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Why Shops Close Again:  
An Evolutionary Perspective on the Deregulation of Shopping Hours*

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Abstract  
This paper introduces a new perspective on the deregulation of shopping hours based on ideas from evolutionary game theory. We study a retail economy where shopping hours have been deregulated recently. It is argued that first, the deregulation leads to a coordination problem between store owners and customers, and second, the ‘solution’ to this problem depends on the specific cost structure of stores and the preferences of customers. In particular, it may happen that, even if extended shopping hours are Pareto efficient stores and customers do not succeed in coordinating on this equilibrium. The analysis explains the observation in Germany, where shopping hours have been deregulated recently, that store owners tend to go back to the former shopping hours again. Moreover, it emphasizes the important role of advertisement campaigns as a signalling device.

JEL classification: L51, C72

Keywords: Shopping hours, Deregulation, Coordination, Equilibrium selection

*Published in: European Economic Review 46, 2002, 51-72
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“It is, perhaps, worth stressing that economic problems arise always and only in consequence of change. As long as things continue as before, or at least as they were expected to, there arise no new problems requiring a decision, no need to form a new plan.”

— F.A. Hayek (1945)

1 Introduction

Shopping-hour regulation is one of the key current issues in European economic policy. While some countries like Portugal, Sweden, and the UK have already decided for complete liberalization, most others still impose strong restrictions on national opening hours. In November 1996 the German government took a first step towards deregulation and extended national shopping hours by 1\frac{1}{2} to 2 hours a day. Since then store owners are allowed to keep open until 8pm on weekdays and 4pm on Saturday afternoon.\(^1\) Although the general policy of restricting opening hours has not been abandoned, the amendment produced at least some extra freedom since it is left to the retail sector to decide whether additional opening hours are used or not.

In this article we propose a game-theoretic model to study the adjustment of shopping hours after the German amendment in November 1996. The main empirical observation is that while initially a great number of stores extended their opening hours, by now many of them have gone back to preregulation shopping hours again. Roughly, within 20 months after the amendment the fraction of active stores decreased by a third from about 60 to less than 40 percent.\(^2\) This finding asks for a theoretical explanation, which is the main aim of this paper.

Our model argues that the return to preregulation shopping hours is due to the strategic uncertainty between decision makers in the retail sector. The idea is that a store’s decision to extend opening hours and a consumer’s decision to shop late are strategic complements. This leads to a coordination problem, where old and new shopping hours are both Nash equilibria of the corresponding game. Based on a microfounded model of individual decision-making we let evolution select for the equilibrium in the economy. We show that even if new shopping hours are the Pareto-dominant equilibrium, preregulation shopping hours are selected if they are less risky.\(^3\) This result gives rise to at least two policy implications: the role of

\(^1\)Before the deregulation stores could stay open until 6:30pm on weekdays and 2pm on Saturday. The strong restrictions on Sunday opening hours remained unaffected.

\(^2\)See precise figures below.

\(^3\)In terms of Harsanyi and Selten (1988), preregulation shopping hours are selected if the equi-
signalling and the effect of location. As both effects are also observed empirically we find strong support for our theoretical explanation.

The empirical basis for our model are two main studies on German shopping hour adjustment that have independently been conducted by the “Hauptverband des Deutschen Einzelhandels” (HDE, 1997) and the ifo-Institute (Halk and Täger, 1999) between one and two years after the amendment. As far as we know these are the only studies concerning this issue that are available by now. In the HDE study, conducted among its members in October 1997, the overall decline in the number of stores deciding to stay open is calculated as 20% (HDE, 1997). While initially 63% of the stores were active one year later only 49% still offered extended opening hours. The highest decline in active stores is observed in residential areas (30%), whereas the least can be found in shopping malls outside the cities (3%). The reactions differ a lot when looking at a store’s size. Among the stores with more than 100 employees around 96% were active initially. One year later precisely the same fraction still was. On the other hand, at the same time 32% of the small stores with only one to five employees have closed again.

These findings are consistent with the study by Halk and Täger (1999), who analyzed opening hours in the German retail market in the period of July and August 1998. The authors find that at the time of the study about 39% of all retail stores are active, while 61% stick to the old schedule from before November 1996. Similar to the HDE study, stores that keep open are mainly large stores and those that are located either in the city centre or in shopping malls outside the cities. With respect to different industries, Halk and Täger indicate that 100% of the hypermarkets, 97% of the department stores, and still 67% of the larger specialist shops have adapted to longer opening hours. They observe that the higher the turnover of an industry the larger the percentage of active stores. In contrast, stores that do not extend their opening hours are mainly small, individually owned shops and those in unfavourable locations.

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4Austria has pursued a similar deregulation of shopping hours. Reactions are comparable to the observations in Germany. See Burger (1999).

5Authors contacted members from the German Chambers of Industry and Commerce, where membership is compulsory. The given figures are statistically adjusted in order to approximate the behaviour of the whole retail market.

6In the study of Halk and Täger (1999) stores owners are also asked for explanations of their behaviour. Those that did not participate in extended opening hours mainly refer to low expected extra revenues (66%), an unfavourable location for late opening hours (47%), and low customer acceptance (45%). Only 31% of the stores quote too high extra costs as the main reason for their behaviour. At the same time stores that extended their opening hours refer to improved customer service (57%), higher expected revenues (47%), and attraction of new customers (37%) as main
Why do we observe this decline in active stores? A first interpretation may suggest that there is insufficient demand on the consumer side, making it non-profitable for store owners to open for a longer period in the evening. Many consumers may simply not buy particular goods at night and therefore it is optimal for stores facing this constraint to close early as under the previous regulation. However, the hypothesis of low demand seems questionable because of two reasons. Firstly, several studies indicate that, especially after the amendment the majority of Germans is in favour of the deregulation and most consumers declare to profit from extended opening hours. This does not necessarily imply that stores’ revenues increase as well. However, Halk and Täger (1998) show that on average about 13% of active consumers claim also to spend extra money when shopping late. Secondly, while the argument based on insufficient demand may perhaps explain heterogeneity with respect to opening hours across different branches (e.g., consumers may like to buy books or food at night but not cars), it is hard to see why it leads to such large heterogeneity of behaviour within a given branch. Simply phrased, why do some bookstores close early but other bookstores keep open? And more specifically, why do mainly small shops close early while large shops stay open?

