Universidad del Rosario
Facultad de Economía

The Discrete Charm of Nominal Illusion

Enrique Fatas
Antonio J. Morales

SERIE DOCUMENTOS DE TRABAJO

No. 220

Septiembre de 2018

The Discrete Charm of Nominal Illusion*

Enrique Fatas

Loughborough University

E.Fatas@lboro.ac.uk

Universidad del Rosario

Enrique.fatas@urosario.edu.co

Antonio J. Morales

Universidad de Málaga

a.morales@uma.es

Wednesday, 12 September 2018

Abstract

We investigate the emergence and persistence of nominal illusion in an experimental entry game where firms must choose which local market to enter, then compete in prices. All local markets are equivalent in real terms and they only differ in the currency the price competition is run under. Our experimental results show a positive, persistent and monotone effect of the nominal exchange rate on (real) posted prices. We provide an explanation in terms of players simplifying the choice set using discrete grids.

KEYWORDS: Price competition, money illusion, experiments, nominal representation

JEL classification numbers: C72, C9, D43, L13

* Enrique Fatas acknowledges financial support from the ESRC Network for Integrated Behavioral Science (NIBS) and Antonio J. Morales acknowledges financial support from research project ECO2014-52345-P.

1. Introduction

Humans are not immune to psychological biases when taking economic decisions (see Kahneman, 2003 and Thaler, 2000). 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 twentieth century,[2] have played a limited role in explaining economically relevant behaviour until quite lately (Tyran, 2007). 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).

The standard view in economics is that nominal illusion is a transitory phenomenon. Economic agents will eventually see through the nominal veil and will start making the *right* choices. Implicit in this argument is that nominal illusion entails a cost, because nominal and real payoffs are not aligned. It is however common to come across situations where nominal and real payoffs are perfectly aligned, as it happens when choices are done using different currencies, and nominal illusion is transient. For examples, one of the most studied cases is the changeover to the Euro in the European Economic and Monetary Union in 2002. The overall conclusion is that money illusion happened and it was transitory (see for example Kooreman et al, 2004, Cannon and Cipriani, 2006 and more recently Bittschy and Duppel, 2015).

Hence, the transience of nominal illusion seems a well-established fact in the economic literature. In this paper, we argue that there might be a unexpected source of more permanent nominal illusion: competitive forces. The basic intuition is that in a competitive setting, nominal illusion may facilitate collusion and once firms are making extraordinary profits, they have no incentives to modify their behaviour.

[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.

[2] See Fisher (1928).

We present experimental data from a one-shot entry game where players must decide in which of three markets to enter. Once the entry decision is done, players compete in prices for 20 periods in a standard static, full information, Bertrand duopoly game. The interesting twist is that all markets are equivalent, meaning that they are different nominal representations of the same economy, e.g. all markets are identical in real terms and only differ in the local currency in which prices are nominated.

We find that subjects spread evenly among the three local markets, which is consistent with the equi-probablility model yielded by all markets being identical in real terms. But when we compare pricing behaviour across different *nominal* representations, we find a significant positive correlation between posted prices and nominal exchange rates: coarser currencies are associated with higher prices. Even more, this monotone nominal illusion is of a permanent nature: prices stay consistently high without converging to the set of Nash equilibrium prices.

Most experimental papers on money illusion consider situations where nominal and real payoffs are not aligned, as in Fehr and Tyran (2001, 2007 and 2014), that report transient money illusion. Fehr and Tyran (2008) and Noussair et al (2012) compare prices before and after a nominal shock, and report a pronounced inertia in the convergence to the unaltered (in real terms) equilibrium, 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 a temporary money illusion phenomenon has a permanent effect. 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. Thus, those players suffering from the illusion effect end up worse off.

Closer to our paper, Eisenhuth (2017) analyses the market survival of money-illusioned economic agents in a dynamic financial market model populated by rational economic agents. Eisenhuth (2017) shows that market forces can wipe out rational agents in the long run, leaving a market full of money-illusioned agents. In our experiment, we find a result similar in spirit: in the long run, all local markets are populated by money-illusioned firms. Our proposed mechanism is though different: if economic agents start focusing on the nominal representations because they are simpler and more salient (as it is the standard view in the literature, see for example Shafir et al, 1997), and they keep using them because it is a very profitable strategy, then competitive forces are simply perpetuating collusive practices. We propose a behavioural toy model that rationalizes the monotone money illusion based on participants choosing grids as a simplifying procedure.

The rest of the paper is as follows. Section 2 presents the experimental design, procedures and hypotheses. Experimental results are discussed in Section 3. Section 4 presents the behavioural model and finally, Section 5 concludes.

2. Experimental design, procedures and hypotheses.

Experimental design

Our experiment consists of an entry game and two sessions. We will use one treatment in Fatas et al (2014) as a reference benchmark. See Table 1 for the details.

Table 1. Experimental design

	Baseline economy	Nominal representation of the economy		
Local Market	**B500**	**M100**	**M20**	**M5**
Local Currency	ECU	Titanio	Methanio	Daphnio
Exchange rate to ECU	1:1	1:5	1:25	1:100
Subjects	84	32	24	24
Number of local 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

In the entry game, experimental subjects had to choose in which local market they wanted to enter to compete in prices. Local markets are characterized by their local currencies, each featuring a different exchange rate to ECU, the experimental currency units. Price competition takes the form of symmetric duopolies with quadratic cost function $c(q) = cq^2$ with $c > 0$ and fixed demand $Q > 0$. In each duopoly, the lowest price firm will serve the whole market and that the demand is split in case of a tie.

Fatas et al (2014) show that for this duopoly price competition game with quadratic costs, the set of Nash equilibrium prices is the interval $\mathrm{NE} = \left[\frac{\mathrm{cQ}}{2}, \frac{3\mathrm{cQ}}{2}\right]$. They run experimental sessions in which subjects did not have the chance to choose between any local markets but were randomly allocated into duopolies in a market with prices nominated in ECUS, $c = 5, Q = 20$ and $P = 500$. Competition lasted for 20 periods with the same rival. The parameter P is the largest price that players could choose, e.g. prices in Fatas et al (2014) were chosen from the interval $[0,500]$.

These experimental sessions in Fatas et al (2014) are a natural baseline for our study. In our experiment we make experimental subjects to choose between three different nominal representations of the very same economy considered in Fatas et al (2014), characterized by different exchange rates of the local currencies to ECU (the currency used in the experimental sessions in Fatas et al, 2014). The three nominal representations are named M100, M20 and M5, and the exchange rates are $e = 5, 25$ and 100, respectively. The exchange rate is simply the number of ECU per unit of the local currency.[3]

To keep the different nominal representations of the 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. 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 local markets are named after the largest admissible price: for example, the largest price available in the market M20 is $500/25 = 20$.

