Essays on commodity cycles based on expanded Cobweb experiments of electricity markets

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A mi mamá
de quien aprendí todo el amor del mundo

Abstract

This thesis studies cycles in commodity markets. Such fluctuations have significant adverse effects on consumers and producers. The properties of commodity price fluctuations are well known. However, there is considerable disagreement about the underlying causes of market fluctuations. Understanding such cycles is essential for policy analysis. We analyze the case of recently deregulated electricity markets, where several authors have expressed a concern that capacity cycles may emerge. The potential occurrence of cycles represents a major threat to electricity security, since there could be periods with insufficient capacity to satisfy demand followed by periods with excess capacity and unsustainably low prices.

Traditional economic literature argues that oscillations are caused by external shocks. We explore an alternative explanation that comes from the internal structure of the system. The method is laboratory experiments. To link to the existing literature we start by investigating the simplest economic model of cycles (the Cobweb model) with standard conditions, linear demand, and constant costs. Step by step, we add complexity (and realism) to the simple model. We introduce long lifetimes of production capacity and then we introduce a two period investment lag in addition to long lifetimes. Consistent with previous experiments and the rational expectations hypothesis, we find no evidence of cycles in the basic design and in the capacity lifetime treatment. Average prices are close to Cournot Nash equilibrium with a bias towards competitive prices. In the investment lag treatment, however, variance and autocorrelation analysis indicate cyclical tendencies.

In a follow up experiment we introduce a constant price elasticity with dynamic demand adjustment. The experiment gives rise to larger and asymmetric fluctuations similar to observed commodity prices (e.g. sugar and coffee prices). In a third experiment, we increase the frequency of decisions. We observe oscillatory behaviour in investment activity and prices. The cyclical tendency is stronger than in the previous experiments, and the results corroborate assumptions made in previous simulation studies of electricity markets. In a fourth paper, we look at empirical evidence of fluctuations in some electricity markets in South America. While the time-series are not long enough to conclude that there are systematic fluctuations, we observe that both Brazil and Chile have experienced very small reserve margins, electricity supply crises, and considerable shortages of electricity. The likely cause is lack of investments in new generation capacity. Argentina and Colombia have high reserve margins and very low spot prices, largely because of the deep recessions in their respective economies.

The thesis contributes to a better understanding of endogenous causes of market fluctuations. This should call for an increased interest in market models that include supply and demand side dynamics. Also, the findings should serve as a motivation to search for alternative stabilising policies in existing markets, particularly in markets where deregulation is considered.

Keywords: *Commodity Cycles, Investment Behaviour, Deregulation, Cycles in Electricity Markets, Perfect Rationality, Bounded Rationality, System Dynamics, Experimental Economics.*

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If we knew what it was we were doing, it would not be called research, would it?
Albert Einstein

1 MOTIVATION AND PROBLEM FORMULATION: FLUCTUATIONS OF COMMODITY PRICES, PRODUCTION, AND INVESTMENTS

There seems to be a widespread belief that commodity markets show cyclical behaviour[1] (Spraos 1990; Cuddington & Urzua, 1989; Cashin *et al* 2002, Cashin & Patillo, 2000; Deaton & Laroque, 1992, 1996, and 2003). Market fluctuations are characterised by amplitudes, period lengths, and by the shape of the cycles. The fluctuations are generally thought to have significant negative effects for consumers and producers, particularly for developing countries (Deaton, 1999; Varagis *et al* 1995; Akiyama *et al* 2001; Akiyama *et al* 2003)[2]. Cycles in commodity prices represent a major problem for both microeconomic and macroeconomic policies, particularly in countries where the economy depends largely on exports of one or two commodities (Deaton & Laroque, 1992). Therefore, the understanding of cycles is essential for policies of national savings and consumption, monetary policy, internal inside-country pricing policies, and for the design of risk-sharing mechanisms (Deaton & Laroque, 1992). In addition, better market knowledge is of course of interest to producers, investors and the banking system.

Despite the importance of the problem, most modern introductory textbooks in economics either ignore commodity cycles (e.g. Mankiw, 2004; Sloman, 2002; Samuelson & Nordhaus, 2001; and Case & Fair, 1996) or they deal with the phenomenon using the highly simplified cobweb model (e.g. Lipsey & Chrystal, 2003). Journal articles dealing with commodity cycles also resort to simplified models that do not necessary reflect the empirical evidence (Deaton & Laroque, 1992; 2003). A few exceptions are not well known in the economics literature (e.g. Meadows, 1970). Even though the properties of the world commodity prices are well known (Deaton, 1999), there is not agreement between economists regarding the causes of commodity price movements (Cashin *et al* 2002; Deaton & Laroque, 1992; 2003; Deaton, 1999). The lack of consensus is a problem to the extent that different models prescribe different policies. For instance, according to Deaton (1999) some African countries have got misleading advice based on improper models (Deaton, 1999).

