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CENTER FOR FINANCIAL STUDIES

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# Strategic Complementarity, Nominal Rigidity and the Non-Neutrality of Money*

Ernst Fehr** and Jean-Robert Tyran***

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**Abstract:** This paper examines whether an exogenous anticipated monetary shock causes real economic effects, i.e. whether anticipated money is neutral. A major finding is that an *anticipated* monetary shock can in fact be massively non-neutral in the short-run, if the economic environment is characterized by strategic complementarity. If the environment is characterized by strategic substitutability, anticipated monetary shocks are largely neutral.

**Keywords:** Strategic complementarity, experimental economics, behavioral macro-economics

**JEL classification:** C92, E32, E52

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## Introduction

*"The work for which I have received the Nobel Prize was part of an effort to understand how changes in the conduct of monetary policy can influence inflation, employment, and production. So much thought has been devoted to this question and so much evidence is available that one might reasonably assume that it had been solved long ago. But this is not the case: It had not been solved in the 1970s when I began my work on it, and even now the question has not been given anything like a fully satisfactory answer."*

ROBERT E. LUCAS JR. (1996: 661)

Do changes in the quantity of money affect real economic activity? Why do such monetary non-neutralities arise? These questions are central to economics at least since DAVID HUME's (1752) contributions. Despite the immense amount of theoretical and empirical literature that has been produced since, different explanations persist, and the question is still open to debate. Abrupt and massive reductions in the quantity of money are claimed to be responsible for severe depressions (BERNANKE and CAREY, 1996 or ROMER and ROMER, 1989) even if the monetary contraction is anticipated (BALL, 1991). On the other hand, various authors contest this view. They claim that money is neutral as long as a monetary shock is fully *anticipated* by economic agents (e.g. LUCAS, 1972; SARGENT, 1976). Some researchers of the real business cycle-school deny even that money is of any importance for business cycle fluctuations.

The purpose of this paper is twofold: First, we want to test the proposition that an anticipated monetary shock does not have real economic effects. Second, if a monetary shock in fact does have real economic effects, we want to isolate the causes of monetary non-neutrality. As will be argued below, experimental methods provide a suitable tool for this purpose. Following theoretical work by HALTIWANGER and WALDMAN (1985, 1989, 1991) and BOMFIM and DIEBOLD (1997), we test the hypothesis that money should be non-neutral when the environment is characterized by strategic complementarity, but should be largely neutral when it is characterized by strategic substitutes.

The paper is structured as follows: Section 1 briefly discusses problems of empirical work with field data and advantages of experimental methods for our examination. Section 2 mentions leading theories of nominal rigidity, and provides an intuitive account of HALTIWANGER and WALDMAN's theory. Section 3 presents the experimental design, and section 4 discusses the results of our experimental study.

## 1. Empirical vs. experimental methods in monetary macroeconomics

This section argues that there may be substantial mismeasurement in macroeconomic aggregates and that this kind of mismeasurement matters for the question of monetary neutrality (A). Fundamental problems of isolating causality in monetary economics are discussed (B). It is argued that experimental methods have several advantages over empirical investigations with macroeconomic field data (C).

*A) Mismeasurement matters*

Often it is difficult to decide in empirical work, which variables to observe at all. One reason for this is that macroeconomic variables are in general aggregate variables which cannot be observed directly, but have to be constructed using data from different sources. Prominent examples of this kind of problems are *price indices*. SHAPIRO and WILCOX (1996) discuss the probable amount of mismeasurement in the consumer price index (CPI) in the U.S. They find that the upward bias of the CPI is centered on *1 percentage point per year*. However, the extent of this bias is not known exactly (see MOULTON, 1996 for a survey). Since price indices are important for the calculation of real quantities from observed or constructed nominal quantities their mismeasurement may also affect the conclusions about the real effects of monetary shocks.