The model we develop in this paper proposes a different explanation that takes account of both points raised above. Our main argument focuses on the strategic uncertainty involved in the interaction between stores and consumers in a deregulated economy. To develop this argument we model the interaction as a non-cooperative game, where stores decide to stay open or to close early and consumers either shop late or go shopping as usual. We then show that the deregulation of shopping hours leads to a coordination problem between stores and consumers. Furthermore, the equilibrium on which agents are most likely to coordinate depends on the specific cost structure of stores and the preferences of their customers. If the conditions are such that the new equilibrium, where stores are open for a longer time and consumers shop late, is risk-dominated in the sense of Harsanyi and Selten (1988) by the old equilibrium, where stores close early and consumers shop early as well, then the economy will eventually tend back to the old shopping hour schedule again, even if the new schedule Pareto dominates the old one.

Following this argument, the observed heterogeneity with respect to opening hours within given branches is a result of the multiple equilibria in the economy. While some

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7 Cf. Institut für Demoskopie Allensbach (1996) and Halk and Täger (1998). Halk and Täger (1998) find that the only group which is opposed (24%) or indifferent (52%) to the deregulation are the pensioners.

8 See the remark in Section 2 of this article.
stores are able to coordinate on the new equilibrium, most of the stores coordinate on the risk-dominant equilibrium, which consequently drives them back to the old shopping hour schedule again. Discussing the effects of signalling we show why mainly larger stores and those located in the city centre or in shopping malls are able to coordinate on the new equilibrium.

The results in our model are based on an evolutionary approach, where agents in the economy continuously adjust their behaviour to the environment they interact with. Interaction is restricted to local neighbourhoods, which seems realistic since people regularly shop only at a small number of stores, and at the same time there is a considerable overlap between different stores and different consumers. Although we obtain our results from a specific evolutionary model first analyzed in Kosfeld (1999), the results do not depend on this particular approach. Convergence to the risk-dominant equilibrium is a well established result and has been proven in other models of local interaction by Ellison (1993) and Blume (1993, 1995).\(^9\) Basically, in all these models our argument will hold as well.

To the best of our knowledge, an evolutionary perspective on the deregulation of shopping hours has not yet been given in the economic literature. In most cases the discussion is restricted to a pure equilibrium welfare analysis. It is argued, for example, that regulations favour small shops, while deregulations favor large shops (Clemenz, 1990; Morrison and Newman, 1983), that deregulations may lead to a general decrease in prices (Clemenz, 1990), or rather to a decrease at small stores and an increase at large stores (Tanguay et al., 1995). Other articles comparing social benefits and social losses of a deregulation include de Meza (1984), Moorhouse (1984), Kay and Morris (1987), Clemenz (1994), and Ferris (1990). A recent paper that rationalizes consumers’ opposition towards a deregulation of shopping hours is Thum and Weichenrieder (1997). Burda and Weil (1998) focus on synchronization effects of regulated shopping hours with respect to free time.

All this important work ignores the question whether it is at all possible to attain the new equilibrium. However, a deregulation is one of the key examples, where an economy is first driven out of one state, it then evolves, and possibly finds a new stable or unstable state. An economic discussion of deregulation should therefore include an evolutionary approach focusing on this question. Here lies the contribution of our paper.

The paper is organized as follows. Section 2 presents the basic model for analyzing the strategic situation after the deregulation takes place. Section 3 studies

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\(^9\)For models that consider global interaction see Kandori, Mailath and Rob (1993), Young (1993) and van Damme and Weibull (1998).
the evolution of the economy as a result from the individual strategy adjustment of agents. Section 4 draws the main conclusion from the model and discusses the role of signalling and location. Section 5 concludes.

2 Shopping on a Lattice

We consider a simple economy, consisting only of two types of economic agents, retail stores and consumers. Let $X$ denote the set of consumers and $Y$ denote the set of stores. For the sake of simplicity and technical tractability we assume that all consumers are identical with respect to their shopping preferences. Stores face the same technology, in the sense of revenue and cost structure. This does not necessarily mean that consumers and stores are fully identical among each other. Concerning consumers, e.g., this assumption has rather to be interpreted as looking only at one specific type of consumers, say employees for example. The same holds for stores, in the sense that all stores shall be of the same type, say for example medium-size supermarkets. Future versions of the model will have to relax this assumption and look at more heterogeneous agents.

Our set-up considers a spatial model of local interaction. Stores and consumers are located on the two-dimensional integer lattice $\mathbb{Z}^2$. Precisely, we assume $X \cup Y = \mathbb{Z}^2$, so agents are identified with their location and every location is occupied by exactly one agent. Thus, the number of agents in the model is countably infinite, which allows us to ignore boundary and other finite population effects in a convenient way.

The distribution of agents among locations is as follows. Agent $z = (z_1, z_2)$ is a consumer if $z_1 + z_2$ is odd. He represents a store if $z_1 + z_2$ is even. What does this structure look like? Imagine the space $\mathbb{Z}^2$ to be drawn like a chess board. Then every black square represents a consumer and every white square represents a store (Figure 1). Clearly, we do not claim this structure to be in any way a literal representation of reality. Instead, the structure shall give a reasonable “playground” for analyzing the interaction between stores and consumers in a rather tractable way. Denote for agent $z \in \mathbb{Z}^2$ by $N(z) = \{z' \in \mathbb{Z}^2 | |z' - z| = 1\}$ the set of neighbouring agents having Euclidean distance equal to one. Then the important feature of the structure is that every store $y$ interacts with a set $N(y)$ consisting of four consumers, and in the same way every consumer $x$ interacts with a set $N(x)$ that consists only of stores.

