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Does Nominal Illusion Generate Collusive Equilibria?

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Theory and Experimental Evidence[*]

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1. Introduction

Humans are not immune to psychological biases when taking economic decisions (Kahneman, 2003). A tendency to make choices disregarding the real consequences of nominal changes has been repeatedly documented.[1] This phenomenon, coined *money illusion* and incorporated into the economic jargon as early as the beginning of the past century, [2] played a limited role in explaining economically relevant behaviour until quite recently (Tyran, 2007), following the traditional economics' convention that learning and market forces eventually wipe out the distortions created by individual irrationalities (see Akerlof and Yellen, 1985 for an early challenging of this view).

Recent empirical papers document how money illusion may persistently mediate inflation and drive real prices in a variety of economic environments, including the housing market (Brunnermeier and Julliard, 2008) and the stock market (Cohen et al, 2005 and Acker and Duck, 2013). In the laboratory, Fehr and Tyran (2001, 2007 and 2014) analyse pricing behaviour using real vs. nominal representations, and Fehr and Tyran (2008) and Noussair et al (2012) compare prices before and after a nominal shock. In this paper we take a very different approach and analyse money illusion in its simplest form, using a static, full information Bertrand game. We compare pricing behaviour across different *nominal* representations of the same economy, and unravel the behavioural patterns of money illusion, e.g. how the features of the nominal representation affect subjects' choices.

In the experiment, firms sell their homogenous good in different countries, or local markets. Firms are endowed with identical production technologies (exhibiting decreasing returns to scale) and countries exclusively differ in the local currency in which prices are nominated, being all local markets identical in real terms. The only difference with respect to previous price competition experiments (as in Dufwenberg

[1] Early evidence about the effects of money illusion came from individual decision-making. Shafir et al (1997) report the results of survey questions designed to assess people reaction to changes in income and prices. They find that although subjects recognize that in the economic transactions, elements of both nominal and real representations are important, the fact that the nominal representation is simpler and more salient makes them to focus more on the nominal one, originating the phenomenon of the money illusion. This introduction document

[2] See Fisher (1928).

and Gneezy, 2000, or Fatas et al., 2014) is that subjects choose a local market, and compete with the other firm setting prices denominated in the local currency.

Our experimental results significantly correlate prices with nominal exchange rates. This *monotone* nominal illusion effect is quite consistent with previous studies analysing spending decisions in foreign currencies, and with field evidence studying the effect of the changeover to the Euro on individual behaviour. Raghubir and Srivastava (2002) study the salience of the nominal representation when individuals are requested to make spending decisions in an unfamiliar foreign currency, and find that consumers underspend when the face value of a foreign currency is a multiple of an equivalent unit of a home currency (e.g., 4 Malaysian ringgits p 1 U.S. dollar) and overspend when it is a fraction (e.g., 1 Bahraini dinar p 2.65 U.S. Dollar).[3] Kooreman et al (2004) analyse the revenues from a door-to-door donation for a charity in the Netherlands before and after the introduction of the Euro. At an exchange rate of 2.20371 Guilder for 1 euro, they report an increase in the revenues of a 10% right after the adoption of the Euro. Cannon and Cipriani (2006) report similar qualitative results in their analysis of church collections in Italy and Ireland.

The added value of our contribution goes well beyond the mere replication in the laboratory of previous empirical results. Exploiting the advantages of generating our own empirical evidence, we explore the behavioural determinants of over competitive prices. While previous studies support the view that money illusion is hard to reconcile with Nash equilibrium, the pinnacle of rational play in Game Theory, we take a more hazardous route to show that Nash equilibrium, with a behavioural twist, rationalizes extraordinarily well the monotone nominal illusion effect and explains over competitive prices (collusion).

The behavioural modification we introduce in our model is that players experience a *different* game in each market, as the strategy space is replaced by a discrete version of the continuous price set, generated by the nominal representation of the local currency. Interestingly, as markets experienced by both firms in each local market are generated by a common nominal illusion, firms may rationally and mutually best

[3] Raghubir and Srivastava (2009) show that the likelihood of spending is lower when an equivalent sum of money is represented by a single large denomination (e.g., one $20 bill) relative to many smaller denominations (e.g., 20 $1 bills).

respond to the prices chosen by other firms in the same discrete strategy space. We show that the Nash equilibria of the different discretized games, one per local market and currency generates a monotone *nominal illusion* effect, both in the model and in the laboratory.

The condition needed to link these collusive equilibria with the monotone nominal illusion effect is that players use the same invariant grid when processing the different nominal representations. This invariance assumption of grids to nominal representations follows the fact that all nominal representations are expressed using the same numerical system and a common decimal system. In a Bertrand game, players set prices choosing a number, in a strategy space derived from a specific, and market specific, nominal representation. By failing to adapt the step size to equivalent nominal representations, players follow the logic described in Psychology as the *numerosity effect* (Pelham et al, 1994): people base their judgements on numbers, without taken into consideration what these numbers would have been if different units had been used. [4] By relying on the number of units leads generated by the local nominal representation, players get trapped in one of the additional nominal equilibria of the experienced games. In other words, we simply assume players use the prominent structure of the decimal system when setting prices (see Albers, 2001 and Selten, 1997) because of the simplicity and salience of the nominal representations.

The potential existence of a variety of collusive Nash equilibria, one per market, is not enough to make useful predictions because it fails to say which grids are to be used by subjects. Any experimental result can be ex-post rationalized by appropriately choosing the most convenient grid. Fatas et al (2014) performs this ex-post fitting exercise where the emphasis is on which grid offers the best fit to the experimental data and it is shown that the behavioural model performs better than alternative behavioural models, such as Quantal Response Equilibrium and level-k. Similarly, the theory of prominent numbers alone is not useful for making predictions because the use of any prominent (convenient) number is trivially compatible with the model.

[4] See for example Wertenbroch et al, 2007 for an investigation of the use of different currency unit or Pandelaere et al, 2012 for an investigation of the use of different time units.

In this paper we show that the aggregation value is bigger than the sum of the parts, i.e. the combination of the coarse grid equilibrium and the theory of prominent numbers is powerful enough to produce precise ex-ante predictions about which prices may be observed and which not in every nominal representation. Interestingly, predictions differ across different nominal representations, rendering the behavioural model falsifiable.[5]

The behavioural model is actually quite parsimonious as compared to the standard Nash model. In our experimental setting and for a typical nominal representation, the set of admissible prices is of the order 10^3, the set of Nash equilibrium prices is of the order of 10^2 and the set of collusive equilibrium prices is of the order of 10^1. Despite its parsimony, the behavioural model organizes successfully the experimental data. Subjects coordinate on a collusive equilibrium price in one out of five occasions, whereas coordination in a Nash equilibrium price is a rare event. The model also predicts accurately well the distribution of posted prices in the different nominal representations.

In most experiments on money illusion nominal and real payoffs are not aligned. This means that if players use nominal payoffs as a proxy for real payoffs, money illusion comes at a cost. Fehr and Tyran (2001) document the existence of a *temporary* money illusion effect when players are exposed to a nominal shock, reporting a pronounced inertia in the convergence to the (unaltered, in real terms) equilibrium.[6,7] Fehr and Tyran (2007) report permanent effects linked with coordination failure in an experimental pricing game with three Nash equilibria. When players finally see through the nominal illusion veil, it is too late as they are already stuck in the "bad"

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[5] This situation is similar to that of utility maximisation. Any behaviour can be rationalized by the maximisation of a utility function that takes value 1 in the observed behaviour and value 0 everywhere else. It is when some axioms are imposed on the class of utility functions that consumer theory is falsifiable.

[6] These findings are confirmed in Fehr and Tyrant (2008), where an additional treatment variable (strategic complements vs strategic substitutes) is added. They find that under strategic substitutes, the adjustment to the nominal shock is instantaneous, whereas it takes considerably more time when the choices are strategic complements. An asymmetric response is also reported in Noussair et al (2012), although in this case to the introduction of a nominal shock (either deflationary or inflationary) in experimental asset markets.

[7] See Petersen and Winn (2014) and the reply in Fehr and Tyrant (2014) for a controversy on the interpretation of the original experimental results in Fehr and Tyrant (2001)

equilibrium (the payoff-dominated equilibrium in real terms). As a result, players suffering from the illusion effect end up worse off.

In our experiment nominal and real payoffs are perfectly aligned.[8] Hence, using a rule of thumb based on nominal prices as a proxy for real prices should naturally generates permanent effects because subjects have no incentives to deviate from any collusive equilibria of the game they experience. In a standard Bertrand competition environment, the model predicts a sizable and stable nominal illusion effect because it is an equilibrium phenomenon, characterized by large positive profits, as collusive equilibria Pareto dominate the original Nash equilibria.

The rest of the paper is as follows. Section 2 presents the behavioural model of money illusion. The experimental design and procedures as well as quantitative predictions based on the behavioural model are presented and discussed in Section 3. Experimental results are discussed in Section 4. Finally, Section 5 concludes.

2. A behavioural model of nominal illusion in strategic price competition

Consider price competition in an economy where nominal variables are nominated in ECUs. We find it useful to state the currency in the economy up front because we will be comparing pricing patterns across markets with different currencies. In the economy, the production technology exhibits decreasing returns to scale with quadratic cost function $c(q) = cq^2$ with $c > 0$ and there exists a fixed demand $Q > 0$. Price competition means that the lowest price firm will serve the whole market and that the demand is split in case of a tie. Next proposition describes the Nash equilibrium of the price competition game.