BELONGIA (1996) provides a striking example of how sensitive conclusions in monetary economics may be with respect to measurement problems. Specifically, he discusses how inferences about the effects of money on economic activity may depend importantly on the choice of *monetary indices*. BELONGIA replicates five studies concerning the quantification of monetary shocks, the symmetry of money's effect on output, the relationship between money and the business cycle, and money-income causality.[3] In four of the five cases, the qualitative inference in the original study is reversed when a simple-sum monetary aggregate is replaced by a Divisia index of the same asset collection. BELONGIA's study indicates that the potential scientific gains of empirical methods that rest on unambiguous measures of money may be quite high.

*B) Problems of isolating causalities*

Why is the debate between real business cycle theory, which poses that anticipated monetary disturbances have no real effects, and Keynesian theories, which claim that such disturbances have important effects on output, so difficult to decide on empirical grounds? (ROMER, 1996: 232-6). Why can we not just regress real GNP on M1 with different lags? The problem is that regressions

3. The replicated studies are: ROTEMBERG (1993), COVER (1992), KYDLAND and PRESCOTT (1990), FRIEDMAN and KUTTNER (1992), and STOCK and WATSON (1989) versus FRIEDMAN and KUTTNER (1993).

of this kind do not provide any evidence in favor of monetary theories and against real theories.

First, a major difficulty in testing empirically for the monetary effects on real economic activity is that the money supply not only influences economic activity but also is influenced by it in turn. This *reverse causation* may happen (as argued by KING and PLOSSER, 1984) because of shifts in money demand stemming from changes in firms' and households' production plans. As a result, we may see changes in the money stock in advance of output movements even if the changes in money are not causing the output movements. In this case lagged money will help predict output even if it does not affect it (for an early discussion see TOBIN, 1970; COLEMAN, 1996).[4]

Second, monetary policy may interact with movements in other aggregates. Suppose monetary authorities adjust the money stock to try to offset other factors that influence aggregate output. If this monetary policy intervention proves to be successful (because it has real effects), we will observe movements in money but not in output. Similarly, suppose fiscal and monetary policies are coordinated (e.g. both are expansionary). In this case we may observe a strong correlation between movements in money and output, even if money has no effect on real economic activity at all. Just as we cannot conclude from the positive correlation between money and output that money causes output, if we fail to observe such a correlation we cannot conclude that money does not cause output.

Third, financial innovations and deregulation of financial markets in the last two decades may have led to large shifts in money demand. If monetary authorities do not adjust money supply to these demand disturbances we may observe correlations between money and output. As a result of such money demand shifts, the estimated relationship between money and output is very sensitive to such matters as the sample period and the measure of money.

ROMER (1996) concludes from these problems that even more sophisticated statistical analyses of the association of money and real variables cannot provide strong evidence concerning the relative merits of monetary and real theories of fluctuations. One way to arrive at meaningful empirical evidence is to look for "natural experiments". An example of this approach is provided by FRIEDMAN and SCHWARTZ (1963) who claim to be able to identify exogenous changes in the

4. To give an example of nonsensical results one can arrive at, when blindly using statistical causality tests, consider the following question (after PINDYK and RUBINFELD, 1991: 218f.): Which came first: The chicken or the egg? THURMAN and FISHER (1988) have finally shed some light on this issue by using causality tests. They use annual data on two variables: total U.S. production of eggs from 1930 to 1983 and total U.S. production of chickens. To conclude that one of the two "came first", it is necessary to find unidirectional causality, i.e. to reject the noncausality of one to the other and at the same time fail to reject the noncausality of the other to the one. Using different lags, the authors obtained a clear rejection of the hypothesis that eggs do not cause chickens, but were unable to reject the hypothesis that chickens do not cause eggs. Thus they were able to conclude that the egg came first!

money stock on the basis of historical analyses. Yet, this claim critically depends on the exogeneity of the money change, which can not be proven beyond doubt in naturally occurring economies.