FIGURE 1
At the beginning shopping hours are regulated in our model. Stores close early and consumers have adapted to this schedule. Stores make a profit $\pi$ and consumers earn a utility from shopping that is given by $u$. For convenience, we normalize a store’s profit and a consumer’s utility before the deregulation to zero, i.e. $\pi = u = 0$.\footnote{This has no effect on the results in the model as only payoff differences will matter.}

Suppose now that the government decides to deregulate existing shopping hours. From now on every store is allowed to keep open for an additional period of time in the evening and, say, on Saturday afternoon.

Then, every economic agent has to decide between two strategies. A store can either decide to make use of the deregulation and open in the evening/Saturday afternoon, or not to make use of the deregulation and close at the usual time as before. In the first case we say the store decides to be active, which is denoted by strategy $A$, in the second case the store is said to be inactive, which is denoted by strategy $I$. Similarly, a consumer is also either active, meaning that he makes use of extended shopping hours, which is denoted by $A$, or he remains inactive and goes shopping as under the former time schedule, which is again denoted as $I$.

Every consumer $x$ who is active is assumed to make use of the extended shopping hours as follows. He first chooses one store $y \in N(x)$ at random. This choice shall be uniformly distributed.\footnote{This assumes that the consumer is not able to let his choice depend on the strategies that are played by each of his neighbouring stores. For example, he cannot choose a particular store that has decided to stay open. The reason is that he does not know this before he chooses the store.} So any store is selected with probability $\frac{1}{4}$. He then visits this shop in the evening and buys something if the store is in fact open, which gives him positive extra utility $w > 0$. However, if the store is closed this creates frustration and costs him a disutility of $e > 0$. Both values are assumed to include real costs for going to the shop. It should be expected, of course, that depending on the type of customer values for $w$ and $e$ can vary a lot. An employee, for example, can be thought of having a rather large $w$ and a rather small $e$, because of inflexible working hours but low costs of mobility. In contrast, a househusband may have more flexibility in his time schedule but rather high costs of mobility. In consequence, he can be expected to have a small $w$ but a large $e$. A consumer who decides to be inactive and thus to shop early as under the former regulation receives the same utility as before, normalized to zero.

Every active store $y$ faces additional costs $c q + d$ and additional revenues $pq$, where $c$ captures variables costs, $d$ gives the amount of fixed costs and $p$, with $p > c$, is the average price of goods that are sold at that store.\footnote{For a justification of a linear cost structure in the retail industry see Nooteboom (1982).} The variable $q$ gives the expected number of active customers that come to that specific store. It takes value
within the set \( \{0, \frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1\} \), depending on how many customers actually choose to shop in the evening. For instance, if all customers are active, since everybody selects that store with probability \( \frac{1}{4} \) the expected number of customers that come to that store is equal to 1. If the store is inactive and decides to close at the same time as before he makes his former profit, normalized to zero.

**Remark.** Note that our model assumes longer opening hours to create extra demand. This relates to the fact that we focus on interaction between firms and consumers, where firms can catch extra surplus from staying open. As mentioned in the introduction Halk and Täger (1998) show that, on average about 13% of active consumers claim to spend extra money when shopping late. The fraction is even higher when looking at young employees or at situations, where consumers mainly visit large shopping malls in the evening (about 20%). Thus, the amount of extra surplus may depend on the considered types of stores and consumers in our model.\(^{13}\)

Let \( \xi : X \cup Y \to \{A, I\} \) denote the collection of decisions of all agents in the economy. Let \( \pi(y, \xi) \) be the expected profit of store \( y \) given that the state of the economy is \( \xi \). Similarly denote \( u(x, \xi) \) the expected utility of consumer \( x \) given \( \xi \). Then the assumptions made so far can be expressed as follows.

\[
\pi(y, \xi) = \begin{cases} 
\frac{p-c}{4} n^A(y, \xi) - d & \text{if } \xi(y) = A \\
0 & \text{if } \xi(y) = I
\end{cases}
\]

\( \xi \) is a function from \( y \to \{A, I\} \).

\[
u(x, \xi) = \begin{cases} 
\frac{w}{2} n^A(x, \xi) - \frac{c}{4} n^I(x, \xi) & \text{if } \xi(x) = A \\
0 & \text{if } \xi(x) = I
\end{cases}
\]

\( n^s(y, \xi) \) gives the number of store \( y \)'s customers who decide for \( s \in \{A, I\} \). Analogously, \( n^s(x, \xi) \) gives the number of stores where consumer \( x \) shops, choosing \( s \in \{A, I\} \).

We assume that additional profits for stores are strictly increasing in the expected number of late-shopping customers and that they are strictly positive if \( q \) equals 1. Precisely, if

\[
F(q) = -d + (p - c) q,
\]

where \( q = \frac{1}{4} n^A(y, \xi) \), we assume that \( F(0) < 0 \) and \( F(1) > 0 \). This means that,

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\(^{13}\)Of course, on an economy wide level business stealing effects may exist as well, which can affect the assumption in our model. These effects will have to be considered in a model, where not only firms and consumers interact but firms compete with each other as well. This, however, is beyond the scope of the present paper. See also the following footnote on this point.
similarly to the consumer case, there are positive profits to gain for each store if only enough agents in the economy adapt to the new time schedule.\textsuperscript{14}

For the sake of completeness recall that, similarly, expected additional utility of consumer $x$ is strictly increasing in the number of stores that are open in the evening. If

$$G(n) = wn - e(1 - n),$$

where $n = \frac{1}{4}n^A(x, \xi)$, then $w > 0$, $e > 0$, $G(0) < 0$ and $G(1) > 0$.

The situation just described can be seen as a spatial game that is played between stores and consumers. Each consumer $x$ plays with four stores that are located around him, given by the set $N(x)$. At the same time each of these stores plays again with four consumers that are located around that store, given by $N(y)$ and including the former consumer $x$. The set of pure strategies for any agent is given by $\{A, I\}$. Payoffs are determined by the functions $u(x, \xi)$ and $\pi(y, \xi)$. Of course, payoffs depend only on the strategies of neighbours. Interaction is local.