A commodity is usually defined as an undifferentiated product, often supplied by many small, independent producers, e.g. agricultural products such as coffee, sugar, and cattle. A variety of industries different from agriculture have also shown cyclical tendencies. Some examples of industries with boom and bust behaviour is the real-estate market[3] (Bakken, 1993), aluminium melting

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[1] I refer in this thesis to commodity cycles rather than the well known *Business Cycles*. *Business Cycles* are related to macroeconomic behaviour while commodity cycles in our context are related to isolated oscillations in a particular industry or market. I make this distinction clear because I have experienced that these issues are often confused.

[2] About 25% of the world (merchandise) trade is primary commodities. Many developing countries are dependent on only one or a few commodities for their export earnings (Cashin & Patillo, 2000; Varagis *et al* 1995). The ratio of primary commodity exports to total merchandise export for countries with low and middle income has been reduced from 72% in 1979 to 47% in 1992; For sub-Saharan African countries, this ratio fell slower, changing from 83% in 1970 to 76% in 1992 (World bank, 1999). Moreover, commodities in Africa represented 72% of the 1992´s exports including energy (Varagis *et al* 1995).

[3] Hoyt (1933, p 387) describes the cycles in the real estate industry as follows:
"Developers scramble to build at many locations around the city, and a great many men work secretly and independently on a great variety of structures in many sections of the city. There is no central clearing house to

(Kaufmann, 1983), and the deregulated airline industry (Liehr *et al* 2001). These industries show similarities in price behaviour. They are also similar with respect to market structure with long lifetimes of capacity and long investment delays. Figure 1 presents some classical examples of commodity cycles in different markets.

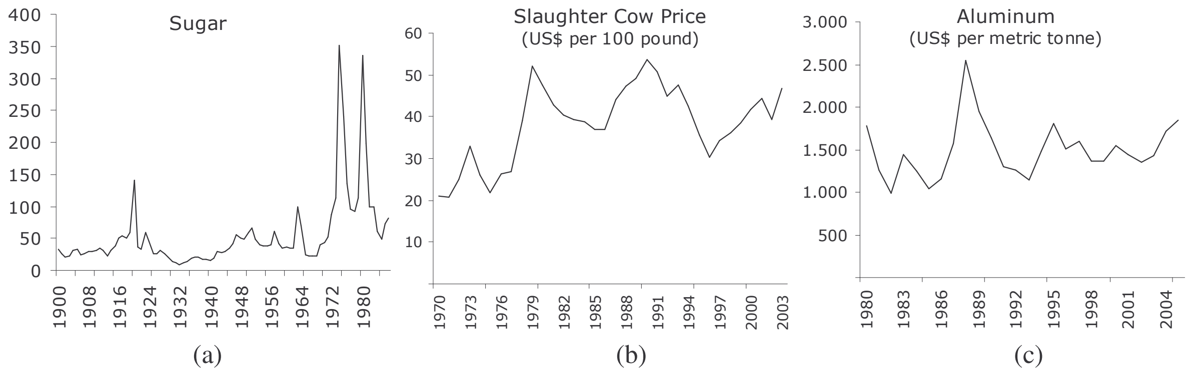

Figure 1. Example of cyclical behaviour for different commodities. Source: (a) Grilli & Yang (1988); (b) Livestock, Meat, & Wool, AMS, USDA; (c) Personal request to World Bank.

This thesis takes particular interest in the electricity industry. The electricity industry has been transformed worldwide since the mid 1980s. The deregulation process has replaced state-owned monopolies with open and competitive markets in those parts of the supply chain where it seemed feasible. Lessons from other deregulated industries such as telecommunication and airlines have been used in market designs. This has prompted several authors to become concerned that cycles of over- and under-capacity could emerge in the newly deregulated electricity markets (Ford, 1999 and 2000; IEA 1999, 2002, 2003; Bunn & Larsen 1992 and 1999; Newbery, 1995; Lomi & Larsen, 1999). The potential cyclicality in electricity markets is based on simulation models (e.g. Ford 1999, Bunn & Larsen 1992; Lomi & Larsen, 1999), and/or by analogy to other industries[4] (e.g. Krapels, 1996; Newbery, 1995; Backus, 1996), given that so far there is no empirical evidence of cycles in electricity these markets (IEA, 1999 and 2003; Ford, 1999).

Secure supply is one of the primary challenges of deregulated electricity markets (IEA, 1999 and 2003). The supply depends on investments and much of the focus has been on the adequacy of these investments. Lack in investments or erroneous timing could lead to shortages and cyclical behaviour with negative effects for consumers and economic performance (IEA, 2002). The potential occurrence of cycles of boom and bust in capacity represents a major threat to security of electricity supply, because there could be periods with capacity deficits followed by periods of excess capacity and unsustainable low prices (IEA, 2002).