*C) Why use experimental methods?*

In laboratory experiments we observe the behavior of real people which are exposed to real economic incentives in a controlled environment (see DAVIS and HOLT, 1993 or FRIEDMAN and SUNDER, 1994 for an introduction to experimental economics). What can experiments contribute to the debate on the neutrality of money? In what respect do experimental investigations have advantages over empirical investigations with field data? An obvious advantage consists in *correct measurement* of endogenous variables like prices and real economic activity. In addition, experiments allow to gather data which are crucial for many economic theories but cannot be directly observed in the field. In our context *expectation data* are especially valuable. The second important advantage of the experimental method is *control over the environment and the information conditions*: Truly *exogenous* monetary shock can be implemented and the theoretical equilibrium values of the economy under study are known. Therefore, we can differentiate between equilibrium and out-of-equilibrium realizations of endogenous variables when we observe the behavior of the economy. In addition, we control what economic agents know about their economic environment and about the information at the disposition of other agents. This allows to implement an anticipated monetary shock, where one can be sure that every agent knows how she and everybody else is affected by this change in the quantity of money. Furthermore, experimental methods allow to implement the conditions stipulated in a theory. This allows to actually *test the behavioral predictions of a theory.*

Finally, experiments allow to establish *causal relations* through controlled *ceteris paribus* variations of the decision environment. By changing only one aspect of the environment and by comparing behavior in the respective treatments we can argue that this change in behavior must have been caused by the change in the economic environment.

## 2. Theories of nominal rigidity and the non-neutrality of money

At present, three important theoretical approaches try to account for nominal rigidities and, thus, the non-neutrality of money. First, New Keynesian theories explain nominal rigidities as arising from fully rational agents, acting in markets with small nominal frictions and imperfect competition. Well-known examples of this literature are collected in MANKIW and ROMER (1991). A second approach follows the pioneering work of LUCAS (1972) and argues that in an economy

with fully rational agents money can be non-neutral if agents do not have full information about the monetary shock. In this line of thinking, the distinction between anticipated and unanticipated changes in the money stock is crucial: If a monetary shock is anticipated, money is neutral.[5]

The third approach relaxes the assumption of perfectly rational agents. This literature analyzes the implications of small deviations from full rationality of few agents. Pioneers in this field are AKERLOF and YELLEN (1985a, 1985b, 1987) and HALTIWANGER and WALDMAN (1985, 1989, 1991) who show that a small relaxation of the assumption of full rationality can have a large impact on aggregate outcomes. BOMFIM and DIEBOLD (1997) complement the analysis by HALTIWANGER and WALDMAN by a dynamic aggregative model with both real and nominal shocks.

### 2.1. Bounded Rationality, Strategic Complements and Substitutes

Since our experiment is directly related to the theory of HALTIWANGER and WALDMAN we provide in the following an intuitive account of their approach. If the strategic environment is characterized by strategic complementarity anticipated monetary shocks have large real effects in the presence of *few* boundedly rational agents. If the environment is characterized by strategic substitutability anticipated monetary shocks are largely neutral even if some agents are boundedly rational. In the context of a price setting game strategic complementarity prevails if an increase in the general price level leads an optimizing firm to increase its own price. Strategic substitutability corresponds to the case where an increase in the general price level leads the firm instead to decrease its price. OH and WALDMAN (1984) claim that important features of macroeconomies can be captured by the concept of strategic complementarity. Examples include monopolistic price competition, increasing returns of scale in production, search in labor markets, and the Keynesian multiplier.[6]

The intuition behind the results of HALTIWANGER and WALDMAN (1985, 1989) can be illustrated in a simple two-player pricing game. Consider first the benchmark case of monetary neutrality. Suppose that the rationality of both players is common knowledge. What happens, when the quantity of money $M$ is halved? Both players cut their nominal prices $P_i$ and $P_j$ by 50% and sell

5. "The main finding that emerged from the research of the 1970s is that anticipated changes and unanticipated changes in money growth have very different effects. Anticipated monetary expansions ... are *not* associated with the kind of stimulus to employment and production that HUME described. Unanticipated monetary expansions, on the other hand, can stimulate production as, symmetrically, unanticipated contractions can induce depressions." LUCAS (1996: 679)
6. See COOPER and HALTIWANGER (1993) for evidence on strategic complementarity in naturally occurring economies.

the same amount of goods as before. The same would have happened in a situation of strategic substitutes. That is, the same response occurs *irrespective* of the strategic properties of the economic environment.