A strategy profile determines a unique strategy for every agent in the economy. As usual a strategy profile is a (pure) Nash equilibrium if no single agent in the economy can increase his payoff choosing another strategy given that everybody else in the economy plays according to that profile.\textsuperscript{15}

There may exist many Nash equilibria in this situation. Several of them can be heterogeneous, meaning that different agents play different strategies. The number of heterogeneous Nash equilibria, and whether they exist at all, depends on the precise values of the parameters chosen in the payoff functions. Nevertheless, there are always two homogeneous Nash equilibria. In the first one every agent is active, i.e. every consumer shops late and every store keeps open. Denote this equilibrium by $E_1 = (A, A)$. In the second one everyone in the economy is inactive, i.e. every consumer sticks to the old schedule, and every store closes at the usual time. Denote this equilibrium by $E_2 = (I, I)$.\textsuperscript{16}

\textsuperscript{14}Positive profits may be a troublesome assumption for the retail industry. Due to strong competition one may expect extra profits to be driven down to zero in the long-run. However, as we will see, Pareto efficiency is not the driving force in our model. In fact, decreasing the value of $F(1)$ makes our argument only stronger, since the old-shopping-hour equilibrium becomes even more risk dominant.

\textsuperscript{15}We restrict attention to pure strategies only.

\textsuperscript{16}To see why these homogeneous Nash equilibria always exist, consider, e.g., equilibrium $E_2$. Independent on the parameters in the model, it is always a best response for consumer $x$ not to go shopping at night if all stores $y \in N(x)$ close early, and in the same way it is also a best response for store $y$ to close early if none of his customers $x \in N(y)$ shop late. By a similar argumentation, this time in the reverse direction, $E_1$ is always a Nash equilibrium independent on the parameters.
In order to have available the criteria of risk dominance and Pareto dominance also in this set-up, we use the following convention. There is a unique $2 \times 2$ coordination game $\Gamma$ that directly corresponds to the just described strategic interaction between stores and consumers in the economy. The game $\Gamma$ is a game between a single consumer and a single store. The payoffs of this game are such that the following holds. Payoffs in the original situation, given by functions $u(x, \xi)$ and $\pi(y, \xi)$, are equal to expected payoffs from randomly matching each agent $z, z \in X \cup Y$, with a single opponent $z' \in N(z)$ with whom he then plays the game $\Gamma$. The random matching is uniformly distributed. Considering equations (1), (2), it is easy to calculate the payoff matrix of the game $\Gamma$. It is given in Figure 2.

**FIGURE 2**

Homogeneous Nash equilibria in the original situation correspond to pure (and strict) Nash equilibria of the game $\Gamma$. We say that a homogeneous Nash equilibrium in the original situation is *Pareto/risk dominant* if the corresponding Nash equilibrium in the game $\Gamma$ is *Pareto/risk dominant* in the sense of Harsanyi and Selten (1988).

So far, assumptions imply that the active equilibrium $E_1$ is the Pareto-dominant equilibrium. Whether it is also risk dominant depends on the relation between equilibrium and off-equilibrium payoffs. Precisely, the equilibrium $E_1$ is risk dominant if $\frac{w}{e} > \frac{d}{(p-c)-d}$, and the equilibrium $E_2$ is risk dominant if the reverse inequality holds.

Risk dominance has an intuitive interpretation in terms of *risk factors*. The risk factor of equilibrium $E_i$, where $i \in \{1, 2\}$, is defined as the smallest probability $\alpha$ such that if one player believes the other player is going to play the equilibrium strategy with probability strictly greater than $\alpha$, then playing according to the equilibrium is the unique best response. The risk-dominant equilibrium is the equilibrium whose risk factor is lowest.

While the notion of risk dominance refers to both players in the same way, the actual degree of risk dominance, measured by the ratio of equilibrium and off-equilibrium payoffs, may in principle be different for both players. However, in order to be able to apply our evolutionary framework, we make the assumption that the degree is the same, i.e. $\frac{w}{e} = \frac{(p-c)-d}{d}$. Note that this condition is satisfied if, e.g., the game $\Gamma$ is symmetric. This leaves us two possible cases.

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17 Although intuition suggests that our results hold also in a more heterogeneous environment (as in Ellison, 1993, heterogeneity may even speed up convergence), we have no formal proof for this case yet. Intuitively, the result should still hold because increasing the degree of risk dominance (even if only for one player) reinforces only the dynamics towards the risk-dominant equilibrium.
Case 1 \( \frac{w}{c} = \frac{(p-c)-d}{d} > 1 \).

Case 2 \( \frac{w}{c} = \frac{(p-c)-d}{d} < 1 \).

In case 1 consumers are of a type such that the utility gain from being active is greater than the costs of arriving at a store that is closed. Similarly, stores are of a type where overall profits from extended opening hours are greater than fixed costs for keeping open. In this case equilibrium \( E_1 \) is risk dominant. In case 2 the opposite is true. Consumers face a rather high cost of arriving at a closed store compared to the possible gains from late-shopping. Stores have greater fixed costs than overall profits from extending their opening hours. In this case equilibrium \( E_2 \) is risk dominant.

3 Evolving Economy

Previous to a deregulation the economy is in equilibrium \( E_2 \). In fact, everybody is forced to play that equilibrium because of the existing regulation. Then, after the economy is deregulated (at time zero in our model) everybody is able to revise his strategy. The question is, whether the economy is able to leave the bad equilibrium and eventually reach the efficient equilibrium \( E_1 \).