Proposition 1. *In a duopolistic price competition game with quadratic costs* $c(q) = cq^2$ *and fixed demand* Q*, the set of Nash equilibrium prices is the interval* $NE = \left[\frac{cQ}{2}, \frac{3cQ}{2}\right]$.

[8] This also happens in those studies testing the impact of nominal shocks on market prices (e.g. Noussair et al, 2012 for real asset markets).

Proof. Given that there are no fixed costs, no firm can have negative earnings in equilibrium. Also, it cannot be equilibrium an asymmetric strategy profile, because the lower quantity firm would find it optimal to slightly increase her quantity. Thus, we are left with symmetric equilibria. The lowest equilibrium price p^- is the one that yields zero profits, which is defined by the equation $p\frac{Q}{2} - c\left(\frac{Q}{2}\right)^2 = 0 \rightarrow p^- = \frac{1}{2}cQ$. The largest equilibrium price p^+ is defined as the price p for which no undercutting $p - \varepsilon$ is profitable, for small ε. The equation $\lim_{\varepsilon \to 0} \pi_i(p - \varepsilon, p) = \pi_i(p, p)$ yields the value $p^+ = \frac{3}{2}cQ$. QED

The Bertrand game with decreasing returns to scale is characterized by a multiplicity of Pareto ranked equilibria, in which only the lowest price equilibrium $p^- = \frac{1}{2}cQ$ yields zero profits. We will denote by $p^+ = \frac{3}{2}cQ$ the Pareto efficient equilibrium.

Our starting point for the behavioural model is the concept of *Coarse Grid Nash Equilibrium* (CGNE). It consists on applying the Nash concept to a *discretised* version of the game, where the continuous strategy set is replaced for a discrete version based on a coarse grid. Fatas et al (2014) prove that in a duopolistic price competition with quadratic costs, the set of coarse grid Nash equilibrium prices associated to a grid of size k is the corresponding discretization of the Nash interval plus the first two multiples of k larger than the Pareto efficient equilibrium p^+. From an outside observer not aware of the discretization process performed by players, these two "new" equilibrium prices would be examples of players colluding on high non-equilibrium prices. Because they will play a key role in our analysis, we will refer to them as "collusive equilibria". Next proposition formally states these ideas; to this end, define $n^-(k)$ and $n^+(k)$ as follows

$$n^-(k) = min\{n | n \times k \geq p^-\}$$

$$n^+(k) = max\{n | n \times k \leq p^+\}$$

Proposition 2. *Consider a common grid* $k > 0$. *Then the set of coarse grid Nash equilibrium prices corresponding to a grid of size* k *is* (p, p) *with* $p = nk$ *for* $n = n^-(k), \dots, n^+(k), n^+(k) + 1, n^+(k) + 2$.

Proof. For fixed firm $j's$ price p, the equation $\pi_i(p^d, p) = \pi_i(p, p)$ defines the price $p^d = \frac{1}{2}[p + p^+]$ that makes firm i indifferent between choosing either price p or price p^d. The difference $p - p^d = \frac{1}{2}[p - p^+]$ gives the maximum profitable deviation. Ask now for which n at $p = nk$ the maximum profitable deviation is exactly the grid size k. The answer is $n = \frac{3}{2}\frac{cQ}{k} + 2$. Noting that $int\left(\frac{3}{2}\frac{cQ}{k}\right)$ is precisely $n^+(k)$, we have that $n^+(k) + 1$ and $n^+(k) + 2$ are also CGNE. QED

Once the equilibrium structures of the continuous and the discretized price games have been characterized, we introduce the behavioural assumption. It refers to a feature of the process by which players discretize the strategy set across different nominal representations of the economy, where a nominal representation is a replica of the economy with the exception that prices are nominated in a different currency (referred as the local currency). Each nominal representation is characterized by an exchange rate, e.g. the number of ECUS for one unit of the local currency.

It is easy to check that the Nash prediction is free of nominal illusion. Consider a nominal representation with exchange rate e. The Nash equilibria expressed in the local currency is the interval $NE_e^* = \left[\frac{1}{2}c_e^*Q, \frac{3}{2}c_e^*Q\right]$, where an asterisk denotes that a nominal variable is expressed in the local currency. We multiply by the exchange rate e to express these prices in ECUS

$$e \times NE_e^* = \left[\frac{1}{2}ec_e^*Q, \dots, \frac{3}{2}ec_e^*Q\right]$$

By noting that $e \times c_e^* = c$, e.g. that the only difference across nominal representations is the currency, we find that $e \times NE_e^* = NE$, i.e. the Nash prediction is immune to nominal illusion.

A different issue is how the discretization process inherent to the coarse grid Nash equilibrium concept interacts with the different nominal representations. This is the content of the behavioural assumption.

Behavioural assumption: *The set of grids is invariant to the nominal representation*

This assumption says that the discretization process is independent from the particular nominal representation of the economy. Players do not take into account that the different nominal representations where they may compete might represent the same economy; they always perform the discretization process using the same set of grids.

This behavioural assumption is reminiscent of the *numerosity heuristic* (Pelham et al, 1994). This heuristic emerges when people fail to take into account the type of unit when evaluating numerical information, and instead, they rely on the number of units. There is wide evidence of the use of the numerosity heuristic in psychological research. In consumption situations, decision makers perceive differences when information is communicated using different units. For example, Wertenbroch et al (2007) reports differences in consumption when monetary differences are reported in different currencies, and Pandelaere et al (2011) reports different behaviour when information is provided in small units (months) rather than large units (years).

Once players based their decision on the salience of numbers over units, it is also well documented that subjects tend to focus on more salient numbers. A well-known phenomenon in stock markets is price clustering around round numbers (Osborne, 1965 is an early reference). This phenomenon has been shown to be robust to changeover: Soonemans (2006) reports that many transactions on the Amsterdam Stock Exchange occurred at prices that were round numbers, both before and after the introduction of the Euro in 2002.

To see the consequences of the fact that players do not adjust the set of grids to the particular nominal representation at hand, we will fix a grid size k and compare the set of coarse grid Nash equilibrium prices across different nominal representations of the economy.

Consider a local market with exchange rate e. The set of coarse grid Nash equilibria expressed in the local currency is[9]

[9] To ease the exposition, we have assumed that the Pareto inferior and the Pareto efficient Nash equilibrium prices of the nominal representations are multiples of k.

$$CGNE_e^*(k) = \left\{\frac{1}{2}c_e^*Q, \frac{1}{2}c_e^*Q + k, \frac{1}{2}c_e^*Q + 2k, \dots, \frac{3}{2}c_e^*Q\right\} \cup \left\{\frac{3}{2}c_e^*Q + k, \frac{3}{2}c_e^*Q + 2k\right\}$$

By multiplying by the exchange rate e and using $e \times c^* = c$, we can express the set of coarse grid Nash equilibrium prices in ECUS

$$e \times CGNE_e^*(k) = \underbrace{\left\{\frac{1}{2}cQ, \frac{1}{2}cQ + ek, \frac{1}{2}cQ + 2ek, \dots, \frac{3}{2}cQ\right\}}_{Discretization\ of\ NE} \cup \underbrace{\left\{\frac{3}{2}cQ + ek, \frac{3}{2}cQ + 2ek\right\}}_{Collusive\ equilibrium\ prices}$$

This expression reveals how the grid size k interacts with the nominal representation to produce the set of coarse grid equilibria: the *effective* grid size is augmented by a factor of e ($k \times e$). The first set in the right-hand side shows that the set of coarse grid Nash equilibrium prices includes fewer Nash equilibria (of the "continuous" pricing game) the larger the exchange rate. But the effect of changing the exchange rate on for example the average equilibrium price is negligible, because we will be averaging over different discretised versions of the same set of Nash equilibria. The second set in the right hand side is more interesting. It refers to the two collusive equilibria, e.g. the two coarse grid Nash equilibria that exceed the efficient Nash equilibrium; note that they are further away from the efficient NE the larger the exchange rate (because the effective grid size $k \times e$ increases). The impact of the two collusive equilibrium prices on the average coarse grid equilibria is non negligible and positive. This observation leads to the following definition of a particular class of nominal illusion.

Definition 1*: Monotone Nominal Illusion: average prices are increasing in the exchange rate.*

Several observations are important. The first one is that the derivation of the monotone money illusion effect obviates the equilibrium selection issue associated to the multiplicity of coarse grid Nash equilibria. Note that definition 1 simply focuses on the "support" of the coarse grid Nash equilibria and it averages over all of them under the assumption that they all have the same probability of being played. It might well be the case that for some nominal representations, some equilibria are more accessible than others and are selected with higher probabilities. Rather than applying any equilibrium selection mechanism either traditional approaches such as risk or payoff dominance, Harsanyi and Selten (1988), or more recent ones based on boundedly rational arguments such as quantal response equilibrium (McKelvey and Palfrey, 1995) or step thinking (Stahl and Wilson, 1995), we keep the model simple by assuming that no further interaction between nominal representations and players choices takes place. The second observation is on the nature of the monotone nominal illusion effect: It is not transitory but a permanent effect, because it is derived from an equilibrium model. We collect these observations in the next lemmas.

Lemma 1. *Coarse grid Nash equilibrium predicts monotone nominal illusion*

Lemma 2. *Coarse grid Nash equilibrium predicts that nominal illusion is a permanent phenomenon*

Before we take a step further and offer quantitative predictions about pricing behaviour in the lab, we describe the experimental setting in which we test the nominal illusion effect in the next section.

3. Experimental design, procedures and behavioural predictions

In this section, we first describe the experimental design and procedures. After that, we derive numerical predictions for the prices in the experiment using the set of natural prominent numbers as grids.

