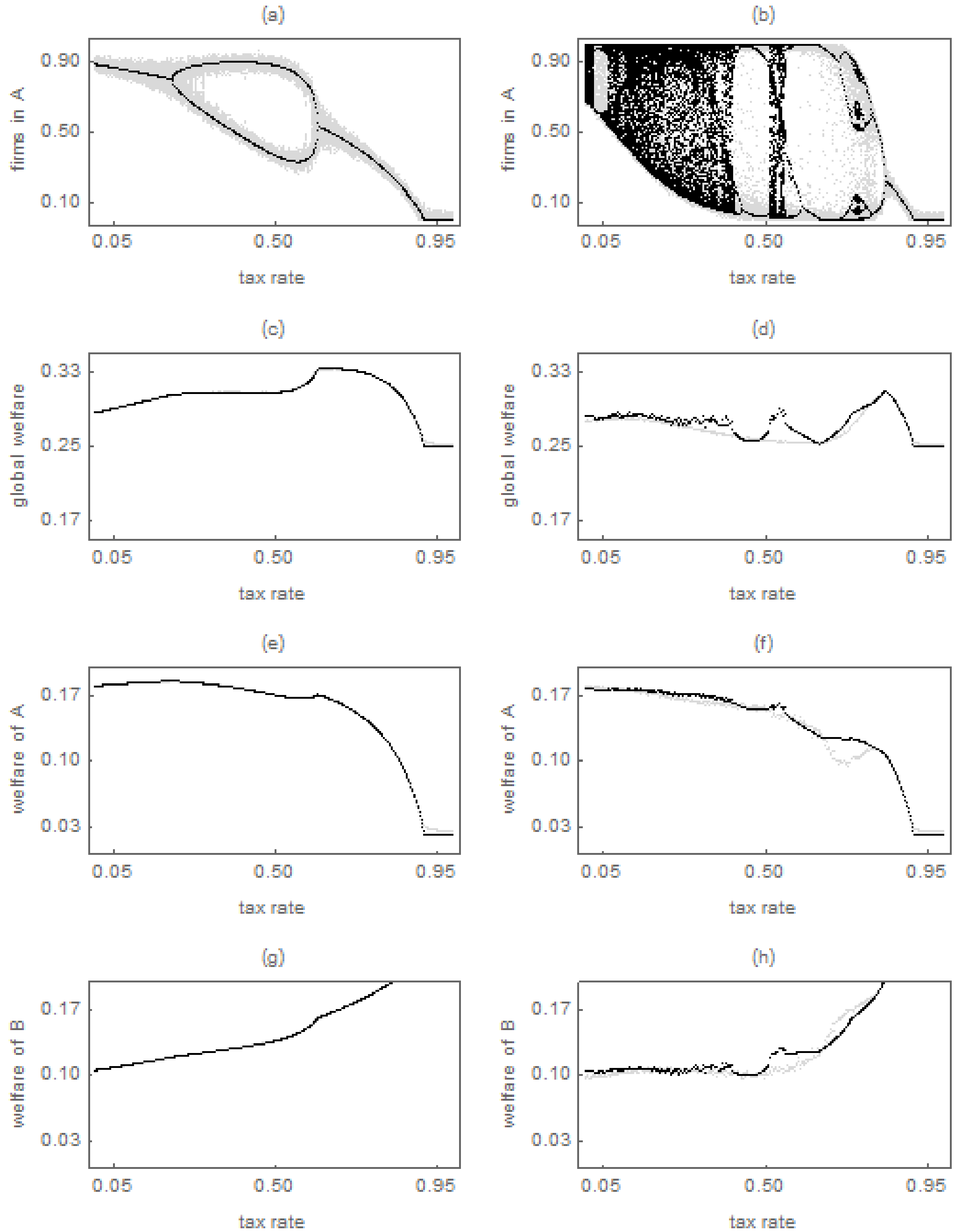

Figure 6: Different profit taxes in region A and in region B. The left panels depict in black the effects of an increase in the tax rate in region A on the number of firms active in region A, on the average global welfare, on the average welfare in region A and on the average welfare in region B, respectively, assuming that $\beta = 37$ and $\tau^B = 0.65$. The right panels show the same for $\beta = 75$ and $\tau^B = 0.65$. The impact of additive normal distributed noise with mean zero and standard deviation 0.015 on these quantities is illustrated in gray.

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