The entry decision that experimental subjects had to take is in which of the three *local* markets (M100, M20 and M5) to enter; subsequently, subjects were randomly matched (under a partner protocol) to compete in a duopoly for 20 rounds among those who selected the same market. Subjects were explicitly told in the instructions that the demand and costs conditions across the different local markets were identical (although

[3] Experiments were run in the same laboratory by the same experimenter. The unit cost was also deflated, and the exchange rate to Euros used was the one used in Fatas et al (2014).

they were never informed of the parameter 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”.

At the end of each round, each subject was informed of their choice, their rival’s choice and their profits and the rival’s profit. A table displaying past choices and profits was also available.

Experimental procedures

Experiments were run in the laboratory for research in experimental economics at the University of Valencia. For the entry game, 80 students (40 duopolies) from business and economics were recruited using a standard electronic recruitment procedure. Two sessions were run and subjects earned 12€ on average (plus the €5 show-up fee) for an experiment that lasted for less than an hour. A set of instructions translated from the Spanish is available in the Appendix. The baseline treatment is the treatment B500 in Fatas et al (2014), which consisted in 42 duopolies.

Hypotheses

Experimental subjects had to make two types of decisions in this experiment. First, the local currency in which they wanted to set the prices and then the pricing strategy over a period of 20 rounds. Our null hypotheses will be based on rational play, characterized by the notion of subgame perfect equilibrium. For alternative hypotheses, the reader is referred to section 4.

In stage 2, and once participants had chosen a market, they were matched in pairs to compete in prices for 20 rounds with the same opponent. Because the local markets are equivalent in real terms, and the null hypothesis is based on the concept of Nash equilibrium, that is not prone to money illusion, the null hypothesis is that pricing behaviour across the local markets is similar.[4]

Hypothesis 1. *Similar pricing behaviour (in real terms) across the local markets*

We now apply backward induction and consider stage 1: the entry decision. Because the local markets are equivalent in real terms, the null hypothesis is that players are indifferent between choosing any local market.

Hypothesis 2. *Equal entry in the local markets*

3. Experimental results

In this section, we present some summary descriptive statistics to compare average behaviour across nominal representations. We later perform a welfare analysis.

3.1 Entry decisions

In the experimental entry game, the first task that subjects faced was precisely in which market they wanted to interact. Out of the 80 participants, 32 chose M100, 24 chose M20 and another 24 subjects chose M5. A chi-square test expecting equal frequencies does not reject the null hypothesis of equal entry in the three local markets (Pearson chi2(2) =1.6000, p=0.449). Hence, our first result confirms Hypothesis 2.[5]

Result 1. *Experimental subjects allocate themselves evenly among the three local markets*

---

[4] Given that the stage game, price competition with quadratic costs, has multiple Nash equilibria, from the Folk Theorem it follows that it would be possible to sustain in the finitely repeated game as a subgame perfect Nash equilibrium prices that are not Nash equilibrium of the stage game. However, we see no reason to believe that different additional equilibria would emerge in different local markets without money illusion.

[5] We cannot discard that subjects self-select to a specific market because they feel attracted to one nominal representation, and then conform to the decisions of the other participants in the same local economy (see Fatas et al, 2018, for a recent analysis of preferences conformism in experiments). However, conformism per se cannot explain differences in market prices.

3.2 Pricing decisions

Table 2 contains some descriptive statistics of posted and market prices across local markets, together with the treatment B500. They are expressed in ECUS so comparison between local markets is easier.

Table 2. Average prices by nominal representation (in ECUS)

		Average posted prices			Average market prices		
		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

This table reveals that in the first period, posted and market prices for the three local markets are significantly larger than the Nash prediction (the efficient NE is 150), they are roughly located in the midpoint of the pricing interval and that the differences among them are not statistically significant, confirming the rationale behind the equal entry hypothesis.[6] However, as competition evolves, a clear ordering in the average price dimension –specially marked in the last five periods- emerges: larger average prices are associated with larger exchange rates. This is in sharp contrast to what it is hypothesized in Hypothesis 1 and to what happens in the baseline treatment B500, where prices stayed around the efficient NE price. Our analysis rejects the universal validity of the Nash predictions across nominal representations and shows a positive relation between exchange rates and mean prices. [7]

[6] Mann-Whitney tests confirm that the differences between the baseline and any nominal representation treatment are significant.

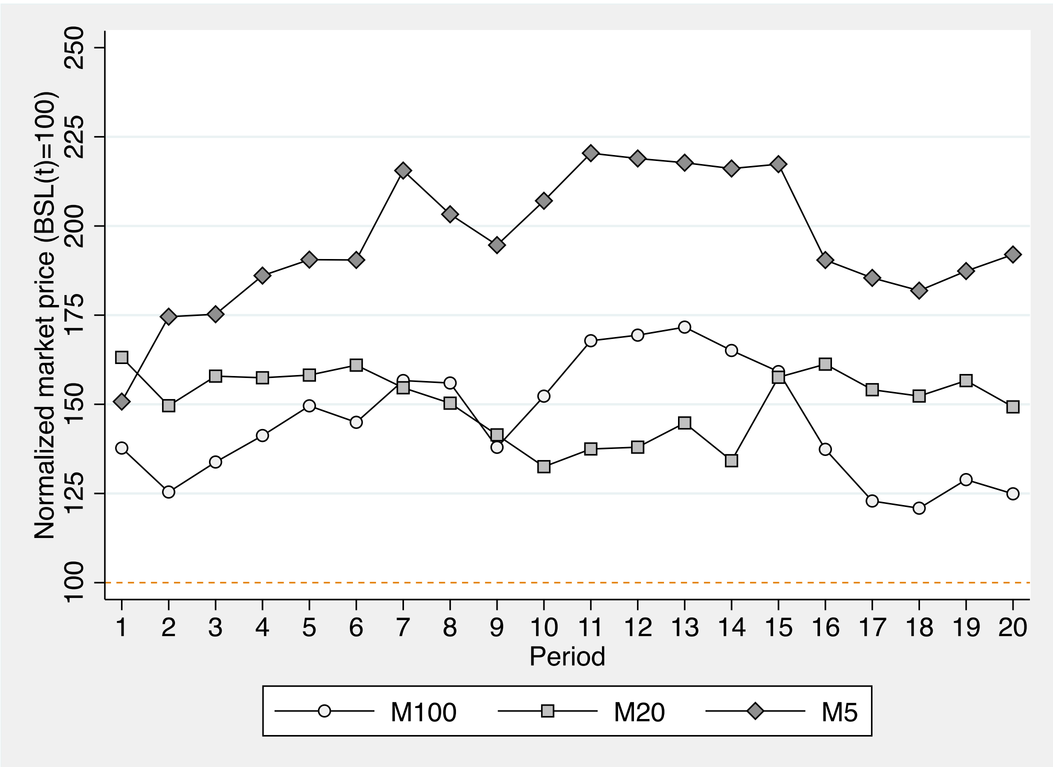
[7] The existence of over competitive prices is not new in experimental Bertrand games, see Dufwenberg and Gneezy (2000) documenting over competitive prices in linear Bertrand games. Fatas et al (2005, 2007 and 2013) show how linear Bertrand games may significantly deviate from the competitive outcome when tacit collusion is facilitated by market features (e.g. price guarantees). None of these papers are consistent with the monotone effect of nominal representations discussed below.