3.1 Experimental design and procedures

Our experiment consists of one game, three treatments and two sessions. Additionally, we use one treatment in Fatas et al (2014) as baseline. See Table 1 for the details.

Table 1. Experimental design

	Baseline	Nominal representation		
Currency	ECU	Titanio	Methanio	Daphnio
Market	**B500**	**M100**	**M20**	**M5**
Exchange rate	1:1	1:5	1:25	1:100
Subjects	84	32	24	24
Markets	42	16	12	12
Price Range	[0, 500]	[0.0, 100.0]	[0.00, 20.00]	[0.000, 5.000]
Decimal places	0	1	2	3

The baseline economy is characterised by $c = 5, Q = 20, P = 500$, and prices nominated in ECU (experimental currency unit). The parameter P is the largest price that players could choose in the experiment, e.g. prices were chosen from the interval $[0, P]$. In our experiment, we consider three different nominal representations of this basic economy, each characterized by a local currency with exchange rate e, the number of ECUS for one unit of the local currency. The three markets are M100, M20 and M5, characterized by exchange rates $e = 5, 25$ and 100, respectively.

In order to keep the different nominal representations of the basic economy equivalent from an *experimental* point of view, we made two adjustments: First, the largest admissible price $P*$ was deflated $P*= P/e$; so as to the keep the maximum profit the same across nominal representations. And second, we adjusted the number of decimal places that experimental subjects could use to maintain the same cardinality of the strategy space across different nominal representations (see Table 1 above for details). Finally, note that the experimental markets are named after the largest admissible price: for example the largest price available in the market M20 is $500/25 = 20$.

At the beginning of the experiment, subjects were asked to choose in which of the three *local* markets (M100, M20 and M5) they wished to compete; subsequently, subjects were randomly matched (under a partner protocol) to compete among those who selected the same market. They were explicitly told that the demand and costs conditions across the different local markets were identical (although they were never informed of the particular values of the demand and cost function, not even that there were decreasing returns to scale) and that the exchange rates that were used to convert profits from the local currency to Euros were such that "your potential benefits are also identical in the three markets".

The self-selection feature of the experimental design raises one interesting issue regarding the rationality of experimental subjects and/or the saliency of the different nominal representations. If there were different types of players, some sophisticated and some more boundedly rational, one could imagine the former anticipating which nominal representation would attract the more limitedly rational ones. This market would be expected to be more profitable and therefore would also be selected by the sophisticated players. As a result, we would end up with an uneven distribution across markets. Fortunately, this was not the case in our experiment: we have 16 duopolies in M100, 12 duopolies in M20 and 12 duopolies in M5.

Experiments were run in the laboratory for research in experimental economics at the University of Valencia. A hundred and sixty four students (82 markets) from business and economics were recruited using a standard electronic recruitment procedure. Two sessions were run and subjects earned 12€ on average for an experiment that lasted for less than an hour. The baseline treatment is the treatment B500 in Fatas et al (2014). A set of instructions translated from the Spanish is available in the Appendix.

3.2 Behavioural predictions

Lemmas 1 and 2 offer qualitative predictions about how prices compare across different nominal representations. But we would like to take a step further and produce quantitative predictions. To this end, we need to specify which set of grids subjects use. Given that the money illusion effect is a nominal effect usually invoked in terms of the simplicity and the salient features of the nominal representation, it seems intuitive that players might take advantage of the prominent structure of the decimal system (Albers, 2001 and Selten, 1997) when discretising the strategy set. This is the content of the Prominence Assumption.

Prominence Assumption: *The set of grids is the set of natural prominent numbers*

The prominent numbers as defined by Albers (2001) are those numbers of the form $a \times 10^i$ for i integer and $a \in \{1, 2, 5\}$. The set of *natural* prominent numbers is yielding the set of grids $\{1, 2, 5, 10, 20, 50 \dots\}$. The *Prominence Assumption* states that players consider multiples of 1, 2 and 5, and their powers of ten when discretising the price set.

Two observations are in place. First, by restricting ourselves to natural prominent numbers, we are assuming that the smallest exactness degree is one and therefore that players do not use decimal places. Note that this assumption can be judged too extreme, especially in treatment M5 where experimental subjects are allowed to choose numbers in the interval $[0,5]$ with up to three decimal places. We view treatment M5 as a tough test for our theory.[10]

Second, it is important that the reader doesn't think of the *Prominence Assumption* in isolation. It is similar as when we believe that players think of integers when facing a standard linear Bertrand competition. The prediction is not that they choose *any* integer, but that they choose the equilibrium prices c.[11] Similarly, when we use the Prominence Assumption in conjunction with the coarse grid concept, the prediction is that players choose the set of coarse grid Nash equilibrium prices of the game. In fact, we will refer to them as the *Selten Coarse Grid Nash Equilibrium* (SCGNE) prices. Table 2 displays the set of SCGNE prices for the three nominal representations that we consider in our experiment, expressed in the local currencies as well as in ECUS.

[10] This is an arbitrary decision, but we will see that it accords well with the experimental data. For the treatment M100, 78.75% of decisions were integer numbers even though subjects were allowed to use one decimal place. For the treatments M20 and M5, this percentage decreases to 55.41% and 41.04% respectively, when the number of decimal places was 2 and 3 respectively.

[11] And $c + 1$ and $c + 2$, as these two prices are also equilibrium prices.

Table 2. Selten coarse grid Nash equilibrium prices by nominal representation

Baseline: Market B500

Grid	SCGNE Prices: In the local currency	SCGNE Prices: In ECUS
1	50, 51, 52… 150, 151, 152	50, 51, 52… 150, 151, 152
2	50, 52, 54… 150, 152, 154	50, 52, 54… 150, 152, 154
5	50, 55, 60… 150, 155, 160	50, 55, 60… 150, 155, 160
10	50, 60, 70… 150, 160, 170	50, 60, 70… 150, 160, 170
20	50, 70, 90… 150, 170, 180	50, 70, 90… 150, 170, 180
50	50, 100, 150, 200, 250	50, 100, 150, 200, 250
100	100, 200, 300	100, 200, 300
200	200, 400	200, 400
500	500	500

Market M100

Grid	SCGNE Prices: In the local currency	SCGNE Prices: In ECUS
1	10, 11, 12… 30, 31, 32	50, 55, 60… 150, 155, 160
2	10, 12, 14… 30, 32, 34	50, 60, 70… 150, 160, 170
5	10, 15, 20, 25, 30, 35, 40	50, 75, 100… 150, 175, 200
10	10, 20, 30, 40, 50	50, 100, 150, 200, 250
20	20, 40, 60	100, 200, 300
50	50, 100	250, 500
100	100	500

Market M20

Grid	SCGNE Prices: In the local currency	SCGNE Prices: In ECUS
1	2, 3, 4, 5, 6, 7, 8	50, 75, 100, 125, 150, 175, 200
2	2, 4, 6, 8, 10	50, 100, 150, 200, 250
5	5, 10, 15	125, 250, 375
10	10, 20	250, 500
20	20	500

Market M5

Grid	SCGNE Prices: In the local currency	SCGNE Prices: In ECUS
1	1, 2, 3	100, 200, 300
2	2, 4	200, 400
5	5	500

Underlined prices denote the collusive equilibrium prices

We can actually see the money illusion effect in Table 2. Consider a grid size, for example $k = 2$, and compare the collusive equilibrium prices (expressed in ECUS) across different nominal representations (they are underlined in Table 2). In the baseline treatment, these non-Nash prices are 152 and 154. They are 160 and 170 in M100. In M20, they are 200 and 250. And finally, they are 200 and 400 in M5. Notice that these prices increase with the nominal exchange rate: this is the monotone money illusion effect in action.

A second feature of the set of SCGNE prices is that the recursive nature of the set of the natural prominent numbers leaves its footprint on the numerical values of the SCGNE prices for given nominal representation. Consider for example the market M100. A price of 200 ECUS is an equilibrium prediction for three different grid sizes: $k = 5, 10$ and 20. The prices that are SCGNE prices for several grid sizes are called to play a prominent role in the aggregate distribution of SCGNE prices in a local market.

Predicting which particular grid each experimental subject will use is beyond the scope of this paper, but we can make aggregate predictions about the distribution of prices in the experiment if we make assumptions about the distribution of grids in the population. As we do not want to favour any prominent grid over the others (we already made a selection of grids restricting them to be natural prominent numbers), we adopt the neutral assumption that grids are uniformly distributed in the population and that any experimental subject will randomly pick (the uniform distribution again) any of the SCGNE prices associated to *her* grid. The average and median SCGNE prices across the nominal representations in the experiment under these assumptions are displayed in Table 3 under the heading “upper bound”.

Table 3. Selten coarse grid Nash Equilibrium predictions by nominal representation

Market	Average Price			Median Price		
	Lower bound	Average bound	Upper bound	Lower bound	Average bound	Upper bound
B500	127.8	157.7	187.6	111	125	139
M100	150.1	186.8	223.6	125	142.5	160
M20	202.0	241	280.0	175	212.5	250
M5	266.6	300	333.3	200	250	300

Note that experimental subjects in a market may eventually become aware that they are using different grids. If this happens, then it is very likely that some interaction between their grids will take place. We find it reasonable to assume that the subject using the larger grid will eventually imitate the rival's most successful (e.g. smaller) grid[12] and that both subjects will end up using the same grid. Imitation dynamics associated to firm competition has been quite successful in organizing experimental data; see for example Apesteguia et al, 2007 in the context of Cournot competition. Of course, the possibility of grid competition is also conceivable, with grids getting smaller and smaller until reaching the minimum exactness: $k = 1$. However this case would imply the absence of a permanent money illusion effect, because the CGNE prices associated to $k = 1$ are basically the Nash predictions. Table 3 also displays the main summary statistics of the distribution of the SCGNE prices when there is grid interaction in the form of imitation of the most successful grid under the heading "lower bound".