Deregulation means that electricity markets become more similar to traditional and not regulated commodity markets. In traditional regulated electricity systems, the government (generally represented by one agency) is responsible for total capacity planning by ensuring enough capacity to cover demand at all times. Although costs are considered by the central investing agency, they act with caution to prevent shortages. This has frequently resulted in overcapacity (IEA, 2002). In deregulated markets, investments are made by market actors. Hence, the total capacity is the sum of individual capacities. Market actors are not responsible for market stability or reliability. If they were, they would have to forecast electricity demand and, additionally, forecast the total supply of competitors. Efforts to coordinate investments to stabilize the market would in many cases be contrary to competition

correlate the impending supply of buildings with the probable demand, so that when all these plans came to fruition, an astonishing number of new structures had been erected."

[4] Note that electricity production and consumption must occur simultaneously. Electricity cannot be stored; therefore, there is no buffer inventory between supply and demand. This calls for cautions, since lack of inventories could lead to higher price peaks than seen in the cycles observed in other commodities (Ford, 1999).

legislation. Hence, in deregulated markets, stability will depend on the availability of information to and the rationality of individual investors.

The main purpose of this thesis is to investigate commodity fluctuations by the use of laboratory experiments. Central questions are: will we be able to generate cycles in the laboratory, what shape will the fluctuations have, and what explains cycles and shapes? Before we say more about the experiments, we turn to the current economic explanations of cycles, starting with commodity markets in general and then address electricity markets in particular.

2 ECONOMIC EXPLANATIONS OF COMMODITY CYCLES

Traditional economic literature attributes fluctuations in commodity prices to external shocks confronting inelastic demand, and to the behaviour of speculators (Deaton & Laroque, 1992), factors that move the price away from rational equilibrium and produce variability. Supply shocks normally causes temporary shortfall in production, and they are normally thought to be large; for instance, wars, pestilence, disease, weather, and political upheaval (Deaton, 1999). If demand is price inelastic, then variance of prices could be a number of times the variance of the supply shock (Deaton, 1999). For instance, Brunner (2000) presents the effect of the macroclimatic phenomenon ENSO (El Niño South Oscillation) on some commodities in South America. Deaton (1999) presents the case of rice in Japan, the poor harvest during 1993 lead the country to increase imports from zero in 1992 to 2.2 million tons in 1993, rice prices doubled and fell sharply after the recovery of Japanese production in 1994. Other commodity prices that have boomed due to external shocks are maize crop because of the flooding in the Midwest of the United States, and coffee because of frost and drought in Brazil.

However, the effects of shocks are not easily predictable. A representative case is illustrated by Deaton (1999, p. 30): *"…the 1975 Brazilian frost that is inevitably identified as the cause of the coffee boom in the late 1970´s was preceded three years earlier by an almost equally destructive frost (40 percent crop (loss, as opposed to 50 percent in 1975) which had no perceptible influence on the price."* This begs the question whether one should be looking for more than one external shock at each point in time. One obvious candidate is to consider demand shocks in addition to or instead of supply shocks, Deaton & Laroque (2003) do this by using a time-series version of the Lewis model (Lewis, 1954), where commodity supply is infinitely price elastic in the long run. They did not find evidence to either support or reject the model. A number of other models have been formulated and tested against real data. Most of them are equilibrium models based on Muth´s rational expectations hypothesis. Normally they assume random *iid* supply shocks (for extensive list of reference for these models, see Deaton & Laroque, 1992).

In spite of the extensive literature based on external shocks, the behaviour of primary commodity prices remains poorly understood. The models have not been able to fully account for the features of the cyclical behaviour of commodity prices (Cashin *et al* 2002; Deaton, 1999; Deaton & Laroque, 2003). This motivates us to consider endogenous explanations of commodity cycles.

Deaton & Laroque (1992) propose a model that incorporates storage where speculators are assumed to move commodities from busting periods to booming periods. This induces autocorrelation in addition to the effects of supply shocks. With this model, they replicate some characteristics of commodity prices, in particular long periods of stagnant prices interrupted by sharp upward spikes. While we acknowledge the potential importance of inventory speculation, we leave it for further research. A main reason for this is that electricity markets have no inventories of the commodity itself, only in terms of supplier controlled raw material inputs.