Result 2. *Hypothesis 1 is rejected: Pricing behaviour reveals a monotone money illusion effect: average prices increase with the nominal exchange rate.*

Table 2 also shows 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, however the average prices for the last five rounds are much higher than the Nash prices. Figure 1 displays the time evolution of average market prices by nominal representation, normalized by market prices in the baseline B500. [8] Visual inspection reveals no noticeable negative trend in any treatment.

Result 3. *The monotone money illusion effect is permanent*

Figure 1. Evolution of average market prices by nominal representation
(normalized by market prices in the baseline B500)



[8] So, a normalized market price of 200 in any given round means that average prices in that local market were twice as high as prices in the same round in the baseline. Figures A1 and A2 in the Appendix show absolute price in ECU, for each round in and in blocks of five rounds, respectively.

Econometric estimations of panel data regressions at the individual level and clustered by group are displayed in Table 3 and confirm the conclusions drawn from the graphical analysis. We offer the estimates over two time horizons: all periods and the last five. The dependent variable is the market price[9] and the independent variables are dummy variables for the three local markets (M5, M20 and M100) and the variable *Period* to capture any time trend. We also include an interaction term to capture time trends specific to nominal representations. The omitted market is the benchmark B500 in Fatas et al (2014), which converges to the efficient Nash equilibrium. This econometric specification quantifies how far from the Nash prediction the different local markets are.

Table 3: Econometric analysis of market prices across nominal representations

Market prices	Last 5 periods	All periods	All periods
Period	-4.999	0.638	0.428
	(4.332)	*(0.454)*	*(0.544)*
M5	138.1***	141.7***	119.9***
	(21.30)	*(9.686)*	*(17.37)*
M20	86.61***	75.47***	78.10***
	(17.74)	*(6.281)*	*(11.17)*
M100	42.68**	66.33***	69.43***
	(16.96)	*(8.275)*	*(14.84)*
M5*period			2.084
			(1.605)
M20*period			-0.251
			(1.193)
M100*period			-0.295
			(1.320)
Constant	248.1***	142.1***	144.3***
	(78.86)	*(5.003)*	*(5.328)*
M5-M20	51.47**	66.27***	41.76**
	(25.38)	*(10.72)*	*(19.23)*
M5-M100	95.396***	75.41***	50.44**
	(24.85)	*(12.00)*	*(21.57)*
M20-M100	43.93**	9.14	8.68
	(21.87)	*(9.47)*	*(16.98)*
Observations	410	1,640	1,640
R-squared	0.142	0.185	0.187

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

[9] We take one observation by market and period. Estimations using posted prices yield similar results.

The estimate for the variable *Period* is not statistically significant over either time horizon, as none of the interaction term with the treatment dummies, confirming the permanent nature of money illusion. The dummy variables for nominal representations M5, M20 and M100 are statistically significant and positive; pair-wise comparisons confirm the treatment effects founded with the aggregate analysis, with the exception of the difference between M20 and M100, which is only significant for the last five periods.

3.3 Payoff analysis

In our experiment, experimental subjects start choosing prices far away from the Nash equilibrium and over time they do not converge to the equilibrium. In fact, a look to the aggregate profits across different nominal representations (Table 4 below, again 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 4. Descriptive statistics of earnings by nominal representation

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

Standard deviation in brackets

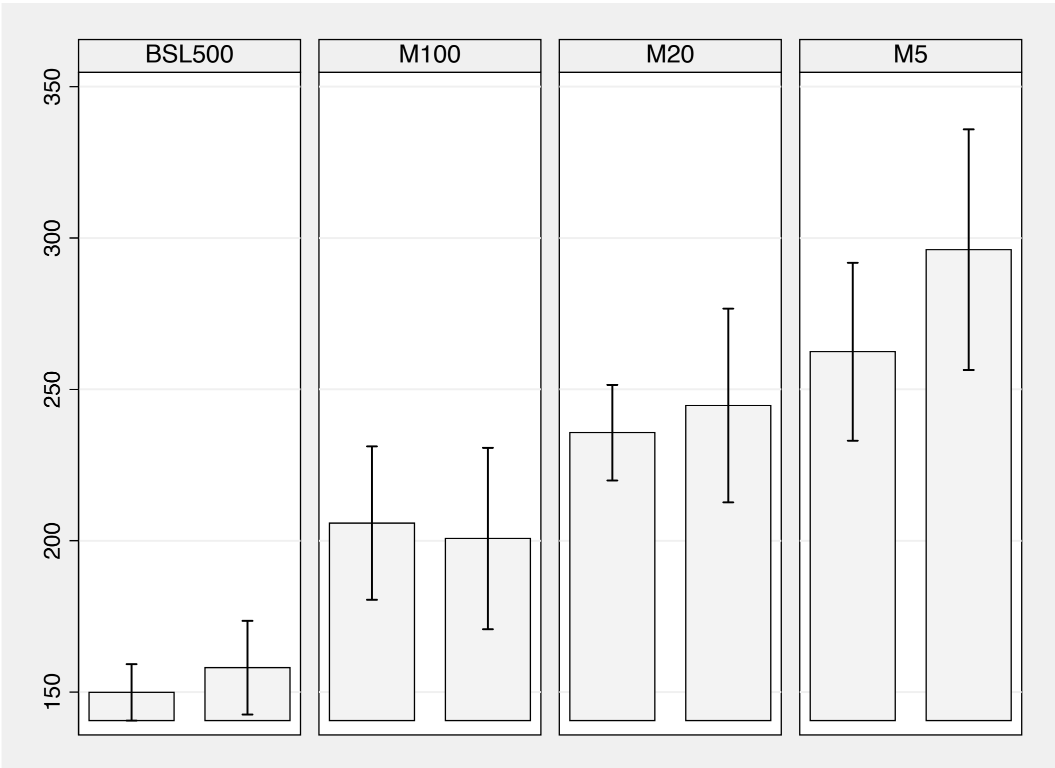
Mann-Whitney tests show significant differences between profits in the baseline and those in any nominal representation. An econometric analysis based on panel data estimations at the individual level and clustered by group shows that pair-wise comparisons are significant (see Table A1 in the Appendix).