Assume the same initial situation as before, but now player $j$ is irrational and does, therefore, not adjust his nominal price. Player $i$ knows this. Assume that strategic complementarity prevails. The reduction of the money supply by 50% increases $j$'s real price $p_j = P_j/M$ by 100%. Due to strategic complementarity player $i$, who is fully rational, will also want to increase her real price $p_i = P_i/M$ and therefore *not* cut her nominal price by 50%, but by less. Thus, under conditions of strategic complementarity the fully rational agents partially *imitate* the boundedly rational agents which gives the latter a *disproportionately large impact on the aggregate* price level.

What happens if a fully rational and an irrational player interact under conditions of strategic substitutes? In this case the rational player $i$ responds to the increase in $j$'s real price by reducing $p_i$ below the previous level. That is, $i$ will cut her nominal price by *more* than 50%. Hence, under conditions of strategic substitutes, the fully rational actors partially *compensate* the behavior of the boundedly rational ones which gives the latter *a disproportionately small impact on the aggregate* outcome. Finally, suppose that both players are rational, but both (counterfactually) *believe* that the other one is boundedly rational. In this case $i$ expects that $j$ will not change his nominal price (which corresponds to an increase in the real price). Under conditions of strategic complementarity $i$ will, hence, increase her real price. At the same time, $j$ expects that $i$ will not change her nominal price which induces $j$ to cut his price by less than 50%. As a result, the aggregate price level exhibits nominal rigidity and leads to the non-neutrality of money. This example indicates that the absence of common knowledge of rationality may be sufficient for the non-neutrality of money if strategic complementarity prevails.[7]

# 3. Experimental Design

## 3.1. General description of the experimental design

To study the impact of nominal shocks on the adjustment of nominal prices we implemented a pricing game. There were two treatment conditions, a strategic substitutes treatment and a strategic complements treatment. Each subject in our experiment was a member of a group of $n = 4$ players. In each period of the experiment every group member $i$ had to choose a nominal price $P_i$. The real payoff of agent $i$ was given by $\pi_i(P_i, \bar{P}_{-i}, M)$, where $\bar{P}_{-i}$ denotes the average price of the other three group members, while $M$ is the nominal shock variable (the money supply). The nominal payoff of agent $i$ was given by $\bar{P}_{-i}\pi_i$. The real payoff functions had the following properties:

1. Homogeneitiy of degree zero in all three variables,
2. Unique maximizer $P_i$ for every $\bar{P}_{-i}$.

According to the implemented payoff functions there was a unique and Pareto-efficient equilibrium for every $M$. It was possible to find the equilibrium solution by iterated elimination of weakly dominated strategies. Moreover, the equilibrium was the only Pareto-efficient point in the feasible price range which was given by the integers [1, 30]. Since $\pi_i$ is homogeneous of degree zero the impact of a change in $M$ on the equilibrium values of $P_i$ and $\bar{P}_{-i}$ is straightforward. A fully anticipated change $\lambda M$ ($\lambda > 0, \lambda \neq 1$), changes $P_i$ and $\bar{P}_{-i}$ to $\lambda P_i$ and $\lambda \bar{P}_{-i}$ for all $i$. Thus, all nominal variables change equiproportionately while the real payoffs remain unaffected. According to the rational expectations approach the change in nominal prices should occur instantaneously. Notice that this holds irrespective of the strategic environment. In contrast, the HALTIWANGER and WALDMAN-hypothesis predicts a slow adjustment of nominal prices under strategic