Table 3 shows that our behavioural model captures the monotone money illusion effect -the average and median SCGNE prices increase with the exchange rate- regardless of the existence of grid interaction. When there is grid interaction, prices are smaller than those under no-interaction because the large grids that give rise to large SCGNE can only be sustained when both players in the market are using the same large grid. Table 3 shows that the average impact of the imitation of grids is

[12] By more successful we mean that smaller grids allow smaller price undercutting which in fact results in more profits.

around 30%, meaning that the average and median SCGNE prices decrease by 30% when grid interaction is allowed.

Note however that grids are not directly observed, but they have to be inferred from the prices chosen by the rival firm. This inference exercise is complex because a given price can arise from more than one grid. Recall our previous example; in the nominal representation M100, a price of 40 in the local currency can be generated by three different grids: $k = 5, 10$ and 20. This leads us to consider the existence or not of grid interaction in the marketplace as limiting cases inside which experimental data must lie (this explains why they have been named lower and upper bounds). In addition we provide the average of these two bounds.

4. Experimental results

In this section we first present some summary descriptive statistics to compare average behaviour across nominal representations. Our analysis will be done using prices nominated in ECUS.

4.1 Aggregate analysis

Table 4 contains some descriptive statistics of posted and market prices across treatments.

This table reveals that the Nash concept predicts quite well in the baseline treatment B500, as posted and market average prices are closed to the efficient Nash equilibrium (150). But when experimental subjects compete in markets with larger exchange rates, average prices exceed the Nash equilibrium prediction. In fact, the tendency for average prices to increase with the exchange rate is already present in the first period.[13]

[13] Mann-Whitney tests confirm that the differences between the baseline and any nominal representation treatment are significant. However, pair wise comparisons between the nominal representations are not generally significant. Given that the Mann-Whitney test is a very conservative approach, we also offer an econometric exercise (see below).

Table 4. Average prices by nominal representation (in ECUS)

		Average posted			Average market		
		Periods			Periods		
Market	# Obs.	First	All	Last five	First	All	Last five
B500	1680	206.58	165.72	169.45	154.52	148.82	158.06
		(97.58)	*(97.47)*	*(119.72)*	*(60.25)*	*(87.55)*	*(113.56)*
M100	640	265.86	238.09	221.94	212.81	215.15	200.74
		(115.65)	*(142.51)*	*(142.84)*	*(72.03)*	*(137.66)*	*(134.30)*
M20	480	294.96	247.7	256.05	252.10	224.29	244.67
		(78.02)	*(98.57)*	*(120.47)*	*(35.29)*	*(85.21)*	*(123.36)*
M5	480	282.33	305.14	304.45	232.96	290.56	296.14
		(109.42)	*(141.37)*	*(152.04)*	*(83.79)*	*(142.81)*	*(153.18)*

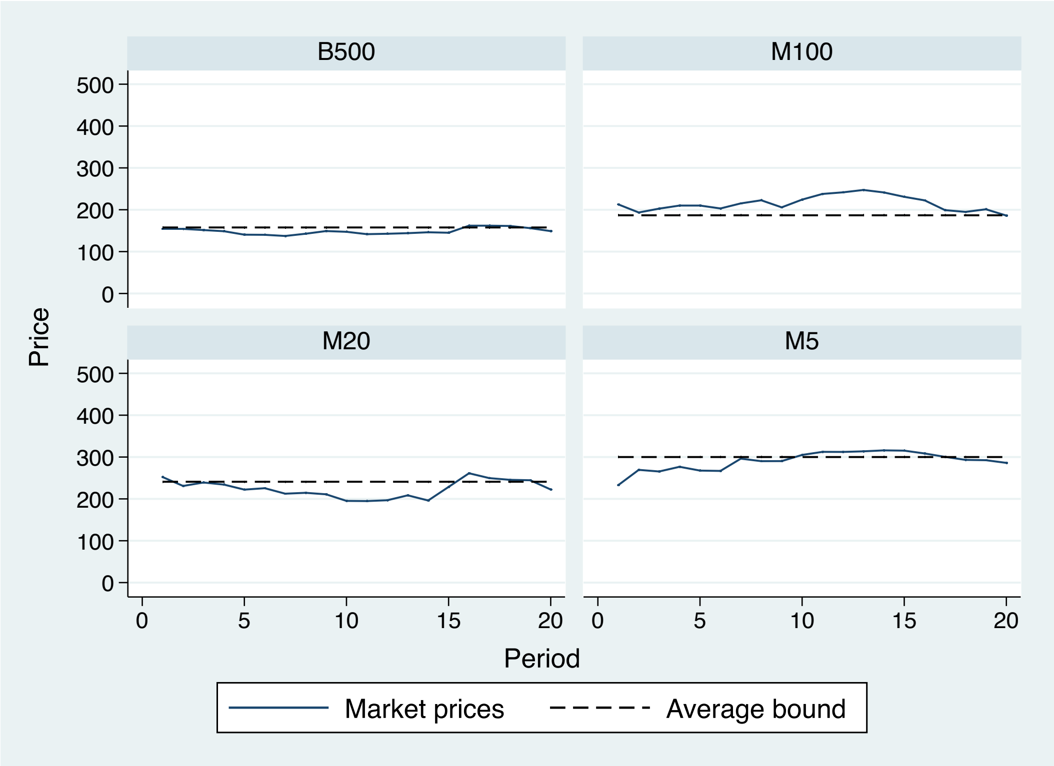
Standard deviations in parentheses

Result 1. Aggregate data reveals a monotone money illusion effect: average prices increase with the nominal exchange rate

This analysis rejects the universal validity of the Nash predictions across nominal representations and it neatly confirms the content of Lemma 1 regarding the positive relation between exchange rates and mean prices. Lemma 2 claimed that the money illusion effect is not temporary. If it were temporary, we would see a decline in prices towards the Nash equilibrium values as time passes. Figure 1 displays the time evolution of average market prices by nominal representation. Visual inspection reveals no noticeable negative trend in any treatment. Figure 3 in the Appendix focuses on the last five rounds, confirming Lemma 2.

Result 2. The monotone money illusion effect is permanent

Figure 1. Evolution of market prices by nominal representation (all periods)



Econometric estimations of panel data regressions at the individual level and clustered by group confirm this result (see Table 11 at the Appendix).[14] We offer the estimates over two time horizons: all periods and the last five. The dependent variable is the individual market price[15] and the independent variables included in the two econometric specifications are dummy variables for all local markets (M5, M20 and M100) and the variable *Period* to capture any time trend.

The estimated value for the variable *Period* is not statistically significant over either time horizon, confirming that money illusion is a permanent phenomenon. The dummy variables for markets M5, M20 and M100 are statistically significant and positive; pair-wise comparisons confirm the treatment effects founded with the aggregate analysis.

An alternative approach to evaluate the existence of the money illusion effect is through price distributions. This approach will be important, as we will later be

[14] We take one observation by subject, and the marginal effects have been clustered by group level.
[15] Estimations using posted prices yield similar results

interested in comparing actual choices to coarse grid Nash equilibrium price predictions. Figure 4 in the Appendix depicts the distribution of posted and market prices (in ECUS) across nominal representations, together with two vertical lines inserted at the boundaries of the Nash equilibrium prices: 50 and 150.

For the baseline treatment B500, most prices lie inside the Nash interval, confirming that the Nash concept captures adequately the observed behaviour. For large exchange rates though, price distributions shift to the right, putting more density on large prices, away from the Nash predictions. This is the monotone money illusion effect.

It is also important to notice that price distributions have some features that deserve our attention. First, for all nominal representations, there are no major differences between posted and market prices (except that the latter puts more density on lower prices). And second, price distributions are multimodal and the location of the local modes is sensitive to nominal representations. The global modal price for treatment M100 happens inside the Nash interval, while for the other treatments it falls to the right of the Nash prediction: 250 for treatment M20 and 200 for treatment M5. This suggests an interaction between the nominal representation and the pricing behaviour that might be at the heart of the explanation of money illusion.

The next two subsections are aimed at assessing how well coarse grid Nash equilibrium captures these empirical regularities.

4.2 Selten coarse grid Nash equilibrium vs. Nash equilibrium

Table 5 displays the predictive success index (PSI) (Selten, 1997) for both equilibrium concepts. This index is computed as the difference between the descriptive power (the proportion of actual prices predicted by a model) and the predictive parsimony (the proportion of all prices consistent with the theory).

Table 5. Comparing alternative equilibrium models by their predictive success

	Nash equilibrium			Selten coarse grid Nash equilibrium		
Market	Predictive Parsimony	Descriptive Power	Predictive Success	Predictive Parsimony	Descriptive Power	Predictive Success
B500	66.76	20	46.76	84.19	22.4	61.79
M100	40.73	20	20.73	62.49	2.9	59.59
M20	14.4	20	-5.60	35.41	0.5	34.91
M5	14.42	20	-5.58	41.04	0.1	40.94
Average	34.07	20	14.07	55.78	6.47	49.30

Our behavioural model outperforms the Nash prediction in terms of the descriptive power and in terms of the predictive success in all markets. In fact, the Nash prediction model performs quite poorly in the markets M20 and M5, with a negative PSI, meaning that it predicts worse than a purely random model. On the contrary, the coarse grid model based on the natural prominent numbers stands up with an average PSI of nearly 50%.