Result 4. *Profits to players increase with the nominal exchange rate.*

4. Alternative explanations: QRE, Level-k, Focal Points and Coarse Grid Nash Equilibrium

In this section, we seek to understand the *permanent* nature of the *nominal illusion*, with players consistently choosing larger prices the larger the nominal exchange rate. Figure 2 captures graphically this phenomenon. It depicts the average market price in ECUs, per nominal representation, for the first and the last block of five rounds, together with the 95% confidence interval. As it can be clearly seen, there is an increasing sequence of average market prices between nominal representations as larger exchange rates are considered but there are no significant differences in average prices within local markets between the first and the last block of five rounds.[10]

Figure 2: Market prices in blocks of 5 rounds
(in blocks of 5 rounds, 1st and last block, all nominal representations)



Why is this happening? In the literature there is a number of alternative models to perfect rationality that have been proposed to account for deviations from the Nash

[10] Figure A3 in the Appendix plots prices in all blocks across all nominal representations.

prescription. Two popular candidates are Quantal Response Equilibrium (QRE, McKelvey and Palfrey 1995, 1998) and Level-k (Stahl and Wilson, 1994 and 1995). It is easy to verify that none of these models can explain the monotone money illusion effect observed in our experiment.

The reason is that both are reminiscent of the Nash concept and rely on computing best responses (mutual noisy best responses for QRE and perfect best responses, but with wrong beliefs, for Level-k) using payoffs in real terms. So, the only possibility for these models to explain the (monotone) money illusion is assuming different values of their free parameter for different nominal representations. For the QRE, the free parameter is the noise parameter, and it is awkward to assume that different exchange rates prompt different values of the noise parameter.

For the level-k model, the free parameter is the belief that a level-1 type holds about the behaviour of level-0 (as higher types will stay arbitrarily close to the level-1 choice because of the undercutting nature of the price competition game). [11] So, unless level-1 types hold different beliefs about level-0 players for different values of the exchange rate, this model cannot account for the monotone money illusion effect. This assumption would be less ad hoc than in the QRE case, as it has been shown elsewhere (Hargreaves Heap et al, 2014) that the behaviour of level-0 types is not portable, but the criteria for the behaviour of level-0 types cannot be based on properties of the payoff matrix, such us payoff dominance, risk dominance, etc… because as the local economies are equivalent in real terms, a level-0 type would behave in the very same way in all of them.[12]

Both alternative explanations were already considered and ruled out in Fatas et al (2014) when they came to explain price competition in the treatment B500. Fatas et al (2014) proposed an alternative model based on the concept of Coarse Grid Nash Equilibrium, which outperformed both QRE and Level-k. Here, we use this concept to

[11] Level-k models tend to fit the data best in one shot interactions. Fatas and Morales (2013) is an example of behaviour consistent with a step-thinking model in the long run of 20 repetitions, as in our experiment.

[12] An interesting alternative would be to assume that a level-0 type chooses prices per some focality criterion; in this alternative scenario, individuals would choose different prices in different local markets. We will explore later this possibility.

rationalize the monotone money illusion effect, and see how our dataset fits our conjecture.

The starting point is the observation that if players replace the (complex) continuous strategy set for a simpler object, a discrete version based on a coarse grid, then the set of Nash equilibrium prices in a duopolistic price competition with quadratic costs associated to players using 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. They call this set *Coarse Grid Nash Equilibrium*.[13]

From an outside observer, not aware of the discretization process performed by experimental subjects, these two "additional" equilibrium prices would be examples of players coordinating on high non-equilibrium prices. Because they will play a key role in our analysis, we will refer to them as "above-Nash equilibria".

As the primitives of the coarse equilibrium are grids, we need to say something about the process by which players discretize the strategy set across different nominal representations. We assume that the set of grids is invariant to the nominal representation.

Behavioural assumption: *The grid does not depend on the units*

This assumption says that the discretization process is independent from the nominal representation of the economy. Players do not consider that the different nominal representations where they may compete represent the same economy; they always perform the discretization process using the same set of grids. This assumption is in fact reminiscent of the *numerosity heuristic* (Pelham et al, 1994). This heuristic emerges when people fail to consider the type of unit when evaluating numerical information, and instead, they rely on the number of units.[14]

[13] We can find in the literature papers around individuals using finite states when processing information by partitioning information or coarsening information, including Rubinstein (1993) or Chen et al (2010).
[14] 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

To see the consequences of this assumption, we 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[15]

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

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

$$e \times CGNE_e\ (k) = \underbrace{\left\{\frac{1}{2}cQ, \frac{1}{2}cQ + ek, \frac{1}{2}cQ + 2ek, \dots, \frac{3}{2}cQ\right\}}_{DNE_e(k)} \cup \underbrace{\left\{\frac{3}{2}cQ + ek, \frac{3}{2}cQ + 2ek\right\}}_{AN_e(k)}$$

The set of coarse grid Nash equilibrium is the union of two sets. The first one, denoted by $DNE_e(k)$, is the discretization of the Nash interval of the continuous price game. This set 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 ($k \times e$). This immediately implies that coarse grid equilibrium is not immune to nominal illusions, but the impact of the nominal changes is rather limited as it reduces to picking different (and fewer) elements of the Nash interval. The second set $AN_e(k)$ is more interesting. It comprises the two above-Nash equilibria and the crucial issue is that they grow unbounded as the exchange rate increases (because the effective grid size $k \times e$ increases with e).

Because the above-Nash equilibria grow unbounded, there is a positive relationship between nominal changes and equilibrium prices. We call this concept *monotone*

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).

[15] 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.

nominal illusion, define it in terms of the strong set order (because of the multiplicity of equilibrium prices) and prove that in fact, coarse grid Nash equilibrium displays monotone nominal illusion.