The very first model to explain cycles endogenously was the well known Cobweb model (Ezekiel, 1938). This model differs from standard market models in that supply is lagged by one time unit. In its original version and depending on assumptions about price elasticities, the Cobweb model produces dampened cycles converging towards equilibrium, sustained cycles, or explosive oscillations. Nerlove

(1958) introduced adaptive expectations in the Cobweb model and Muth (1961) introduced rational expectations. The assumptions about rationality were shown to be very important for both cyclicality and speed of convergence. The supply lag Cobweb model has been used repeatedly to test for expectation formation and cyclicality in experimental economics. Lagged supply models have been studied by Carlson (1967), Sonnemans *et al* (2004), Holt & Villamil (1986), and Sutan & Willinger (2004) and by repeated play Cournot models by Rassenti *et al* (2000), Huck *et al* (2002). The predicted cycles of the Cobweb theory did not materialize in these experiments, while some random fluctuations were sustained[5] (Miller, 2002). The experiments lend some support to the rational expectations hypothesis (e.g. Carlson, 1967).

Meadows (1970) criticises and expands on the Cobweb model, providing a more comprehensive endogenous explanation to commodity cycles. Notably, Meadows makes use of prior information about time delays in the production process, and finds that delays are typically longer than one season, and that production responses can be distributed in time. He also finds that production capacities can have lifetimes that by far exceed one season. In addition to these factors, he introduces product inventories in his model, and assumes that these play a vital role in price determination. The reason for this is that the inventories are much more well defined and better measured than total demand and total supply. Meadows' model reproduces price cycles of hogs, cattle, and chicken when supplied with prior biological data for each of these three sources of meat. The model received positive reviews (Crom, 1971; Oliver, 1973); however, Oliver argues that the model could have had a much wider audience if it had been presentation in a journal paper rather than in a book. Despite the potential of the model to explain cycles, the model and its decision rules have not been tested so far econometrically or in laboratory experiments. We will investigate a simplified version of his model in the laboratory, where the major difference is that we do not include inventories.

As follow-ups to Meadows' study, cyclical behaviour has been studied using simulation models for different commodities and industries. Robinson (2001) modelled the dynamics of avicultural markets and Bakken (1993) showed cycles for real state markets. Liehr *et al* (2001) studied the cycle-generating structures in the airline market and the identification of alternative strategies for effective management. Claims about potential cyclicality in deregulated electricity markets are based on simulation models of the same type as Meadows' model[6] (e.g. Ford, 1999; Bunn & Larsen, 1992; Lomi & Larsen, 1999) Similar to Meadows, these models rely on decision rules assumed by the modeller, where the assumed rationality has not been tested.

We conclude that interesting models with more realistic dynamics than the Cobweb model exist, and that they seem to explain cycles in many markets. Since, market fluctuations could also result from external shocks, and since external shocks do occur, there is still uncertainty about what causes market fluctuations. Studies of investment functions, and their degree of rationality could help remove some of the uncertainty and controversy. Here we will investigate market dynamics in a laboratory setting with no external shocks. Hence, any tendency towards fluctuations in this setting must have an endogenous explanation. To establish a link to the literature, we start by simple Cobweb model designs. Then, step by step, we add dynamic complexity and realism to the basic design to observe if this influences cyclical tendencies.

Our experiment should also provide some empirical evidence to test hypothesis of cycles in deregulated electricity markets, where time-series are still too short to indicate regular cycles (IEA, 1999 and 2003; Ford, 1999).

[5] Asymmetries in costs lead to stronger random fluctuations than symmetric costs (Rassenti *et al* 2000)

[6] For the particular case of recently deregulated electricity markets, there is no empirical evidence to support the hypothesis of cyclical behaviour (IEA, 1999 and 2003; Ford, 1999), while there is evidence for the other commodities previously mentioned.

3 HYPOTHESIS TO BE TESTED BY LABORATORY EXPERIMENTS

In this section, we present the hypotheses to be tested in the laboratory experiments. We first present the need for dynamic complexity in commodity markets, and then we show a brief summary of the experiments and the research hypotheses in each of them. Finally we look for empirical evidence in real markets.

3.1 Previous experiments: lack of necessary dynamic complexity

The use of laboratory experiments of commodity markets has been limited to very simple designs. Most experimental markets do not include dynamic structures and are reset each period (e.g. Plott, 1982; Smith 1982). In these experiments, there are no elements carrying over to future periods, such as capacities, unfulfilled orders and inventories. Dynamics have been considered in studies of speculative bubbles. First, Miller *et al* (1977) took the simplest intertemporal possible market based on the Williams´ two season model, where carryovers were allowed only from one season to the next one They found that the markets worked very efficiently with no signs of instability (Miller, 2002). Following, Smith *et al* (1988) considered asset markets lasting 15 periods. These markets regularly produced bubbles followed by crashes under a variety of market parameters. For commodity markets, dynamics have been introduced by lagged supply models (Carlson, 1967; Sonnemans *et al* 2004; Holt and Villamil, 1986; Sutan & Willinger, 2004) and by repeated play Cournot models (Rassenti *et al* 2000; and Huck *et al* 2004). The predicted cycles of the Cobweb theory did not materialize in these experiments, while some random fluctuations were sustained (Miller, 2002).