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7. KEYNES (1936: 156) speculated that the market value of assets on financial markets may become unhinged of "fundamentals" and become dependent on free-floating expectations: "... professional investment may be linkened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; so that each competitor has to pick, not those faces which he himself finds the prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view. It is not the case of choosing those which, to the best of one's judgment, are really the prettiest, nor even those which the average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the fourth, fifth and higher degrees."
This chain of argumentation is analogous to the „Gang of Four" explanation of cooperation in finitely repeated prisoners dilemma situation (KREPS et al. 1982): The authors aim at explaining how cooperation can arise even if all agents are selfish profit maximizers. The authors suggest a possible rescue of standard theory by putting the bound on uncertainty about the rationality of other agents instead of rationality itself. They assume that, although both agents in fact are unboundedly rational, one player thinks the other might be boundedly rational. The absence of common knowledge of rationality is enough to induce cooperation with the usual rationality assumptions.

complements, while under strategic substitutes nominal adjustment should be faster.

### 3.2. Experimental procedures and parameters

Each group of four participated in a pricing game that lasted 40 periods. During the first 20 periods we implemented payoff functions with $M_0$. After period 20 the nominal shock variable was changed to $M_1 = M_0/3$ (see *Table 1* for a summary of all major parameters and design features). In each group there were two types of agents. Agents of type $x$ had a payoff function that implied the choice of relatively low prices in equilibrium. Before the shock their equilibrium choice was $P_{0x} = 9$; after the shock their equilibrium choice was at $P_{1x} = 3$. The payoff function of type $y$ agents implied equilibrium prices of $P_{0y} = 27$ before, and of $P_{1y} = 9$ after the shock. Since in each group there were two agents of type $x$ and two of type $y$, the overall average price was $\bar{P}_0 = 18$ in the pre-shock equilibrium and $\bar{P}_1 = 6$ in the post-shock equilibrium. In each of the 40 periods subjects had to choose a nominal price $P_i$. In addition, they had to provide an expectation about $\bar{P}^e_{-i}$ together with an indication of the subjective confidence in their expectation. To indicate confidence, they had to choose a number from 1 to 6 where 1 was an indication that this subject is not all confident about the precision of her expectation, while 6 indicated absolute confidence about the precision of $\bar{P}^e_{-i}$. At the end of a period each subject $i$ was informed about the realization of $\bar{P}_{-i}$ and about the real payoff $\pi_i$.

* Insert ***Table 1*** about here *

An important design feature concerns subjects' information about payoff functions. Payoffs were represented in matrix form (see appendix for payoff tables) where each column shows $\Pi_i(P_i, \bar{P}_{-i}, M)$ for a given value of $\bar{P}_{-i}$. It was thus relatively easy to determine the best reply for any expected $\bar{P}^e_{-i}$ -value (see shaded cells[8]). Each subject of type $x$ ($y$) also received the payoff tables for subjects of type $y$ ($x$). Since this was publicly known, payoff functions were common knowledge.

Payoff tables A1 to A4, show nominal payoffs for agents of type $y$ in the case of strategic complementarity and strategic substitutes, respectively. To calculate real payoffs $\pi_i$, subjects had to divide ('deflate') nominal payoffs by $\bar{P}_{-i}$ (the 'price level'). Note that except for the slope of the best reply function the structure of payoffs is the same. For a given $\bar{P}_{-i}$ the payoff function is sym-

8. Since the feasible prices were the integers in the interval [1, 30] subjects received a 30 by 30 matrix. Of course, the subjects were given tables without shaded cells.

metric and bell-shaped, and the payoff-steps are the same.[9] The equilibrium values are the *same* in both treatments. In the tables shown, prae-shock equilibrium is at a price of $P_i^* = 27$ and an average price of $\bar{P}_{-i}^* = 15$. As can be seen, the reaction function is "flattened" around the equilibrium to make equilibrium play more stable.