Definition 1. *Monotone Nominal Illusion: For every* $e > 0$ *there exists* $\hat{e} > e$ *such that* $EP_{e'} \geq_s EP_e$ *for* $e' > \hat{e}$

Proposition 1. *Coarse grid Nash equilibrium displays monotone nominal illusion*

Proof. Fix grid k and consider nominal exchange rate e. We divide the proof in two steps. Step (i) Let e be such that the effective grid size ek is larger or equal than the efficient NE $\frac{3}{2}cQ$. This implies that $DNE_e(k) = \emptyset$ and $AN_e(k) = \{ek, 2ek\}$. Let $\hat{e} = 2e$. Then we have $DNE_{\hat{e}}(k) = \emptyset$ and $AN_{\hat{e}}(k) = \{2ek, 4ek\}$, it follows that $AN_{\hat{e}}(k) \geq_s AN_e(k)$ which implies that $AN_{e'}(k) \geq_s AN_e(k)$ for $e' > e$ because the collusive equilibria are increasing in the exchange rate. Step (ii) Let e be such that the effective grid size ek is smaller than the efficient NE $\frac{3}{2}cQ$. This implies that the largest element of $AN_e(k)$ is smaller than four times the efficient NE, i.e. $6cQ$. Let $\hat{e} = 6cq/k$. Then the effective grid size of nominal exchange rate is $\hat{e}\times k = 6cQ$ and we have $DNE_{\hat{e}}(k) = \emptyset$ and $AN_{\hat{e}}(k) = \{6cQ, 12cQ\}$ and it follows that $AN_{\hat{e}}(k) \geq_s DNE_e(k) \cup AN_e(k)$. cqd

This proposition reads that larger equilibrium prices are associated to larger nominal exchange rates. And this in fact encapsulates the two main features of the experimental data and Figure 2: (i) players choosing prices larger than Nash equilibrium prices the larger the exchange rate, and (ii) the lack of convergence to the efficient NE.

In the following, we provide evidence on the use of coarse grid Nash equilibrium in our experiment. It is not a straightforward exercise as grids are not directly observable; so, we use as a proxy the adjustment of posted prices by experimental subjects. As we explain below, we define price adjustments as the changes in prices from one round to the next. The rationale for this approach is the following: conditional on subjects using grids, the coarser their (unobservable) grids, the larger their (observable) changes in prices. As we are aware of the limitations of this imperfect measure, we will be particularly cautious when interpreting the results of our quantitative analysis.

Table 5 contains the estimates of various econometric models where the dependent variable is the market price (the unit of observation is the market outcome per period) and the covariates are period, dummy variables for nominal representations M5, M20 and M100, the proxy for grids discussed above and the interaction terms between treatment variables and the grid proxy. In all models in Table 5 we use as the proxy for grids the *largest* price adjustment, in absolute terms, any firm in the market have used in the first *five* rounds.

Beyond its limitations, this measure has three merits: first, it captures changes in prices, rather than absolute posted prices. Firms decreasing or increasing prices using the same *Grids* (i.e. price adjustments) while posting collusive or competitive prices are indistinguishable from this metric's perspective. Second, we hypothesize that firms will explore the market in the first five rounds sometimes keeping the same price two consecutive rounds (i.e. without adjusting the price up or down), sometimes moving up or down in the strategy space (i.e. positive price adjustment). Our measure of Grids does not depend on the frequency of positive adjustments. Lastly, we are agnostic on the heterogeneity of firms in any treatment. Market heterogeneity may happen because firms are sophisticated enough to post prices in a competitive manner, not being affected by the nominal representation of prices, or because they use different price adjustment schemes. The interaction terms allow us to disentangle *treatment* effects from *grid* effects in the different conditions. [16]

[16] The econometric estimates are robust to different specifications of the proxy for grid, as for example the average or the median Price update.

Table 5: Market prices and grids

	(1) All periods	(2) All periods	(3) All periods	(4) Periods 1-10	(5) Periods 11-20
Period	0.638	0.638	0.638	-0.0799	-0.0148
	(0.454)	*(0.439)*	*(0.430)*	*(1.063)*	*(1.339)*
M100	66.33***	50.16***	-41.03***	-29.97*	-52.08***
	(8.27)	*(7.31)*	*(12.29)*	*(15.75)*	*(18.89)*
M20	75.47***	72.43***	45.72***	55.84***	35.59
	(8.28)	*(6.20)*	*(12.22)*	*(11.01)*	*(21.97)*
M5	141.74***	135.07***	38.22**	39.09**	37.34
	(9.68)	*(9.11)*	*(14.99)*	*(17.36)*	*(24.50)*
Grid		0.0200***	0.0256	0.0530**	-0.00186
		(0.020)	*(0.0213)*	*(0.0232)*	*(0.0358)*
M100*Grid			0.352***	0.298***	0.406***
			(0.0511)	*(0.0674)*	*(0.0772)*
M20*Grid			0.126***	0.0876**	0.164*
			(0.0471)	*(0.0401)*	*(0.0859)*
M5*Grid			0.408***	0.352***	0.464***
			(0.0541)	*(0.0732)*	*(0.0803)*
Constant	142.116***	98.27***	136.5***	135.5***	151.6***
	(5.003)	*(6.437)*	*(6.506)*	*(7.656)*	*(22.58)*
Observations	1,640	1,640	1,640	820	820
R-squared	0.185	0.241	0.284	0.318	0.265

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Model (1) confirms how market prices differ across the nominal representations, relative to the omitted treatment: B500 in Fatas et al (2014). As discussed above, the dummy variables are significant and increasing in the sequence M100-M20-M5, even when coefficients M100 and M20 are not significantly different from each other. Model (2) strongly suggests that prices in markets with larger grids are significantly larger. Interaction terms are included in models (3) to (5). Grids play a significant (and positive) role in all four markets (including the omitted treatment B500) in all rounds and in the first ten rounds (see interaction terms in models 3 and 4).

Model 5 presents interesting evidence about the balance between the effect of grids and any other treatment effect we do not capture with our measure. When disentangled from the effect of grids, no treatment dummy plays a positive effect on prices (being the M100 dummy significant and negative). In contrast, the impact of larger grids is still positive and significant in the three local markets in the last ten rounds (marginally significant for M20). Taken together, we interpret these results as confirmation that

Market prices are strongly driven by *Grids*. In other words, the differences observed in Tables 2 to 4 and Figures 1 and 2 come from firms using larger grids in each condition. As the positive and significant coefficients of the interaction terms strongly suggest, while markets with larger price adjustments (i.e. the *Grid* effect is supported) set over-competitive prices, those markets without large price adjustments do not (i.e. any additional treatment effect is not supported, as no treatment dummy coefficient is significantly above zero).

Note that while the interaction terms of M100 and M5 are of a similar size in both halves of the experiment, and for all rounds, the interaction term for market M20 is not significantly different from the effect of Grids in the B500 omitted treatment in the first half of the experiment (first 10 periods), and remains significantly below the other two in the second half (last 10 periods). We do not have a good explanation for that difference, and our experimental dataset does not allow us to test alternative hypotheses.