3.2 Base experiment: from standard simple Cobweb (Cournot) markets to complexity

We create dynamic experimental markets where subjects make isolated investment decisions. We start out with the Cobweb design. The Cobweb model is identical to the simple lagged supply model with symmetric constant marginal costs and a linear demand function, i.e. a homogeneous Cournot market under standard conditions (Huck, 2004). Hence, the starting point links the ensuing treatments and experiments with the literature. The standard conditions for Cournot/Cobweb markets (Huck, 2004, p.106) are:

a. Interaction takes place in fixed groups
b. Interaction is repeated over a fixed number of periods
c. Products are perfect substitutes
d. Costs are symmetric
e. There is no communication between subjects
f. Subjects have complete information about their own payoff functions
g. Subjects receive feedback about aggregated supply, the resulting price, and their own individual profits
h. The experimental instructions use an economic frame

Step by step, we add complexity (and realism) to the basic Cobweb market by introducing long lifetimes of production capacity and long investment lags. Typically physical capital lasts many years, over which repeated investment decision are made. New capacity is added to existing capacity; vintages are introduced. Typically, also, capacity additions require a sequence of operations: planning, choice of suppliers, production of parts, transportation, construction, and testing; or time for gestation and growth in biological production systems. In total, capacity additions take several years in most commodity markets. Full capacity utilization is assumed. Thus, production is equal to the sum of capacities of all vintages.

3.3 Formal hypotheses to be tested

We consider both cyclicality and efficiency. We formulate the null hypothesis based on the rational expectations hypothesis (Muth, 1961) and the standard assumption about optimal decision making. The null hypothesis is convergence to a stable Nash equilibrium. Minor and seemingly random variations around the equilibrium value will be consistent with this hypothesis. Systematic cyclical tendencies are not consistent with the hypothesis since rational agents could predict these and benefit from countercyclical investment decisions, which over time would stabilize the market.

The alternative hypothesis is formulated based on bounded rationality theory (Simon, 1979), assuming that complex dynamic problems are approached with heuristics (Sterman, 1987b; Tversky and Kahneman, 1987). Heuristics are used instead of truly optimal strategies because cognitive capabilities are limited and there are considerable deliberation costs. People typically prefer simplifying heuristics for such problems. Such heuristics could lead to optimal results for simple problems (Gigerenzer, 1999), while the results are likely to deteriorate with increasing complexity. A series of experiments supports the latter claim (Paich and Sterman, 1993; Diehl and Sterman, 1995; Kampmann 1992; Sterman 1989, Herrnstein and Prelect, 1991, Moxnes, 2004).

Regarding market efficiency, it is difficult to predict the outcome of bounded rationality. While simplified heuristics are likely to bias outcomes, the biases may be both in the directions of monopoly and perfect competition. Accordingly, the current literature does not present a clear prediction of efficiency (Conlisk, 1996b, and Foss, 2003). Hence, in this regard we consider the experiment exploratory.

Regarding cyclicality, we formulate a more precise hypothesis expressing the intended rationality of the subjects. While there is one and only one optimal strategy according to rational expectations theory; there are many possible heuristics and outcomes for bounded rationality. Moreover, one should expect strategies to be case dependent and to vary over individuals (Tversky & Kahneman, 1987; Conlisk, 1996a). We draw the heuristic based on previous experiments with similar dynamic complexity. The heuristic assumes that people are not able to follow the optimal strategy (rational behaviour), instead they adjust capacity towards a desired capacity. The capital is adjusted only through investments; and the investment function is based on the anchoring and adjustment heuristic (Tversky & Kahneman, 1994) and inspired by to a related problem (Sterman, 1989). That is, we assume they use a feedback strategy, where the desired capital is indicated by the expected price. We rely on the assumption about adaptive price expectations, formulated by Nerlove (1958) in his analysis of the Cobweb theorem. Previous experiments support this heuristic for people that are confronted with simple lagged supply decisions (e. g. Carlson, 1967; Sterman, 1987b; Heiner, 1989).

4 DESIGNS OF EXPERIMENTS AND THE MAIN FINDINGS

Critics of experimental economics argue that real markets are inherently more complex than the markets analysed in laboratories. Behaviour in a very complex system may be governed by different laws than those used in simple systems (Gigerenzer *et al* 1999, Plott, 1982, p. 1522). We have responded to this criticism by adding complexity and realism step by step. Our results clearly suggest that complexity matters and that the subjects are not able to fully counteract the effects of complexity by altered behaviour.

There are three experimental papers. All experiments are supposed to be rough representations of electricity markets, however, with different assumptions and simplifications. The following list gives an overview of the experiments and the treatments in each experiment.