Result 3. Selten Coarse Grid Nash Equilibrium model outperforms the Nash prediction in terms of descriptive power and in terms of predictive success index in all nominal representations

Computing for each nominal representation which percentage of observed prices are predicted by none, both or only one of the competing equilibrium concepts is an alternative way for assessing the relative importance of each equilibrium model to capture data. Table 6 displays such analysis.

Table 6. Taxonomy of market prices by equilibrium concept in the last 5 rounds (%)

	Nominal representation							
	Without undercutting				With undercutting			
Equilibrium concept	B500	M100	M20	M5	B500	M100	M20	M5
Only NE	0	18	12	20	0	10	5	20
Both	77	36	12	3	77	44	18	3
Only SCGNE	13	28	42	32	13	34	52	50
None	10	19	35	45	10	13	25	27
Total	100	100	100	100	100	100	100	100

Let us focus first on the first four columns, where the counting exercise is strictly applied. First, the overlapping between the two equilibrium concepts declines with the nominal exchange rate, reaching a value of only 3% for market M5. This means that for large values of the exchange rate both models do provide contrasting predictions about pricing behaviour. And in fact, the behavioural model is more successful in capturing pricing behaviour than the Nash one, as the figures under “only SCGNE” are consistently larger than those under “only NE”. Second, the percentage of market prices not predicted by either model is increasing, starting at 10% and reaching the largest value, 45%, for the market M5. These figures are a bit worrying because they point to the inability of the equilibrium models to capture almost half of the market prices for the treatment M5.[16] However, these computations need to be interpreted with caution, as the strict application of the behavioural model would miss relevant pricing behaviour intimately linked to the existence of SCGNE prices.

We are interested in spotting undercutting behaviour around SCGNE prices, e.g. prices that are an epsilon below a SCGNE price, because this behaviour hangs by a SCGNE price and therefore it should be counted as supporting the behavioural model. This raises the issue of how small the undercutting behaviour needs to be for revealing the connection to a SCGNE price. In this respect we are practical and assume that small means undercutting by one decimal place in the local currencies (recall that experimental subjects choose prices nominated in local currencies). Also,

[16] This is not really surprising because the behavioural model assumes that subjects do not use decimal numbers in a treatment, M5, where subjects are allowed to use up to three decimal places.

we allow for uninterrupted sequences of undercutting prices by one decimal place as being indicators of SCGNE prices. For example, in the market M20, prices 7.97 and 7.85 (in the local currency) are considered consistent with the behavioural model because they form an undercutting sequence of prices below the SCGNE price 8 (in the local currency). [17] The last four columns of Table 7 perform the counting exercise when undercutting strategies below SCGNE prices are taken into account. The percentage of market prices that are not predicted ever exceeds 25% in any treatment; meaning that the equilibrium models predict 3 out of 4 observations in the last five rounds of the experiment and that the behavioural model account for at least 2 out of 4 market prices in the last five rounds of the experiment.

The analysis performed in this section does not take into consideration that an equilibrium theory requires by definition that all subjects choose *simultaneously* the same equilibrium price. The first two columns of Table 7 display the percentage of equilibrium play according to both competing equilibrium models across nominal representations.

Table 7. Comparing alternative equilibrium models by compliance with symmetric pricing and equilibrium predictions

	Equilibrium play		Symmetric pricing		
Market	NE %	SCGNE %	%	NE %	SCGNE %
B500	10.71	15.35	15.95	67.16	96.27
M100	2.19	17.81	19.69	11.11	90.48
M20	0.41	12.92	13.33	3.13	96.88
M5	0.00	30.00	32.08	0.00	93.51

Table 7 makes clear the superiority of the behavioural model: on average, there is coordination in a SCGNE price in one out of five observations. On the contrary, the percentage is basically zero according to the Nash model; that is, firms never coordinate in any of the Nash equilibrium prices. A complementary issue is in which prices firms tend to coordinate. Roughly speaking, we ask ourselves if the prices in

[17] The largest uninterrupted sequence of undercutting prices happens at the local market M5 and a price of 2 in the local currency. The sequence is composed of 8 prices, going from 1.999 to 1.8.

which firms coordinate correspond to SCGNE prices or to Nash equilibrium prices. The third column of Table 7 shows that the percentage of symmetric pricing is relatively constant across markets (it is 20% on average) and that the predictive allocation between the Nash model and the behavioural model cannot be more asymmetric (columns fourth and fifth respectively): of all instances of price coordination, more than 90% where in SCGNE prices, whereas this percentage decreases dramatically for the Nash equilibrium prices, reaching values as low as 3% and 0% in markets M20 and M5 respectively.

Result 4. More than 90% of the instances of price coordination happen at SCGNE prices for all nominal representations, whereas this percentage is almost zero for the Nash equilibrium prices

Alternatively, we perform a taxonomy exercise on symmetric pricing for the last five periods, defined as the percentage of the symmetric price instances that happens at prices that are predicted by both, none or only one of the two equilibrium models. Results are displayed in Table 12 in the Appendix. This exercise makes clear that symmetric pricing takes place mainly in prices predicted only by the behavioural model, averaging 90% across nominal representations, while coordination hardly occurs at prices predicted only by the Nash model (it is striking that in markets M20 and M5, there is no single instance of price coordination in a price predicted by the Nash model, while this percentage is 95% for the behavioural model). Again this reinforces the superiority of the behavioural model to account for the pricing patterns in the experiment.

3.3 Selten coarse grid Nash equilibrium vs. experimental data

In this section we study how well the behavioural model captures the regularities observed in the data. A two-fold approach is followed: In first place, a comparison between some summary statistics of posted and predicted prices (under the two interaction conditions) is performed; recall from Section 3.2 that both conditions can be considered as lower and upper bounds. Table 8 displays the mean and median lower and upper bounds, together with the corresponding data for all and the last five periods. Table 8 shows that except in one occasion (M100, all periods), all experimental data lie inside the two theoretical bounds predicted by the behavioural model (12 out of 16 cases). This suggests that the behavioural model captures very well the main descriptive statistics of the experimental data.

Table 8. Summary statistics and SCGNE dynamics

	Average posted price			
Market	Lower bound	All periods	Last five periods	Upper bound
B500	127.8	165	169	187.5
M100	150.5	238*	222	223.5
M20	202.0	248	256	280.0
M5	266.6	305	304	333.3

	Median posted price			
Market	Lower bound	All periods	Last five periods	Upper bound
B500	111	130	115	139
M100	125	190*	159	160
M20	175	247.7	236	250
M5	200	250	232	300

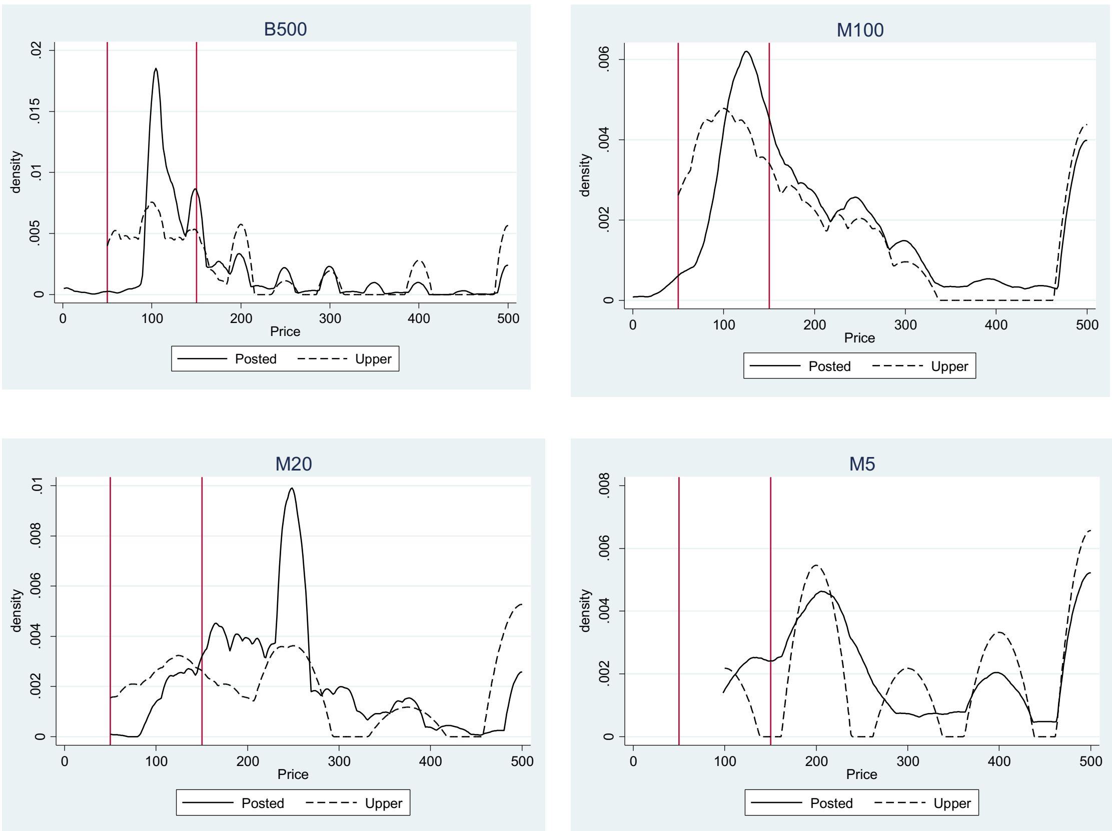
An asterisk * denotes that the data is outside the theoretical prediction interval.