To answer this question we apply the evolutionary model of Kosfeld (1999). Our results, however, do not depend on this approach. Other models of strategy adjustment including those of Ellison (1993) and Blume (1993, 1995) lead to the same conclusion. In the model of Kosfeld (1999) individual Poisson rates (flip rates) determine an agent’s probability to change strategy. The basic idea is that an agent changes his strategy the more likely the better, in terms of payoffs, the other strategy is. In our framework this can be implemented by setting flip rates equal to the positive part of the expected payoff-gain from switching strategy.\(^{18}\)

Denote \( \Xi \) the set of all possible states of the economy \( \xi : X \cup Y \rightarrow \{A, I\} \). A state of the economy determines a unique strategy for each agent. Be \( \xi_t \in \Xi \) the state of the economy at time \( t \) and \( \xi_t(z) \) the strategy that is played by agent \( z \) at time \( t \). Time is continuous. Denote \( r(z, \xi_t) \) the flip rate of agent \( z \) given that the state of the economy at time \( t \) is equal to \( \xi_t \). Then, for a consumer \( x \in X \),

\[
\begin{align*}
    r(x, \xi_t) &= \begin{cases} \\
        \frac{w}{c} n^A(x, \xi_t) & \quad \text{if} \quad \xi_t(x) = I \\
        \frac{w}{c} n^I(x, \xi_t) & \quad \text{if} \quad \xi_t(x) = A.
    \end{cases}
\end{align*}
\]

\(^{18}\)We give a more formal derivation of flip rates in the Appendix.
For a store $y \in Y$, 

$$r(y, \xi_t) = \begin{cases} 
\frac{p-c-d}{4}n^A(y, \xi_t) & \text{if } \xi_t(y) = I \\
\frac{d}{2}n^I(y, \xi_t) & \text{if } \xi_t(y) = A.
\end{cases}$$

(6)

Note that flip rates and hence probabilities for adjustment are monotonic: the more opponents choose a particular strategy, the higher the probability for an agent to flip to that strategy. Monotonicity follows from the fact that playing the same strategy is a Nash equilibrium. Moreover, adjustment is smooth. Instead of adjusting to best responses with probability one, agents switch the more likely the better the other strategy is.

Having defined the individual adjustment of strategies we can now ask again, where evolution will lead the economy most likely to settle down. The answer is given in the following proposition.

**Proposition 1** Let $\mu$ be the initial distribution of states of the economy, denote $\mu_t$ the distribution of the stochastic process $\{\xi^\mu_t\}_{t \geq 0}$ at time $t$. (i) For any initial distribution, the only states that receive positive probability under the limiting distribution $\lim_{t \to \infty} \mu_t$ are the two equilibria $E_1$ and $E_2$. (ii) If the initial state of the economy is completely mixed in the sense that with probability one it contains both infinitely many agents that use the new shopping hours and infinitely many agents that do not, then $\lim_{t \to \infty} \mu_t$ puts probability one on the risk-dominant equilibrium.

*Proof.* See Appendix.

Proposition 1 has two important implications for the economy. Firstly, any heterogeneous equilibrium is unstable. In this sense, the economy really faces a coordination problem: agents coordinate either on equilibrium $E_1$ or on $E_2$. Secondly, whenever the number of both types of agents, those that use the new shopping hours and those that do not, is infinite, the economy eventually converges to the risk-dominant equilibrium. Suppose, e.g., that an infinite subset of agents (possibly all, or just all consumers, or only an infinite subset of consumers) randomizes. They flip a coin that says $A$ with probability $\theta > 0$, and $I$ with probability $1 - \theta$, where $0 < \theta < 1$. This implies that the initial state is completely mixed.\(^{19}\) The answer to the question,\(^{19}\)

\(^{19}\)In reality obtaining an infinite set is of course more troublesome. One would like to know how robust the result is if we consider finite initial sets instead. It is shown in Kosfeld (1999) that convergence to the risk-dominant equilibrium is ensured with positive probability for any(!) nonempty initial set of agents playing the risk-dominant strategy. The complete mix is necessary only to ensure convergence to the risk-dominant equilibrium with probability one.
whether the economy is able to leave the inefficient equilibrium $E_2$ and eventually reach the efficient one $E_1$ therefore depends on which equilibrium is risk dominant.

**Corollary 1** In case 1, agents coordinate eventually on the efficient equilibrium $E_1$. In case 2, agents coordinate on the inefficient equilibrium $E_2$.

Thus we obtain a clear result in the form of a classical dichotomy. In case 1 the economy can in fact be expected to reach the efficient equilibrium. However, in case 2 it may be that for some time there are some consumers and stores that practice the new time schedule but eventually they will disappear and everybody will go back to the old shopping hour schedule again. The reason for this is that the new equilibrium, even if it is Pareto dominant, is more risky.

### 4 Implications

Having set up and analyzed the evolutionary model of shopping-hour adjustment our next step is to apply this model to the German economy.

We believe that the situation in Germany very much looks like case 2 rather than like case 1. The reason for this is as follows. On the one side, consumers were used to go shopping early, because they always had to do so. They have arranged their everyday life with an opening hours schedule for a long time period during the past. Since they are not used to the possibility to shop late they will still do most of their shopping during the former opening hours. Commodities that they might purchase outside the old system will be less important for them. Certainly, people may like to go shopping in the evening. Still, the additional personal gain from that shopping which, in the present model, is expressed by the value of $w$ can be expected to be rather small. At least, smaller than the cost of going to the store and facing the risk of standing in front of a closed door, which is captured by the value of $e$. Because people do their main shopping within the old time system it costs them extra effort to visit a store in the evening. Consequently, the degree of frustration or disutility from arriving at a closed store is very high. Thus, it should be expected that $w < e$.

On the other side, stores face a high pressure of additional fixed costs. If they decide to stay open, they first have to look for more clerks who they can hire, or they have to convince the employed staff to work longer. Personal investigation and the discussion in Germany suggests that especially the latter is a rather difficult procedure. It can be a very costly one as well, since employees ask for higher wages when working in the evening or on Saturday afternoon. In contrast, it is not sure
how much additional profit the store will earn from sales in the evening. Even when considering overall profit to be positive, as it is done in the model, it is very plausible that at least at the beginning it will not be that high. The reason is again, that consumers are not used to shop outside the old opening hours system. Therefore, they will still do most of their important purchases within the old system. Altogether, also on the store side the inequality is most likely to look like $(p - c) - d < d$.