E1. Linear demand, 5 year long time steps
- T1. Simple supply lag
- T2. T1 plus long lifetime of production capacity

T3. T2 plus one extra investment lag

E2. Constant price elasticity, 5 year long time steps

T1. Simple supply lag

T2. T1 plus delayed demand adjustments

T3. T2 plus long lifetime of production capacity

T4. T3 plus one extra investment lag

E3. Linear demand, 1 year long time steps, long lifetime of capacity, extra investment lags

In the experimental papers we have tried many methods to analyse the data. While many of these are kept in the papers, some of them will be removed before sending the manuscripts to journals. The paper 4 seeks for empirical evidence of instabilities in electricity markets. Following, we present the main findings and conclusions of each paper.

4.1 Paper E1: Cyclical behaviour, a function of market complexity? Expanding the Cobweb experiment

E1 reports a series of Cournot markets with groups of five seller subjects. The subjects decide on production over time and the market price is determined according to a static linear demand curve. To mimic the electricity market while keeping the experiment simple, decisions take place at five year intervals. Step by step, we add complexity (and realism) to the simple cobweb market (T1). First we introduce lifetimes of capacity extending beyond one period (four vintages) (T2). Then we add an extra investment lag (T3) while keeping the vintages of T2. We explore whether prices converge over time to a unique, static noncooperative Nash equilibrium, and we investigate tendencies towards cyclical behaviour.

The simplest treatment, T1, is a Cournot market under standard conditions (Huck, 2004), identical to the Cobweb model. Experimental results show that smoothed prices converge towards a price level close to the Cournot Nash equilibrium but with a bias towards competitive prices. This is consistent with previous experiments of the Cobweb model (Carlson, 1967; Sonnemans *et al* 2004; Holt & Villamil, 1986; Sutan & Willinger, 2004) and of repeated Cournot markets (Rassenti *et al* 2000; and Huck *et al* 2002). Thus, T1 provides a link between the literature and the ensuing treatments.

T2 and T3 show similar results regarding the convergence of smoothed prices. When it comes to fluctuations and cyclicality, we observe differences between the treatments. In all treatments we find sustained price variations, like in the earlier Cobweb and Cournot experiments. However, T3 shows stronger fluctuations measured by the variance of the price as well as cyclical tendencies measured by autocorrelation. The only factor that makes T3 different from both T1 and T2 is the extra investment lag. The investment lag complicates the task, and the participants are not able to fully counteract its effects.

To explain the market behaviour, we propose that people use one and the same simple heuristic based on bounded rationality theory. Simulations of the heuristic lead to fast convergence for T1, rapidly converging cycles in T2, and greater and slowly converging cycles in T3. Observed behaviour is consistent with this hypothesised behaviour. However, regressions of the hypothesised investment heuristic indicate that in T1 and T2 subjects use somewhat different heuristics, or at least heuristics with different parameter values from those hypothesised.

T3 estimates are not significantly different from the hypothesised values. However, the investment function does not explain much of the variation in T3 investments. In all cases we observe a large fraction of seemingly random occurrences, which complicates the search for patterns of behaviour. Previous Cournot games, similar to T1 (Rassenti *et al* 2000; Huck *et al* 2004), also fail to explain investments. The authors indicated a need for further research in this regard. Nevertheless, we still suspect that there must have been feedback guiding decisions; otherwise smoothed prices would not have been that stable and close to CN. While we have tested only one hypothetical investment function, further investigations may reveal more powerful investment functions.

Our results are interesting in that the observed cyclical tendencies in T3 are not generated by exogenous shocks as is often assumed. In our experiment, observed behaviour must be caused by internally generated shocks in combination with heuristics that strengthen and propagate fluctuations. Our simulations with a rational agent suggest that employed heuristics play an important role in addition to the internally generated shocks.

4.2 Paper E2: Asymmetric commodity cycles: evidence from an experimental market

This paper also reports on a series of five players Cournot markets with groups of five seller subjects. Analogous to E1, step by step, we add vintages in capacity (T3) and an extra investment lag to the supply side of the simple commodity market model (T4). The two experiments differ in that we introduce a constant elasticity demand (with a maximum price) for all treatments with gradual dynamic adjustment (T2, T3, and T4), instead of the linear static demand of E1.

Similar to previous experiments (e.g. Huck, 2004; Rassenti *et al* 2000; E1) we find little evidence of cyclical behaviour before vintages and investment lags are introduced. Similar to E1, we find that the supply side additions lead to larger variance in price and to stronger autocorrelation. However, the price behaviour differs from E1 in that fluctuations become asymmetrical measured by positive skewness. Consistent with E1, the average prices across treatments are approximately 50 percent higher than the competitive equilibrium. Since the constant price elasticity and the maximum price of the current experiment implies a much higher Cournot Nash equilibrium than the linear demand of E1, the current experiment shows a much larger downward bias relative to the Cournot Nash equilibrium.