The resulting picture is that the differences in market prices observed in Figure 2 above are largely generated by firms using larger grids, as our Result 5 summarizes:

Result 5. *As predicted by the Coarse Grid Nash equilibrium, experimental markets with large grids are associated with large market prices.*

One feature missing in the previous analysis is that both players should choose the same price in a coarse grid Nash equilibrium. Table 5 above focuses in the analysis of market prices and cannot capture whether by being in one treatment *all* firms coordinate more easily above competitive levels (again, a *treatment* effect), or whether only those firms choosing larger grids can sustain symmetric prices above Nash (a *grid* effect). In table 6 we use the same covariates as in Table 5 with a different dependent variable: a categorical dummy variable identifying those instances in which firms choose identical prices above Nash Equilibrium prices (150 in the B500 benchmark). Whenever prices, above or below Nash, are not symmetric, the dependent variable takes the value of 0. Table 6 below displays the marginal effects of 4 probit models.

Table 6: Probability of price coordination above Nash Equilibrium prices

	(1) All periods	(2) All periods	(3) All periods	(4) Periods 11-20
Period	0.00503***	0.00465***	0.00465***	-0.00141
	(0.000895)	*(0.000853)*	*(0.000772)*	*(0.00304)*
M100	0.143***	0.0703***	-0.0573***	-0.122***
	(0.0270)	*(0.0173)*	*(0.00992)*	*(0.0208)*
M20	0.0186	0.00693	-0.0318**	-0.0676**
	(0.0211)	*(0.0171)*	*(0.0144)*	*(0.0324)*
M5	0.243***	0.193***	-0.0257**	-0.0304
	(0.0351)	*(0.0306)*	*(0.0131)*	*(0.0385)*
Grid		0.230***	-0.104	-0.214
		(0.0259)	*(0.0653)*	*(0.133)*
M100*Grid			0.499***	0.907***
			(0.0835)	*(0.173)*
M20*Grid			0.246**	0.519**
			(0.104)	*(0.222)*
M5*Grid			0.494***	0.774***
			(0.0903)	*(0.187)*
Observations	1,640	1,640	1,640	820

Marginal effects of the grid proxy and the interaction effects are multiplied by 1000
Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 6 follows closely the rationale of Table 5, and confirms the very different roles played by the *treatment* and the *grid* effects. The main novelty of Table 6 comes from the maybe unsurprising results that coordination on high prices increases with time, as the estimate for the variable period is significant and positive in models (1) to (3), being the effect insignificant in the second half of the experiment, and significantly stronger in local markets M100 and M5.

As in table 5, symmetric prices are significantly more likely in markets with larger grids. Once interaction effects are considered, while dummies for treatment variables are significantly below zero, all interaction effects are significantly positive. Our cautious interpretation of both the negative and positive signs is driven by the very different effects of treatment and grid effects. As grids seem to be of little help in the quasi-continuous benchmark treatment B500, firms with small grids in our local markets coordinate above Nash Equilibrium prices less frequently (as the negative marginal effects suggest). Coordination in over-competitive prices is however much easier, and frequent among firms with large firms, as the substantial and positive marginal effects of the interaction terms suggest.

As the estimates of the interaction effects are not increasing in the exchange rate, we rule out a simple explanation of the monotone nominal illusion effect linked with a focality effect based on integers. If participants in our experiment exclusively used round prices, larger exchange rates would imply a lower number of prices (i.e. if players restricted themselves to thinking in integers, there would be 101 prices to choose from in M100, 21 in M20 and 6 in M5). Our econometric estimates discard this possibility and it shows that over-competitive coordination is related to the use of grids, as the concept of coarse grid Nash equilibrium suggests.

Result 6. *Symmetric equilibrium profiles are not the result of focality but it depends on the use of grids.*

5. Conclusions

In this paper we have experimentally studied 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 follow a very different route and show that nominal illusion can be a phenomenon that far from being transient, does not decay over time. We do so by studying a one-shot entry game where players face first a choice of which local market to enter to compete in prices, with the feature that all local markets are equivalent because they all are different nominal representations of the same economy. Despite subjects allocating themselves in equal numbers across the local markets –which reinforces the rationale that players conceive all nominal representations as payoff-equivalent in real terms- the pricing dynamic reveals an interesting pattern: larger prices associated to larger nominal exchange.

This monotone nominal illusion effect is consistent with results found in one-shot individual decision making studies. 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).

As the interesting feature of the monotone nominal illusion in our experiment is that it persists over time, we propose a mechanism explaining persistence: if economic agents start focusing on the nominal representations because they are simpler and more salient (as it is the standard view in the literature, see Shafir et al, 1997) and they keep using them because it is a very profitable strategy, then market forces may be simply perpetuating collusive practices. We operationalize this intuition by offering a behavioural toy model that characterizes nominal illusion in a simpler and powerful way: we assume players explore and simplify the choice set by thinking on multiples of convenient numbers. Our model then let players follow a standard equilibrium logic, best responding to other players.

Our results are consistent with this intuition. While firms exploring the strategy space in larger price adjustment intervals in the first five rounds of the experiment, maintain over-competitive prices in the last five periods, firms using smaller grids do not. Coordination above Nash equilibrium prices follows a similar logic. This intuitive approach shows that in frictionless markets, prices may stay above competitive markets because there are no incentives to deviate from any equilibria, once reached. 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.

REFERENCES

Acker, D. and N. W. Duck (2013), "Do Investors Suffer from Money Illusion? A Direct Test of the Modigliani–Cohn Hypothesis", *Review of Finance* 17, 565-596

Bittschi, B. and S. Duppel (2015), "Did the Introduction of the Euro Lead to Money Illusion? Empirical Evidence from Germany", ZEW Discussion Paper 15-058

Brunnermeier, M.K. and C. Julliard (2008), "Money illusion and housing frenzies", *The Review of Financial Studies* 21, 135-180

Cannon, E. and G. Cipriani (2006), "Euro-Illusion: A Natural Experiment", *Journal of Money, Credit and Banking* 38, 1391-1403

Chen, Y., Iyer, G., & Pazgal, A. (2010). Limited memory, categorization, and competition. *Marketing Science*, *29*(4), 650-670.

Cohen, R.B., Polk, C., Vuolteenaho, T. (2005); "Money illusion in the stock market: The Modigliani–Cohn hypothesis", The *Quarterly Journal of Economics* 120, 639–668

Dufwenberg, M., & Gneezy, U. (2000). Price competition and market concentration: an experimental study. *international Journal of industrial Organization*, *18*(1), 7-22.

Eisenhuth, R. (2017), "Money Illusion and market survival", *Macroeconomic Dynamic*s 21, 1-10

Fatas, E., and Mañez, J. A. (2007). Are low-price promises collusion guarantees? An experimental test of price matching policies. *Spanish Economic Review*, *9*(1), 59-77.

Fatas, E., and Morales, A. J. (2013). Step thinking and costly coordination. *Economics Letters*, *120*(2), 181-183.