Result 5. The behavioural model nicely captures average behaviour across nominal representations.

In second place, we investigate how well SCGNE price distributions replicate the main features of the experimental data. For this, we rely on kernel density estimates for the price distributions, as they are a convenient way to address the undercutting behaviour issue. Figure 2 displays price distributions for actual posted prices and the upper bound predictions.

Note the precision with which the behavioural model replicates the main features of the data distribution for the different nominal representations. The best fit happens for treatment M100, where the distribution of SCGNE prediction is extremely close to the data distribution. For the other nominal representations, the SCGNE model nicely captures the modal behaviour: for the market M5, the local modes at 200 and 400 (these peaks are not predicted and not observed for the other nominal representations) and for the market M20 the local mode is situated at 250.

Figure 2. Posted price distribution and SCGNE prices by nominal representation. All periods



This goodness of fit is more remarkable when it is recalled that no particular equilibrium price is favoured over the other equilibria by any equilibrium selection process in the computation of the behavioural predictions. Predicted local modes differ across treatments not because different nominal representations select different coarse grid Nash equilibrium prices but because some prices are coarse grid Nash equilibrium for many different grids. Different nominal representations yield different values for these multigrid equilibria that happen at the same places that are observed in the experiment.

Result 6. The behavioural model captures the main features of the price distribution, particularly the local modes, across the different nominal representations.

We believe that this ability of the SCGNE model to replicate accurately the position of the spikes in the price distribution across the different nominal representations, e.g. the most chosen prices for each nominal representation, is one of the features that lends stronger support to the equilibrium theory of grid pricing.

3.4 Payoff analysis. Understanding the permanent nature of the money illusion effect

Almost all experimental papers dealing with money illusion find that the effect is transitory. In those experiments where subjects experiment a nominal shock (the introduction of a new currency, for example), experimental subjects eventually converge to the new optimal situation, although the rate of convergence depends on whether the shock is positive or negative (Noussair et al, 2012), or whether actions are strategic complements or substitutes (Fehr and Tyran, 2001).

There is only one instance, Fehr and Tyran (2007), in which although the money illusion effect is temporary, the impact is permanent. The reason is that Fehr and Tyran (2007) devise an experimental setting in which the payoff-dominant equilibrium in nominal terms is, by design, the payoff-dominated equilibrium in real terms. Money illusion, although temporary in nature, had permanent effects because when players finally see through the nominal veil, it is too late to get away as they are already stuck in the "bad" equilibrium. As a result, those players suffering from the illusion effect end up worse off.

In our experiment and in a more natural price setting, nominal illusion results from new equilibria through the interaction between the nominal representation and the prominent structure of the decimal system. Experimental subjects have no incentives to deviate as they find themselves playing equilibrium prices. Even more, the collusive equilibrium prices are characterized by large positive profits, larger than the profits associated to the standard Nash equilibrium prices. A look to the aggregate profits across different nominal representations (Table 9) –for all periods and the last five- reveals profits in excess of the Pareto superior Nash equilibrium (which are the profits in the baseline treatment B500) across the different nominal representations, with an increasing pattern.

Table 9. Descriptive statistics of earnings by nominal representation

	Average earnings in ECUS	
Market	All periods	Last five periods
B500	567.95 *(1169.27)*	718.76 *(1408.73)*
M100	1249.95 *(1800.86)*	1094.94 *(1768.14)*
M20	1309.54 *(1539.34)*	1588.42 *(1699.70)*
M5	2066.02 *(2032.66)*	2111.40 *(2186.30)*

Mann-Whitney tests show significant differences between profits in the baseline and those in any nominal representation. An econometric analysis based on panel data estimations at the individual level and clustered by group shows that pair-wise comparisons are significant (see Table 12 in the Appendix).

Result 6. The nominal illusion effect is permanent; players' profits increase with the nominal exchange rate.

5. Conclusions

Nash equilibrium is synonymous with rational play in strategic settings. A vast set of empirical and experimental findings disputes Nash predictions in many settings and casts doubts on the validity of its underlying rationality assumption. Money illusion is an archetypical example of a situation in which small individual irrationalities may have a large impact on market behaviour and welfare. In this paper we study money illusion defined as the human tendency to make economic decisions on the basis of nominal rather than real variables. As such, nominal illusion may lead economic agents to making wrong choices, generating substantial but temporary welfare losses. The rationale behind this transitory effect is that agents will eventually see through the nominal veil, and will discover the incentives to best respond, amending their errors.

In this paper we develop and test a simple equilibrium model of nominal illusion. The model characterizes nominal illusion assuming that players always simplify the nominal choice set by thinking on multiples of convenient numbers, and then let players follow a standard equilibrium logic, best responding to other players. This intuitive approach to nominal illusion generates sizable and permanent effects as long as players use the same convenient numbers to simplify the choice set, and experience a market specific game. Once trapped in a collusive equilibrium, the incentives to deviate from it disappear, decision makers fail to recognize that different economies are equivalent in real terms, and nominal illusion generates a monotonic effect on prices.

Our model reconciles these two economic concepts by operationalising the very same argument used to invoke nominal illusions: the simplicity and salience of nominal variables. The model predicts a non transitory and monotone relationship between nominal denominations of the local currencies operating in each market in a standard and stylized price competition experiment. The results do not only confirm both hypotheses, but predicts the vast majority of symmetric price profiles and outperforms other models.

Our results are consistent with the idea that in frictionless markets, prices may stay above competitive markets because there are no incentives to deviate from any equilibria. By reconciling the logic of rationality, as captured by mutual best responses, with the existence of well documented behavioural biases, as nominal illusions, our results show how convergence to competitive solutions, as in the standard Bertrand-Nash equilibrium, may be slow, or may never happen.

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Appendix 1. Additional quantitative analysis

Table 11: Econometric analysis of the monotone nominal illusion effect and of profits across nominal representations

	Market prices		Market profits	
Variable	All periods	Last five periods	All periods	Last five periods
Constant	142.11***	248.05***	443.93***	1706.44**
	(5.00)	(78.86)	(53.87)	(862.52)
Period	0.63	-4.99	11.81**	-54.87
	(0.45)	(4.33)	(4.94)	(47.27)
M5	141.74***	138.07***	1498.06***	1392.63***
	(9.68)	(21.29)	(108.62)	(237.51)
M20	75.46***	86.60***	741.58***	869.65***
	(6.28)	(17.73)	(68.14)	(199.34)
M100	66.33***	42.67*	682.00***	376.17**
	(8.27)	(16.95)	(91.28)	(185.28)
M5 – M20	66.27***	51.46**	756.47***	522.98*
	(10.72)	(25.38)	(119.65)	(285.61)
M5 – M100	75.40***	95.39***	816.06***	1016.46***
	(12.00)	(24.84)	(134.19)	(275.98)
M20 – M100	9.13	43.93**	59.58	493.47**
	(9.46)	(21.87)	(104.17)	(243.91)
# Obs.	1640	410	1640	410
R-sq between	0.1851	0.1422	0.1716	0.1223

Robust standard errors in parentheses
*** p<0.01. ** p<0.05. * p<0.1

Table 12: Analysis of the last fives rounds

Panel a: Taxonomy of symmetric prices (in percentage)

	Nominal representation			
Equilibrium concept	B500	M100	M20	M5
Only NE	0	7	0	0
Both	66	14	0	0
Only SCGNE	31	79	100	89
None	3	0	0	11
Total	100	100	100	100