Thus, if the German economy can in fact be described by case 2, our theoretical model gives a precise explanation for why currently many stores and consumers in Germany are tending back to the old shopping hours again. It does not necessarily have to be the case that the new time schedule is less profitable, i.e. additional utility/profit from using the new schedule is negative. It is simply enough that the new schedule is more risky than the old one. This already ensures that agents are most likely to coordinate on the preregulation equilibrium.

Our assumption on the initial complete mix of strategies seems also very realistic if we consider the study of the “Institut für Demoskopie Allensbach” (1996) conducted among consumers during the early time period from November 15 until November 23, 1996. There consumers report that 77% of the stores they regularly shop at have indeed changed their opening hours at least partly, while 16% of the stores have not changed their opening times very much. At the same time 44% of the consumers report to have used the new shopping hours already. Altogether, the initial collection of decisions among stores and consumers appears to have been very heterogeneous, which is in accordance with the sufficient condition in Proposition 1.

Apart from explaining the decrease in active stores, our model can also provide a rationale for why we observe such large heterogeneity within given industries — a fact that cannot be explained, e.g., by presuming insufficient demand. The main argument is simple: some have solved the coordination problem, others have not. In the following we reason why mainly large stores and those located in the city centre or in shopping malls outside the cities are successful with this respect, and why small stores and those in unfavourable locations are not. The key strategy is to deploy the positive effects of signalling.

By signalling it is understood that before the game is played agents send signals reflecting their willingness to coordinate on either this or the other equilibrium. Although in a retail economy such signalling seems rather complicated and difficult for the consumer side, it is in fact a very easy procedure for stores. They just need an advertising campaign, announcing that from now on they are going to stay open for a longer time period. In our model agents are not allowed to signal their prospective
play. However, the effects of signalling in coordination problems have been analyzed formally, e.g. by Matsui (1991) and Kim and Sobel (1995). The common result in these models shows that signalling in the sense of cheap-talk or preplay communication leads indeed to efficiency. Having the possibility to announce their willingness to play either this or the other equilibrium agents do no longer coordinate on the risk-dominant but on the Pareto-dominant equilibrium. Signalling is a powerful mechanism to overcome problems of coordination.

However, in a retail economy the potential to signal prospective behaviour is not the same for every type of store. While large stores and especially chains of stores usually find it easy to signal their extension of opening hours because of a much lower cost-gain ratio, smaller and in particular individually owed stores often don’t see the advantage of expensive advertising. In consequence, these stores either don’t signal at all, or reduce their signalling to some sort of word-of-mouth communication, hoping thereby to provide enough information to the consumer side.\textsuperscript{20} Looking at the available data we find that exactly these stores are the ones that go back to preregulation shopping hours, while most, if not all, of the larger stores have successfully extended their opening hours. This is exactly what our model predicts. Since the preregulation equilibrium risk-dominates the new one, in general evolutionary forces drive agents in the economy towards the old equilibrium. Therefore, while on the one side those stores that simply react to their environment eventually get stuck at this equilibrium, on the other side those stores that extend their strategy space and make use of signalling are able to successfully coordinate on the new equilibrium. Seen under this light, the observation that those stores that close early again also give low expected revenues and low customer acceptance as the two major reasons for their reaction (Halk and Täger, 1999) is no surprise either. Since expectations are a result of stores’ observations, stores that do not signal will eventually end up in a situation with low expected revenues and low customer acceptance. The question is, though, who first started the chain of reactions.

The location of a store may have a great effect on the use of signalling, too. Stores in the city centre have the advantage of being surrounded by many other stores of different types. Together these stores create an attractive environment to the consumer offering a large variety of products and shopping opportunities. The same holds true for shopping malls located outside the city. Yet, with respect to the coordination problem caused by the deregulation of shopping hours the high density of stores in the city centre and in shopping malls has a further and significant effect: it

\textsuperscript{20}Unfortunately, we are not aware of any data that looks at this issue.
reduces the necessary amount of signalling on the individual level. If stores are located closely together they can exploit the positive externalities of advertising. They can cooperate in marketing and advertisement strategies and can thereby exploit the same economies of scale that are profitable for the large stores and chain stores. In the city centre it is often the existing urban structures that proves helpful with this respect. For example, stores that are located in the same street — usually the main shopping street — often cooperate and advertise under a common name or brand that is related to the name of the street.

Clearly, the existence of positive externalities generates also a free-rider effect, which may reduce cooperation between stores. While this holds in particular for the city centre, where stores are individually independent the problem is less severe or even absent in private shopping malls that, at least with respect to marketing and opening-hour regulation, are often governed by a single management. In this case the joint signalling of extended shopping hours is much easier.

Following our analysis, it comes to no surprise that those stores that are located in the city centre or in shopping malls are the ones that could successfully coordinate on the extended shopping hour equilibrium. Due to an easy strategy of signalling these stores have a considerable advantage compared to those that find themselves in rather unfavourable and isolated locations. According to Halk and Täger (1999) among the stores that return to the old opening schedule about 47% refer to their unfavourable location as a major reason for their decision to close early again. While in general this may also indicate low demand for late night shopping in these areas, our analysis reveals a further critical effect: because more extensive signalling is needed these stores will find it harder to coordinate on the risk-dominated equilibrium.

5 Conclusion

Not every consumer will want to shop late and not every store will want to keep open in the evening. The aim of this paper is not to argue that extended opening hours are a good strategy per se. Instead, it shows that even if extended opening hours are Pareto efficient, it is not necessarily the case that national deregulation itself will lead the economy to the Pareto-dominant state. If we believe that stores and consumers strategically react to their (local) environment, risk dominance becomes important and in consequence the preregulation equilibrium can have the larger basin of attraction.\footnote{A further remark may be appropriate at this point. By definition, Pareto optimality always relates to a given set of agents and strategies. As the focus of our model is on the strategic}
The conclusion of our approach is twofold. As in general deregulation is one of the key current issues in European economic policy, the paper shows that a complete economic understanding of deregulation must include a dynamic approach as well, since this is the only way to properly assess the possibility of realizing the desired economic effects at all. Moreover, if these economic effects are not realized automatically, as it is true in the case of multiple equilibria, a dynamic approach may also indicate policies that help realizing them. As with respect to the deregulation of shopping hours we have seen that signalling is a critical strategy. Hence, coming back to the original question, we do not only obtain an explanation for why some shops keep open and others close again, we can also offer a policy advice to shops that are in the particular situation. If a shop wants to extend its opening hours, it should first check whether this can be profitable at all. If not, stop doing it. If yes, open but signal!