At the end of period 20, we implement the change in the quantity of money by distributing new payoff tables (see Tables A2 and A4, respectively). We told subjects that everything else remained unchanged, specifically group composition. This was common knowledge, and the monetary shock was thus fully anticipated. Subjects were given enough time to study the new payoff tables (10 minutes in total) and to decide on the prices they want to set in period 21. All tables given to subjects show payoffs represented in nominal terms. Subjects were instructed how to deflate (they had to solve several exercises before the experiment and were all equipped with a pocket calculator). Our experimental subjects had presumably above average skills and were probably more apt to perform divisions, and thus less prone to behave boundedly rational than the average person in the population. After having checked that all subjects answered the control questions correctly we read the summary page aloud to let the subjects know that everyone received the same instructions.

9. The property that the profit function is symmetric in $P_i$ cannot be seen very easily. This is so because we used a continuous profit function which may have it's maximum for a given $\bar{P}_{-i}$ at a non-integer $P_i$. Since we show only (rounded) profits for integer prices, it is not obvious that we in fact hold the shape of the profit function constant and just shift it's maximum to higher prices for $i$ at higher values of $\bar{P}_{-i}$ (see appendix).

# 4. Experimental results

In total, 23 groups consisting of four subjects participated in our experiment. 11 groups played the pricing game under conditions of strategic complements, 12 groups played the pricing game in the substitutes treatment. Subjects were paid sFr. 15 (approx. US$12) for showing up. Average total earnings were around sFr. 35 (approx. US$28). Subjects were paid out immediately after the session which lasted 90 minutes on average.

## 4.1. Main results

*Figure 1* shows the evolution of nominal average prices of the median group[10] over time. As can be seen, in both treatments nominal prices are very close to the theoretical prediction $\bar{P}_0^* = 18$ throughout the last three periods before the shock. However, after the shock we observe massive nominal inertia in the complements treatment while prices in the substitutes treatment jump to the new equilibrium prediction of $\bar{P}_1^* = 6$. Obviously, the strategic property has a large and systematic effect on the degree of nominal rigidity.[11]

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

A similar picture emerges when we look at the percentage of subjects who choose exactly their equilibrium price (see *figure 2*). Before the shock the percentage of equilibrium choices is slightly higher in the complements treatment. Yet, in period 21 there is a large drop in this percentage in the complements treatment while in the substitutes treatment there is only a minor decrease. Thus, the anticipated shock seems to have acted as a disequilibrating force in the complements treatment. For example, it takes 15 periods until this treatment effect vanishes. The percentage of subjects who choose equilibrium prices in the complements treatment rises from 11% in period 21 to 80% in period 40. This fact is an indication of the convergence process to equilibrium.

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

10. Note that the identity of the median group may change from period to period.
11. A median test of the null hypothesis that overall average prices across 5 periods are the same in both treatments yields the following results: Before the shock we cannot reject this hypothesis at the 5%-level. After the shock, we can reject this hypothesis for periods 21-25, 26-30, 31-35 at the 5%-level. We cannot reject the hypothesis for periods 36-40.

The treatment effect can also be seen when looking at the distribution of individual prices in periods 20 and 21. *Figure 3* shows these distributions for subjects of type *y*. Before the shock almost all subjects play the equilibrium of $P_{0y} = 27$ in both treatments. After the shock there are only few individuals in the complements treatment who jump to the new equilibrium value of $P_{1y} = 9$, and the whole distribution is *above* the equilibrium. In contrast, the post-shock distribution in the substitutes treatment is very different. Most individuals jump directly to the new equilibrium. Moreover, most of those who do not play the equilibrium *overadjust* their nominal prices. Under the assumption that subjects play best replies to their expected $\overline{P}_{-i}$ this data pattern suggests that in the complements treatment the majority of subjects expects the other group members to choose nominal prices above the equilibrium whereas in the substitutes treatment the majority expects equilibrium play of other group members. Furthermore, if some agents expect other group members not to adjust nominal prices sufficiently, the rational response is to choose nominal prices above equilibrium in the complements treatment, but nominal prices below equilibrium in the substitutes treatment. This prediction of the HALTIWANGER and WALDMAN-theory receives confirmation in the data.