Economic theory does not define any particular shape for the demand curve and leaves this as an empirical question. Depending on the availability of close substitutes, the demand curve could be close to linear or convex with close to constant price elasticity. Hence, one assumption is not necessarily more realistic than the other. It is however reassuring that our simulations and experimental results with a convex demand curve produce fluctuations similar to observations from real markets with positive autocorrelation, positive skewness and sharp upward peaks (Deaton, 1999; Cashin, 2002). This is an important result, given that previous models have not been able to clearly account for all of these features (He & Westerhoff, 2005; Deaton & Laroque, 1992). Moreover, our results could be extended to different commodities with similar market structure because, as Plott (1982) says, "*The theory takes advantage of the fact that principles of economics apply to all commodities which are valued independently of the source of individual values or the ultimate use to which the commodities are to be put*".

Subjects in E1 were availed with a profit calculator to help identify the Cournot Nash equilibrium. Such a profit calculator was not available in this experiment. The profit calculator may have influenced the choice of heuristics in E1. Nevertheless, we observe that both E1 and E2 present similar average prices relative to the competitive price, which indicates that the profit calculator was not of great importance.

4.3 Paper E3: Cyclical behaviour in electricity markets: an experimental study

This paper reports five players Cournot markets with groups of five seller subjects. Analogous to the most complex treatment in E1, we have vintages in production capacity, a long investment lag and linear demand. The two experiments differ in that we increase the frequency of decisions. Instead of five years between decisions, we allow for investment decisions every year in E3. The experiment has a four year investment lag and capacity has a life time of 16 years, such that it resembles an electricity market. While we did not find strong support for cyclicality in E1 and E2, the results of E3 support the hypothesis of cyclical tendencies in electricity markets. We find several indications of cyclical behaviour by: visual inspection, spectral analysis, and autocorrelograms. All measures are consistent with cyclicality.

We observe that subjects have the tendency to initiate new projects when they perceive high prices, while they tend to ignore capacity under construction and the involved delivery delay. Once new capacity is in place, the market has surplus capacity and therefore prices fall. There are no external disturbances in the experiment, hence this often quoted cause of fluctuations can be ruled out in this experiment. The players generate sufficient disturbances themselves to keep the cycles alive over time.

Investors face a difficult dynamic decision problem that includes long time delays and accumulations, where bounded rationality is more likely to explain the behaviour than perfect rationality. We investigated a hypothesis that people use a simple investment heuristic consistent with bounded rationality theory. A statistical test of the heuristic suggests that investments are positively related to reported price expectations. The other variables come out mostly insignificant. Interesting to note though is that simulations with the estimated heuristic shows cyclical behaviour of the type observed in the experiment, while simulations with purely random investments show quite different types of price behaviour. Hence, it seems clear that the observed price cycles are related to player decisions. For most markets and individuals we cannot reject a hypothesis saying that expectations are adaptive and unbiased. However, low r^2 values indicate that the expectation formation is more complicated than assumed here. Hence, the search for better models to explain expectation formation, as well as investments, is an interesting topics for further research.

4.4 Paper 4: Lessons from deregulation: Understanding electricity markets in South America[7]

In the final paper, we take a look at the development of some deregulated electricity markets in South America. We compare the evolution of deregulation, from initiation to the current state, in four South American countries: Argentina, Brazil, Chile, and Colombia. All four countries have implemented different deregulated market systems, allowing a unique possibility to compare the performance of different implementations of deregulation in one continent and observe the potential occurrence of instabilities in prices. We describe the course undertaken by these countries and the results attained so far, we estimate the price volatility, and also compare and contrast the development of the different electricity industries.

Despite the short life of these markets, we observe the first boom in prices. Although it is too soon to observe weather these peaks are part of a cycle, the undesired situation of cycles show up: shortages. Chile came out of a critical situation in 1999 with extremely high prices and shortages; Brazil faced a supply crisis in 2001 also with very high prices and shortages, and Argentina was experiencing a similar situation, with much lesser effects, during the year 2004; after a long recession. Colombia is now facing a (dangerous) decline in reserve margin. The reason for these shortages has been delays and lack of investments mainly in new generation capacity. Thus, so far, the data are more in support of cyclical tendencies than of regimes with stable prices.

In this respect, we conclude that there is a need for detailed understanding of possible market developments four to six years ahead. This would allow the regulator to understand whether there is a possibility for electricity shortage and in which cases this might happen. We also argue that regulators have to “face up to” the expected shortages of electricity. This includes sharing the concern with investors and consumers as well as with politicians; it also involves explaining the circumstances under which a shortage might happen (as well as the likelihood of it) and the consequences, in terms of interruptions and potential economic cost to the country. By means of these considerations, Colombia might still be able to prevent a possible crisis of the types that Argentina, Brazil and Chile were not able to prevent. In this connection it should also be clear that not all situations can be prevented; but with foresight and determination it is likely that the majority of these situations could be prevented.