Panel b: Evolution of market prices by nominal representation

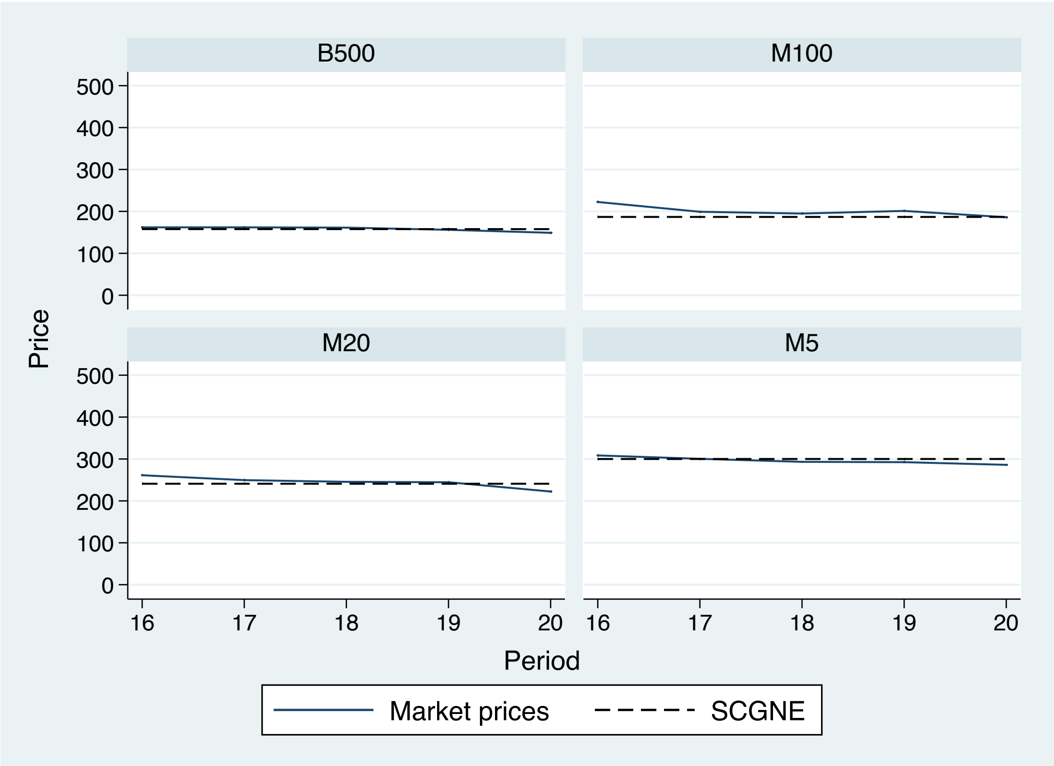
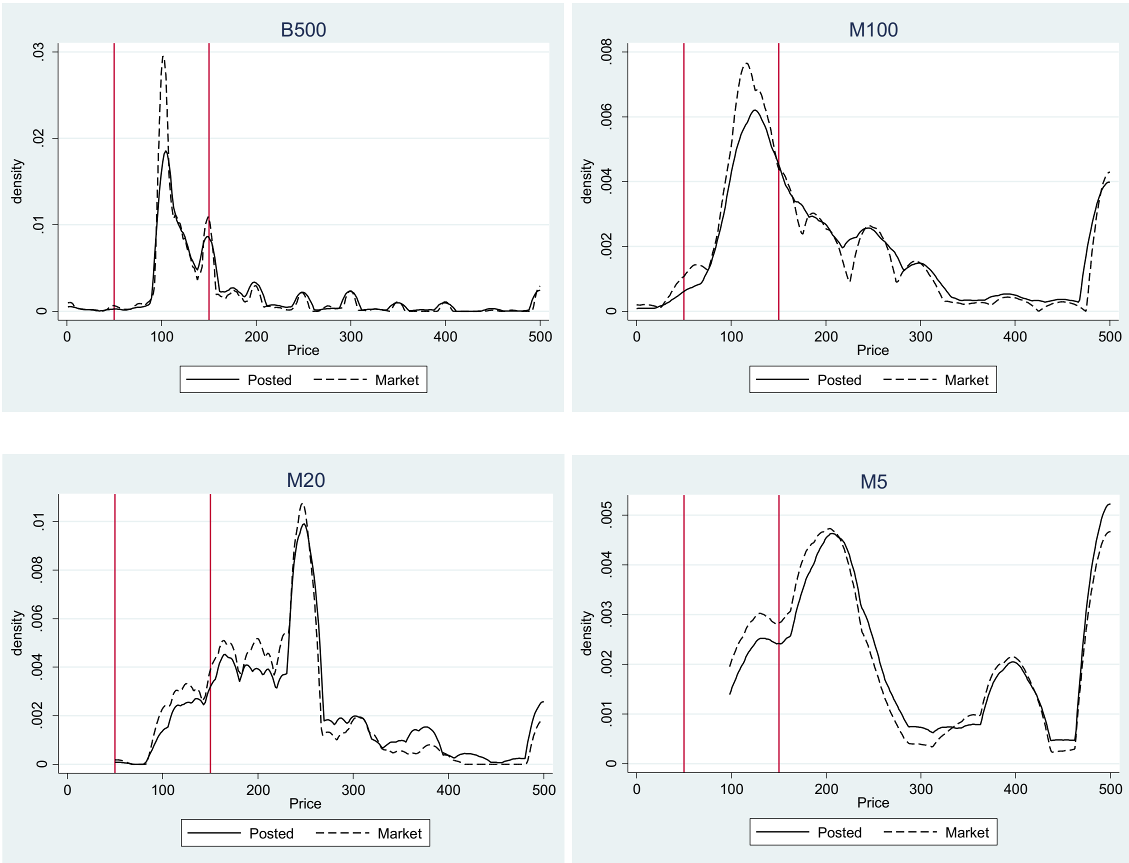


Figure 4. Distributions of posted and market prices by nominal representation, all periods (note the different scales on the vertical axis)



Appendix 2. Experimental instructions

1. This experiment lasts for 20 independent rounds (what happens in one round does not affect your results in any other round). Only for participating in the experiment, you guarantee a minimum payment of €5.
2. In this experiment, you are a company that takes two decisions: the country where you sell your product and the selling price. Each market is composed of two companies. The first decision is taken only once at the beginning of the experiment, while the second is taken in every round. We will explain the consequences of these two decisions, starting with the second one.
3. The *profits* of your company depend on your income minus your costs. Your *income* is the product of your demand (the number of units sold) multiplied by your selling price (the price at which you sell). Your *demand* in each round depends exclusively on your decisions (*your selling price*) and the decisions of the other company in your market (*the other selling price*):
4. The market *Demand* in each round is *fixed* and the two companies offer exactly the same product. There are two possible scenarios:

   a) The two prices are equal. Then the two firms equally share the demand.
   b) The two prices are different. Then the company with the lowest price gets the whole market demand in that round and the other company does not sell anything.
5. The *cost* function is increasing. This means that for the whole market the cost of production is more than the double than for half market. No production is costless. Independently of your company's market share, you are required to attend the whole demand.
6. In a round you can obtain *profits* or *losses* which will be compensated between the different rounds, but the losses will never become effective at the end of the experiment. Every time you make a decision you will know the past values of price and benefits obtained by the two companies in each round and your accumulated benefits.
7. Your other decision is to choose the country where you sell your product during the 20 rounds of the experiment. In this experiment there are 3 different economies: *Titan. Methane and Daphne*. The only difference between the three economies is the currency used in each country: *Titanio* (Ti), *Metanio* (Mt) and *Daphnio* (Df). Depending on which country you decide to sell your products, you must choose a price in the currency

8. If you decide to sell your product on Titan, you can choose a sale price between **0 and 100** Tt. If you decide to sell your product in Methane, your price should be between **0 and 20** Mt, and if you decide to sell at Daphne, your price should be between **0 and 5** Df. The number of decimal places that you can use varies in each market (1. 2 and 3. respectively).
9. Once you choose the economy in which you want to sell your product, you will be randomly paired with another participant who has chosen to sell its product in the same country. For each country we will form separate markets for 2 companies whose composition will not change throughout the experiment. If the number of firms in a country is odd, one of them will be chosen randomly by the computer to compete in another (and be warned of this). You will never get to know the identity of the other participant with whom you are paired.
10. Demand and costs are identical in the 3 countries. However, the exchange rates that convert your profits into Euros are different, so your potential benefits are also identical in the three economies. At the end of experiment the profits will be exchanged at the rate of 1Tt = 5€. 1Mt=25€ and 1DF = 100€. Your final profits will be the sum of the initial € 5 plus the accrued benefits over the 20 rounds.

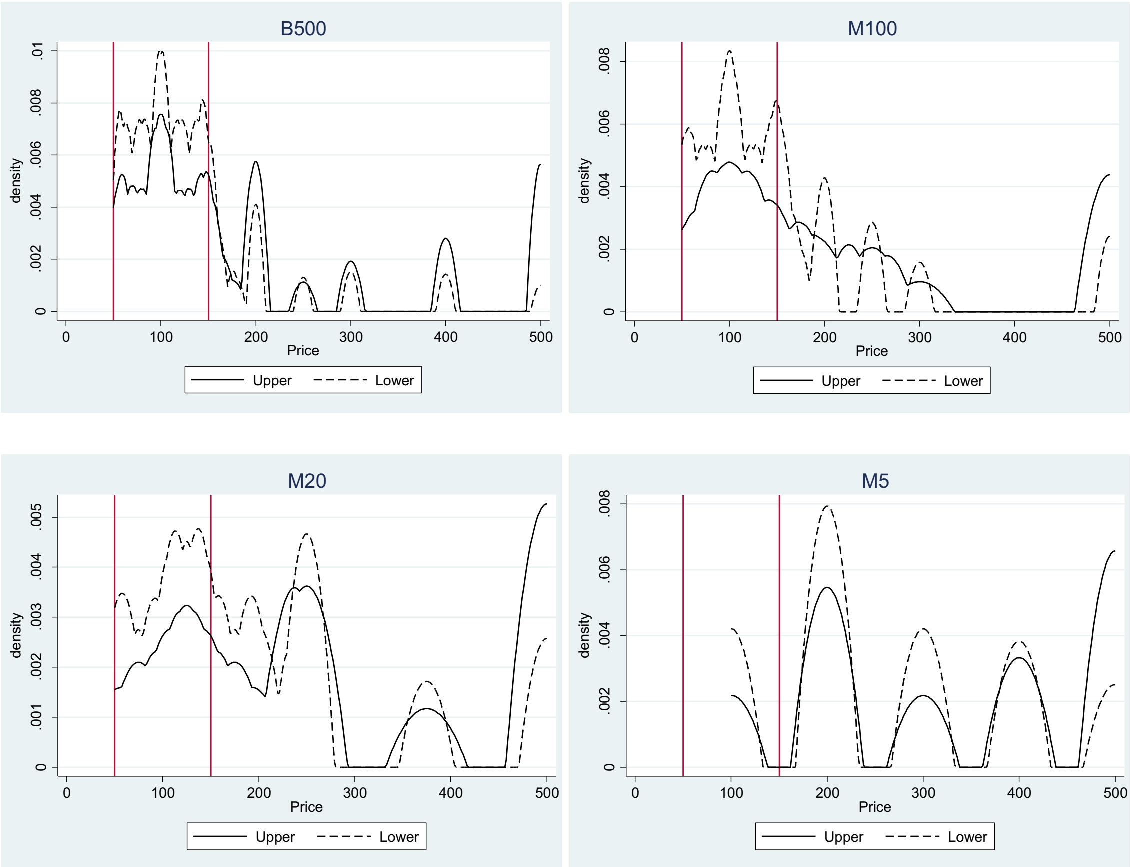
Appendix 3. Online supplementary material, or for referees