Acknowledgements

I would like to thank Steffen Huck, Dolf Talman, Josef Zweimüller, the editor and two anonymous referees for valuable comments and suggestions. This research has been financially supported by the European Commission through a Marie Curie Research Fellowship at CentER, Tilburg University, The Netherlands.

interaction between individual consumers and stores, competition effects between stores have been neglected. If competition generates strong negative externalities between stores, on a economy wide level the extended-opening-hour equilibrium may become a Pareto-inferior state. In such a world, where individual and social incentives conflict, policy advice will clearly look different.
Appendix

Derivation of flip rates

In this paper we follow the evolutionary model of Kosfeld (1999), where agents stochastically adjust their strategy to a changing environment given by the play in their local neighbourhood. Technically, strategy adjustment is implemented by individual Poisson rates (so-called flip rates) $r(z, \xi_t)$. This works in such a way that for any time interval $\delta \downarrow 0$ it holds that

$$\text{Prob}[\xi_{t+\delta}(z) \neq \xi_t(z)] = r(z, \xi_t) \cdot \delta + o(\delta).$$

In words, the probability for agent $z$ to flip within a time interval $[t, t + \delta]$ equals the product of the flip rate at time $t$ times the length of the interval $\delta$ plus a term vanishing of order $\delta$ as $\delta$ goes to zero.

The main behavioural assumptions on adjustment are that, firstly agents stay with their strategy in case of successful coordination with their neighbours, and secondly they are more likely to switch if the other strategy earns relatively higher payoffs.

**Assumption 1** Flip rates are zero if all agents in the neighbourhood coordinate on the same strategy, i.e. agents play a Nash equilibrium. Precisely, for any $z \in \mathbb{Z}^2, \xi \in \Xi$

$$r(z, \xi) = 0 \iff \forall z' \in N(z) : \xi(z') = \xi(z).$$

**Assumption 2** Flip rates depend on payoff differences in a linear monotonic way. The higher the relative payoff advantage of a strategy the larger the rate to flip to this strategy. Precisely, for any $z \in \mathbb{Z}^2, \xi \in \Xi$

$$r(z, \xi_{z,I}) - r(z, \xi_{z,A}) = v(z, \xi_{z,A}) - v(z, \xi_{z,I}),$$

where $v$ represents a store’s profit function in case $z$ is a store and a consumer’s utility function in case $z$ is a consumer (as defined in equations (1) and (2)) and

$$\xi_{z,s}(z') = \begin{cases} \xi(z') & \text{if } z' \neq z \\ s & \text{if } z' = z, \end{cases}$$

with $s \in \{A, I\}$.

Assumption 1 captures the idea that individual learning forces are weak at Nash equilibria of the game. If no single neighbouring opponent plays the other strategy, this other strategy is not a best response to any of the neighbours’ currently played
strategy. Hence there is no reason to play that other strategy. Thus flip rates are zero. In this situation an agent’s behaviour coincides with pure best-response behaviour.

Assumption 2 is motivated by the idea that agents do not over-sensitively react to changes in their local environment by always adjusting their strategy towards best responses with probability one. Instead, agents are assumed to follow the rule: the larger the payoff difference between the other strategy and the current strategy the more likely I flip to the other strategy. Since payoffs in the underlying coordination game are finite, flip rates are always finite, as well. This ensures, by (7), that agents are locked in with their current strategy for infinitesimally short periods of time.

The main difference between this approach and the evolutionary models of Ellison (1993) and Blume (1993, 1995) is the role of noise in the strategy adjustment of the players. While these authors follow the approach of Kandori, Mailath, and Rob (1993) and Young (1993) and model noise in the form of mutations or mistakes that are made by otherwise fully rational players, in our model noise is introduced by smoothing the players’ individual reactions: Assumption 2 implies firstly that a player does not always switch when the other strategy is optimal, and secondly that sometimes he may switch even if the other strategy is currently suboptimal.

Recalling the definitions of payoffs in our economy, Assumptions 1 and 2 still leave some degrees of freedom to define flip rates. The first assumption gives boundary conditions while the second one fixes relative values only. However, if we stick to the simplest version possible, in which flip rates depend linearly on the number of neighbours playing the other strategy, and use the fact that the payoff from being inactive is zero, flip rates are equal to the positive part of the expected payoff-gain from switching strategy. We thereby obtain the rates given in equations (5) and (6).

**Proof of Proposition 1**

The convergence result rests on the dynamic equivalence of our evolutionary process and the *biased voter model*. The latter is an interacting particle system first studied by Schwartz (1977) and Bramson and Griffeath (1981). See Liggett (1985) for a good introduction to the theory of interacting particle systems.

Part (i) of Proposition 1 follows from the immediate observation that $E_1$ and $E_2$ are both absorbing states for the process and the fact that there is no other absorbing state. The proof for the latter relies heavily on duality theory for interacting particle systems. For our adjustment process the dual process is a continuous time particle jump process on $\mathbb{Z}^2$ where each particle jumps with rate $r_1$ to a neighbouring site and also produces a particle in an unoccupied site with a rate equal to $r_2$, with these rates
depending on the payoffs in the game (see Kosfeld, 1999, for details). If a particle attempts to occupy a site that is already occupied the two particles coalesce. The claim then follows from Schwartz (1977), who shows that whenever the dual process of a Markov process on $\Xi$ is monotone and fulfills a certain growth condition, then any invariant distribution must be a convex combination of the two distributions corresponding to homogeneous equilibria $E_1$ and $E_2$. In our setting a process is monotone if flip rates are increasing functions in the number of neighbours that play the other strategy, which is obviously fulfilled.