Fatas, E., Georgantzís, N., Máñez, J. A., & Sabater-Grande, G. (2005). Pro-competitive price beating guarantees: experimental evidence. *Review of Industrial Organization*, *26*(1), 115-136.

Fatas, E., Georgantzís, N., Máñez, J. A., and Sabater, G. (2013). Experimental duopolies under price guarantees. *Applied Economics*, *45*(1), 15-35.

Fatas, E., Haruvy, E. and A. J. Morales (2014), "A psychological re-examination of the Bertrand paradox", *Southern Economic Journal* 80, 948-967

Fatas, E., Heap, S. P. H., & Arjona, D. R. (2018). Preference conformism: An experiment. *European Economic Review*, *105*, 71-82.

Fehr, E. and J-R Tyran (2001), "Does money illusion matter?", *American Economic Review 91,* 1239-1262

Fehr, E. and J.R. Tyran (2007), "Money illusion and coordination failure", *Games and Economic Behaviour* 58, 246–268

Fehr, E. and J.R. Tyran (2008), "Limited Rationality and Strategic Interaction, The Impact of the Strategic Environment on Nominal Inertia", *Econometrica* 76, 353-394

Fehr, E. and J.R. Tyran (2014), "Does Money Illusion Matter?: Reply", *The American Economic Review* 104, 1063-1071

Fisher, I. (1928), *Money Illusion*, Adelphi, New York

Hargreaves Heap, S., Rojo Arjona, D., & Sugden, R. (2014). How Portable Is Level-0 Behavior? A Test of Level-k Theory in Games With Non-Neutral Frames. Econometrica, 82(3), 1133-1151.

Kahneman, D. (2003), "Maps of bounded rationality: Psychology for behavioral economics", *American Economic Review* 93, 1449–1475

Kooreman, P., Faber, R. and H. Hofmans (2004), "Charity donations and the Euro introduction—Some quasi experimental evidence on money illusion", *Journal of Money, Credit and Banking* 36, 1121–1124

Noussair, C., Richter, G. and J.R. Tyran (2012), "Money Illusion and Nominal Inertia in Experimental Asset Markets", *Journal of Behavioral Finance* 13, 27-37

Osborne, M.F. (1965), "The dynamics of stock trading", *Econometrica* 33, 88-111

Pandelaere, M., Briers, B. and C. Lembregts (2011), "How to Make a 29% Increase Look Bigger: The Unit Effect in Option Comparisons", *Journal of Consumer Research* 38, 308-322

McKelvey, Richard D. and Thomas R. Palfrey (1995) "Quantal Response Equilibria for Normal Form Games," *Games and Economic Behavior* 10, 6-38

McKelvey, Richard D. and Thomas R. Palfrey (1998) "Quantal Response Equilibria in Extensive Form Games," *Experimental Economics* 1, 9-41

Pelham, B.W., Sumarta, T.T. and L. Myaskovsky (1994), "The Easy Path From Many To Much: the Numerosity Heuristic", *Cognitive Psychology* 26, 103-133

Ariel Rubinstein, "On Price Recognition and Computational Complexity in a Monopolistic Model," *Journal of Political Economy* 101, no. 3 (Jun., 1993): 473-484.

Raghubir, P. and, J. Srivastava (2002), "Effect of Face Value on Product Valuation in Foreign Currencies," *Journal of Consumer Research*, 29, 335–47

Shafir, E., Diamond, P.A. and A. Tversky (1997), "Money illusion", *The Quarterly Journal of Economics* 112, 341–374

Stahl, D.O. and P. W. Wilson, (1994), "Experimental evidence on players' models of other players", *Journal of Economic Behavior & Organization*, 25(3), 309-327

Stahl, D.O. and P. W. Wilson, (1995), "On players' models of other players: Theory and experimental evidence", *Games and Economic Behavior* 10, 218-254

Thaler, R.H. (2000), "From Homo Economicus to Homo Sapiens." *Journal of Economic Perspectives*, 14(1): 133-141.

Tyran, J. R. (2007), "Money illusion and the market", *Science* 317, 1042-1043

Wertenbroch. K., Soman, D. and A. Chattopadhyay (2007), "On the Perceived Value of Money: The Reference Dependence of Currency Numerosity Effects", *Journal of Consumer Research* 34, 1-10

Appendix 1. Additional quantitative analysis and figures

Figure A1. Evolution of market prices in ECUs by nominal representation
(all periods)

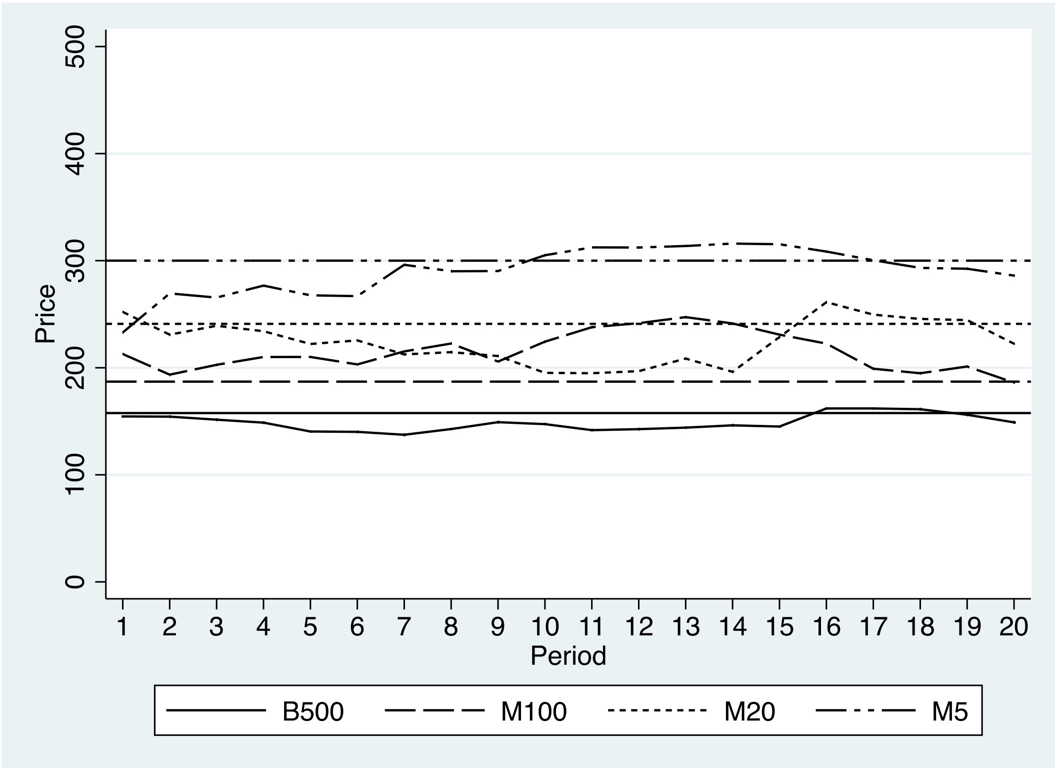


Figure A2: Market prices
(in blocks of 5 rounds, all markets)