Table 1. SCGNE and NE predictions in ECUS

Market	NE	SCGNE
B500	50, 51, 52, …, 150	50, 51, 52, …, 148, 149, 150, 151, 152, 154, 155, 160, 170, 180, 200, 250, 300, 400, 500
M100	50, 51, 52, …, 150	50, 55, 60, … , 140, 145, 150, 155, 160, 170, 175, 200, 250, 300, 500
M20	50, 51, 52, …, 150	50, 75, 100, 125, 150, 175, 200, 250, 375, 500
M5	50, 51, 52, …, 150	100, 200, 300, 400, 500

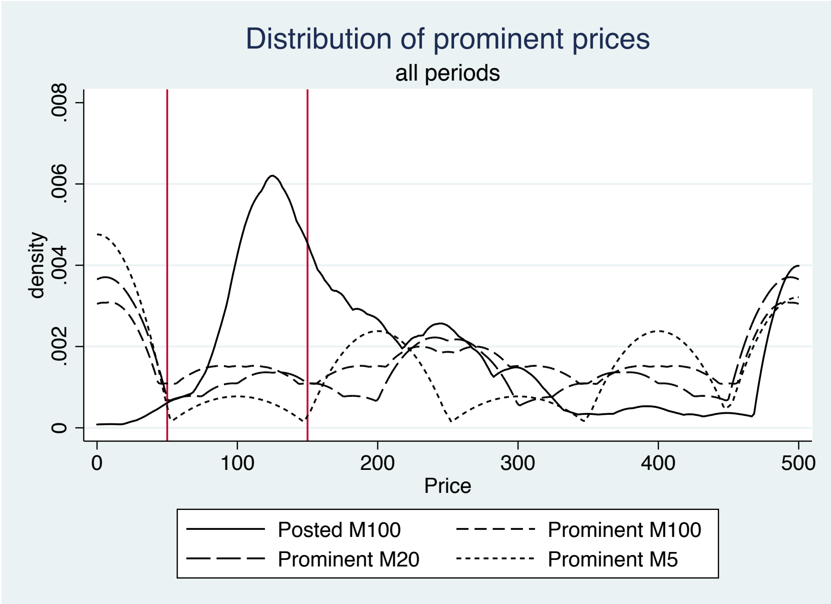
This table shows that the concept of coarse grid Nash equilibrium interacts with the nominal representation in a rich and complex way. It is not true that the behavioural model predicts every round price. For example, 185 or 350 are never SCGNE. Also, some round numbers are SCGNE prices for some but not all treatments; for example, a price of 400 is SCGNE price for the treatments B500 and M5 but not for M100 or M20. Finally, there are round numbers that are SCGNE for all treatments; for example, 200. This table also displays the set of NE prices in column two. Note that the number of NE prices is constant across nominal representations, while the number of SCGNE prices decreases with the exchange rate: there are one hundred and thirteen values for the market B500, twenty eight SCGNE for the market M100, ten SCGNE for the market M20 and finally five SCGNE for the market M5. This feature is important when assessing the predictive merit of the behavioural model with respect to the Nash prediction

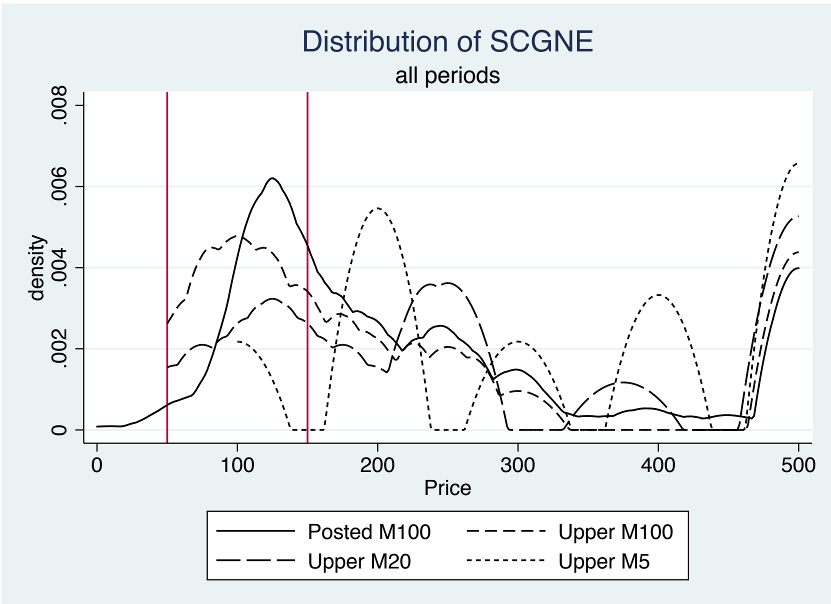
Figure 1. Distribution of SCGNE prices by nominal representation (note the different scales on the vertical axis)



This figure compares for each nominal representation, the distribution of SCGNE prices under two alternative scenarios regarding the interaction of individual grids at the market place: upper (when there is no grid interaction and a firm choice corresponds to a uniform pick from the set of SCGNE defined by its own grid) and lower (when there is grid interaction and duopolists in a market end up using the lower of the two grids, an firms choose uniformly a price from the set of the SCGNE prices defined by the smallest grid in the market). For given nominal representation, the lower distribution puts more probability mass on low price, away from large prices, but the two distributions are multimodal ones, with peaks located at the same positions.

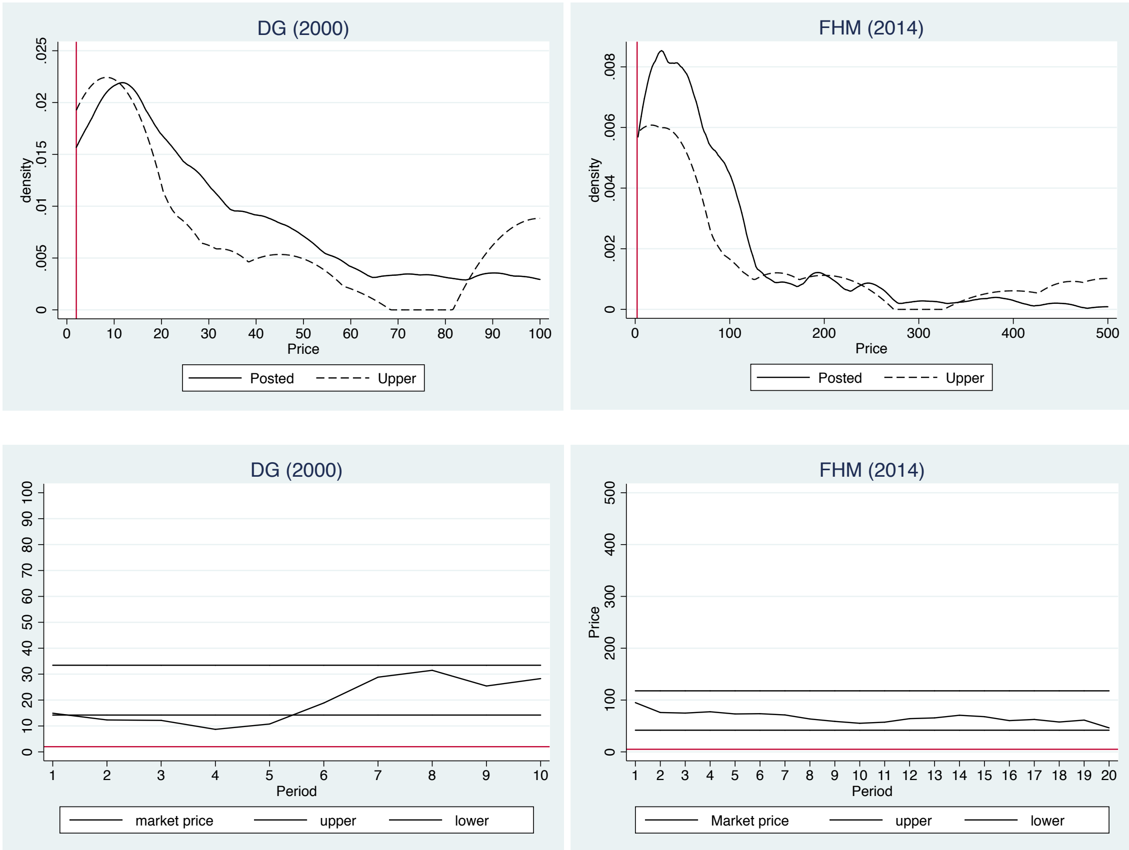
Figure 2. Prominent vs SCGNE distributions





This panel is intended to show how relevant the coarse grid equilibrium concept is to the predictive power of the behavioural model. To this end, it displays in the upper panel the distribution of prominent prices in all nominal representations. The distributions are computed assuming that the grids used by firms are one randomly chosen prominent number. Note how flat these distributions are across nominal representations, as opposed to the distribution of SCGNE displayed in the lower panel. The distribution of posted prices for M100 is included as a reference point.

Figure 3. SCGNE in linear duopolies in Dufwenberg and Gneezy (IJIO, 2000) and in Fatas, Haruvy and Morales (SEJ, 2014)



In the first row, we compare using kernel density estimates, actual posted prices distributions in DG(2000) and in FHM (2014) to predictions based on the proposed behavioural model. In the second row, figures depict the time evolution of the average market prices over periods. Horizontal lines at the upper and lower bounds help to compare actual prices to the predictions based on the behavioural model. The Nash prediction is 2 (red line)