Part (ii) is an implication of the following result. Suppose we are in case 1, where $E_1$ is the risk-dominant equilibrium. Denote $\tau$ the stopping time of reaching the risk-dominated equilibrium $E_2$ and define $\kappa := \frac{w}{c} = \frac{(p-c)-d}{d}$, which, as we are in case 1, is greater than one. Let $N$ be the number of agents playing the risk-dominant strategy $A$ in the initial state of the economy.

**Lemma 1**

$$\text{Prob}[\tau < \infty] = \begin{cases} \kappa^{-N} & \text{if } N \text{ is finite} \\ 0 & \text{if } N \text{ is infinite.} \end{cases} \quad (11)$$

**Proof.** Consider first the case when $N$ is finite. If $t_m$ denotes the time of the $m$th flip of $\xi_t$, then $R_m = |\{z|\xi_t(z) = A\}|$ is a random walk on $\mathbb{N}$ where

$$R_m - R_{m-1} = \begin{cases} 1 & \text{with prob. } q \\ -1 & \text{with prob. } 1 - q, \end{cases}$$

with $q = \frac{\kappa}{\kappa+1}$ and $1 - q = \frac{1}{\kappa+1}$. This follows from the flip rates of the adjustment process: $\frac{q}{1-q} = \kappa$. For $r \in \mathbb{N}$ define the waiting time $W := \min_{m \geq 0}\{R_m \notin (0,r]\}$, i.e. the waiting time for the first moment the random walk leaves the interval $(0,r)$. By the lemma of Borel-Cantelli it follows that $W$ is almost surely finite. Because of the positive drift $\frac{\kappa-1}{\kappa+1}$ towards infinity, $R_m$ is not a martingale. Therefore define the function $h(l) = (\frac{1-q}{q})^l$. $h(l)$ is a harmonic function with respect to $R_m$, i.e. $(Kh)(l) = h(l)$, where $K(l,\cdot)$ denotes the transition function of the random walk $R_m$. Now $H_m = h(R_m)$ is in fact a martingale and since $H_{m\wedge S}$ is clearly bounded, by the martingale stopping theorem it follows that $E[H_S] = E[H_0]$. With $q_0$ and $q_r$, denoting the probability for $R_S$ to be 0 and $r$, respectively, this is equivalent to

$$q_0 h(0) + q_r h(r) = h(N)$$

$$\iff q_0 \left( h(0) - h(r) \right) = h(N) - h(r)$$

$$\iff q_0 = \frac{h(N) - h(r)}{h(0) - h(r)}$$

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\[ q_0 = \frac{(1-q)N - (1-q)r}{1 - (1-q)^r} \Rightarrow \]

Now let the interval \((0, r)\) grow to infinity, then \(P[\tau < \infty] = \lim_{r \to \infty} q_0\). Since the latter limit is equal to \((1-q)^N = \kappa^{-N}\), this proves the finite case.

The infinite case follows from the finite one by exhausting the space \(\mathbb{Z}^2\) via a sequence of finite boxes with increasing radius centered around the origin, using monotonicity of the process.

Lemma 1 shows that the probability to hit the absorbing state \(E_2\) in finite time depends on the number of agents that play \(A\) at the beginning and the ratio of individual weights of adjustment \(\kappa = \frac{\varepsilon}{\tau} = \frac{(p-c)-d}{\kappa}\). The probability decreases exponentially as the number of initial \(A\)-strategists grows. In particular, if \(N\) is infinite we obtain almost sure coordination on the risk-dominant equilibrium \(E_1\).

By replacing \(\kappa\) through \(\frac{1}{\kappa}\) the analogous result holds for case 2, in this case ensuring almost sure convergence to the risk-dominant equilibrium \(E_2\) if only infinitely many agents play strategy \(I\) initially. Thus, overall a completely mixed initial state, where both infinitely many agents play \(A\) and infinitely many agents play \(I\), ensures almost sure convergence to the risk-dominant equilibrium, independent which case actually prevails. This proves Proposition 1.

**Remark.** In Lemma 1 the degree of risk dominance, expressed by \(\kappa\), directly enters the equation. The more risk dominant the particular strategy is, the faster the probability to enter the risk-dominated equilibrium decreases as \(N\) grows. In the other direction, as both equilibria become equally risky (i.e. \(\kappa\) approaches 1) the probability to reach the equilibrium where everybody plays the risk-dominated strategy tends to 1 for finite \(N\). This is due to \(N\) being finite and the whole population being infinite (hence the number of agents playing the risk-dominated strategy being infinite, as well). The degree of risk-dominance plays a similar role with respect to the spatial spread of risk-dominant play in the total economy, which can be seen as a measure for the expected waiting time to reach the risk-dominant equilibrium. Bramson and Griffeath (1981), e.g., prove that the growth of the set of agents playing the risk-dominant strategy eventually grows at least linearly in time. Moreover, one can show that the growth speed is related to the value of \(\kappa\) in the way that the larger \(\kappa\) the faster the growth of risk-dominant play. Hence, considering the issue of time in our evolutionary model, we see that our asymptotic prediction works the better the more risk-dominant the one of the two equilibria \(E_1\) and \(E_2\) is.
References


Figure 1: Shopping on a Lattice

- consumer
- store
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<thead>
<tr>
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<th>Consumer</th>
<th>Store</th>
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<tbody>
<tr>
<td></td>
<td>$A$</td>
<td>$I$</td>
</tr>
<tr>
<td><strong>A</strong></td>
<td>$w, (p-c) - d$</td>
<td>$-e, 0$</td>
</tr>
<tr>
<td><strong>I</strong></td>
<td>$0, -d$</td>
<td>$0, 0$</td>
</tr>
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Figure 2: Game $\Gamma$