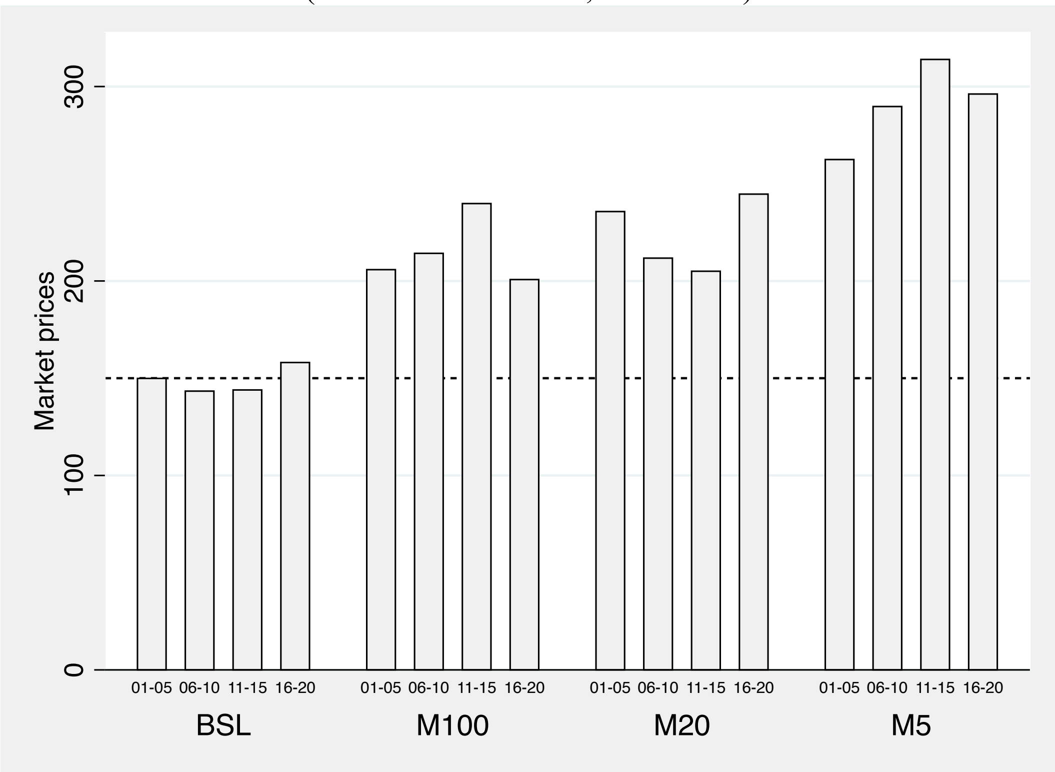
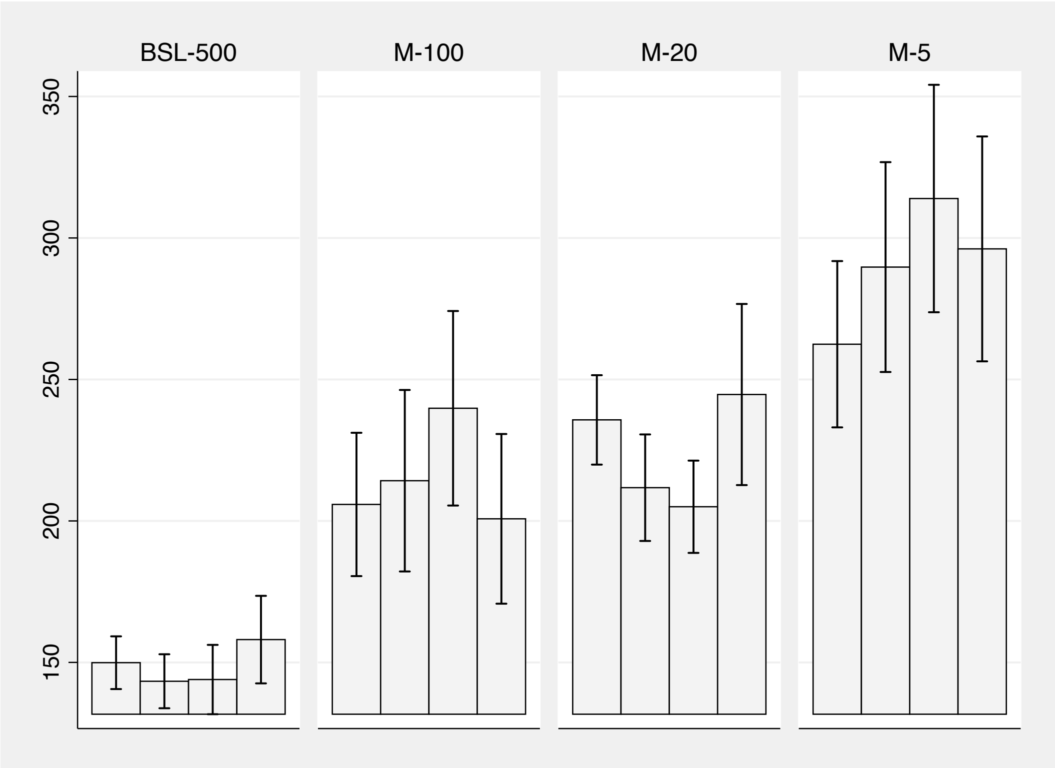


Table A1: Profits in ECUs across nominal representations

	Market profits	
Variable	All periods	Last five periods
Constant	443.93***	1706.44**
	(53.87)	*(862.52)*
Period	11.81**	-54.87
	(4.94)	*(47.27)*
M5	1498.06***	1392.63***
	(108.62)	*(237.51)*
M20	741.58***	869.65***
	(68.14)	*(199.34)*
M100	682.00***	376.17**
	(91.28)	*(185.28)*
M5 – M20	756.47***	522.98*
	(119.65)	*(285.61)*
M5 – M100	816.06***	1016.46***
	(134.19)	*(275.98)*
M20 – M100	59.58	493.47**
	(104.17)	*(243.91)*
# Obs.	1640	410
R-sq between	0.1716	0.1223

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

Figure A3: Market prices in blocks of five rounds



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 the experiment, the profits will be exchanged at the rate of 800Tt=160Mt=40Df=€1. Your final profits will be the sum of the initial € 5 plus the accrued benefits over the 20 rounds.