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5 POLICY IMPLICATION AND FURTHER RESEARCH

Commodity cycles are known to cause problems for consumers, producers as well as nations that depend on a small number of commodities for their export earnings. Hence, price stabilisation is an important policy issue (Akiyama *et al* 2001). Our study suggests that commodity price fluctuations are not only caused by external shocks. Market actors may contribute considerably through seemingly random behaviour and through inappropriate investment heuristics. Thus, policy focus should not be exclusively on external events, policies should also consider the working of the market, i.e. its internal dynamics.

In this regards, two types of policies have been formulated or implemented (Varangis *et al* 1995): policies to buffer the effects of commodity cycles for producers and countries, and policies to damp or reduce commodity cycles on a world scale. Among the particular policies are:

- *Commodity stabilisation funds*: These funds are supposed to help stabilise government expenditures. Saving income in boom years, governments can adjust their expenditure such that they do not need to cut spending in leaner periods (Varangis *et al* 1995). This fund could be treated as international foreign reserves, for example, the Norwegian Petroleum Fund was to a large extent motivated by potential oil price fluctuations (NOU, 1983).
- *Access to financial markets:* Some countries have only few alternatives for investing during the booms. The development of financial markets helps to provide various alternatives for investments.
- *Contingent borrowing facilities:* Facilities to provide loan for countries that have suffered substantial export revenue shortfalls.
- *Hedging:* Market based hedging instruments (futures, options, swaps) can increase the predictability of anticipated commodity related revenues. They can also assist private sector exporters and traders in handling their commodity price risks. These instruments are complementary of stabilization funds. In fact, the first futures contracts were invented to handle weather-induced volatile agricultural markets back in the 18th century, in Chicago.
- In the particular case of electricity markets, there are proposals of capacity payments (payments for holding excess capacity or capacity in reserve) and financial institutions such as option markets.

Implementation of policies in real life is not an easy task. It implies politics, groups of interests, market actors; and in many cases, different countries which increases the difficulty for implementation. The proper result of a particular policy is an empirical question to be tested in real life. However, a bad policy could be catastrophic in terms of costs and timing.

Our results suggest that policy makers should consider the effects of investment delays and capacity accumulations. We have observed people trend to overreact to high prices, which, together with investment delays and capacity vintages, lead to price oscillations. These factors should be part of the formulation of stabilising policies, which is not an straight forward task. We infer that examples of policies could be providing information about important conditions of the system such total investment volumes or planned capacity (in case the government are able to collect such data); or policies that take into account general education in the dynamic of the particular markets. However, the detailed formulation and effectiveness of such policies would be an interesting topic for further research.

The applicability and effectiveness of alternative policies that consider the internal structure of the production systems require analysis. One could use laboratory experiments, as we have used in this thesis, to test directly policies before implementation in real life. Such experiments are test-beds similar to the wind tunnel for engineers, where the market design with a particular policy can be assessed in a laboratory with real subjects that acts motivated by monetary payments.

In the present experiments we added realism to the standard Cobweb model. However, our experiments still have a number of assumptions different from reality. Some of these factors are interesting to study in further research:

- The effect of a deterministic profit calculator: this instrument helps subjects to find the CN equilibrium very accurate, which in reality nobody knows precisely. One could explore the effect of absence of the profit calculator or introduce uncertainty.
- The effect and importance of external events and uncertainty: further research could observe the effect of external shocks, similar to those observed in real markets and check the effect in an accompanying experiment. It is interesting to see the relative impact on commodity cycles from the external shocks (exogenous variables) entering supply chains with complexity (endogenous variable).
- Effects of treatments related to information. The information was incomplete for subjects in all experiments. They know the state of the total market, but they do not know the individual behaviour. More (or less) information may or may not result in weaker fluctuations than what has been observed in this thesis.
- Effect of market actors: one must consider the fact that all experiments with only two exceptions were performed with students. Although some experiments have found little or no difference between students and market actors (Moxnes, 1998), it may be a factor that affect market stability.
- Effects of including inventories, capital goods markets, credit markets, etc., factors that were not represented in our experiments.

An important research topic of Industrial Organization is that firm-level heterogeneity strongly influences the market behaviour (Klepper & Graddy, 1990; Ranssenti *et al* 2000). Differences in productivity and firm structure result in differences in profitability, number of survivor firms, and market behaviour. According to empirical studies, the factors that cause the firm heterogeneity are inferred from market behaviour under the hypothesis of equilibrium instead of direct observations (Rassenti *et al* 2000).

Through all the experiments, our results suggest heterogeneity of behavioural strategies. It could contribute to asymmetric market share distributions, despite the fact that the initial conditions assume homogeneity of the firms. Such heterogeneity in behaviour could also, to some extent, contribute to asymmetries observed in real markets. Further research could investigate the dynamics of market shares based on the empirical evidence in our laboratory data.

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