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

*Table 2* shows the number of groups who had average prices above, in, or below equilibrium over 5 period-intervals. The impression of *figure 3* is reconfirmed at the group level. Over time more equilibrium play is observed in both treatments. The data reveals that convergence to equilibrium is from above in the complements treatment. Note that there is only one observation below equilibrium over the 20 periods after the shock in the complements treatment, whereas subjects frequently choose prices below equilibrium in the substitutes treatment. For example, in the complements treatment in periods 21 - 25 no group was below the equilibrium whereas there are 51 observations above the equilibrium.

* Insert ***Table 2*** about here *

How did the money supply shock affect real incomes? *Figures 4* and *5* provide the answer to this question. *Figure 4* displays the average real income losses of subjects as a percentage of the real equilibrium payoff. As can be seen, average losses were close to zero in both treatments before the shock. After the shock losses occur in both treatments. They are, however, much larger

and last longer in the complements treatment. In period 21 the average efficiency loss amounts to 65% in the complements treatment while in the substitutes treatment it is only 18%. In period 24 the difference is still substantial (27% versus 9%) In periods 21 to 30 aggregate efficiency losses in the substitutes treatment are only 40% of those in the complements treatment. *Figure 5* depicts the evolution of the real efficiency loss of the median group loss over time. This figure shows an even more impressive treatment effect. Whereas only minor median losses occurred in the substitutes treatment, the median loss in the complements treatment is substantial and lasts for 10 periods. In our view, these results provide evidence against the view that anticipated monetary shocks do not have real effects irrespective of the strategic environment. The data show that the strategic environment is indeed a key factor and that massive non-neutrality of money prevails under strategic complementarity.

### 4.2. Best reply behavior

In principle monetary shocks can be non-neutral due to subjects who do not play best replies after the shock. The near rationality approach of AKERLOF and YELLEN (1985a, 1985b) derives the non-neutrality of money from this behavioral hypothesis. Although in the context of our experiment it was rather simple to detect the best reply to any given $\overline{P}^e_{-i}$ it may still be possible that the shock induces some subjects to deviate from best reply behavior. Since for a given subjective price expectation best reply behavior is independent of strategic interaction, we interpret best reply behavior as an *indicator of individual rationality*. In our present experiment, conditions were not favorable for near-rational behavior. Agents incurred significant losses of at least 25% of their best reply payoff if they made an error of $\Delta P = \pm 2$, which certainly are not of second order. One may speculate whether under conditions which favor 'near-rational' behavior (i.e. deviations from optimality lead to *small* losses) this kind of behavior would have considerable repercussions on the aggregate.

*Figure 6* shows the percentage of subjects who play best reply to their subjective expectation of $\overline{P}^e_{-i}$. Before the shock between 80 and 90 percent of the subjects choose best replies. Note that the percentage is even higher in the complements treatment. After the shock the percentage of best replies drops for three periods from roughly 90% to approximately 70% in the complements treatment. In the substitutes treatment, however, there is no such drop – the percentage even increases after the shock. From period 24 onwards best reply behavior is again very similar in both treatments.

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

Despite the differences that occur immediately after the shock the hypothesis of no treatment differences cannot be rejected in any period after the shock at the 5% level.[12]

### 4.3. Expectations

Price expectations were quite precise before the shock, as can be seen in *figure 7*. In the periods after the shock, behavior seems to be much more difficult to predict. In the complements treatment the percentage of subjects holding exactly correct expectations drops from almost 80% before the shock to 5%, and only slowly catches up to pre-shock levels. Only 15 periods after the shock the percentage of correct expectations exceeds the pre-shock level. In the substitutes treatment the post-shock decrease in the percentage of correct expectations is much smaller. Moreover, already after four periods pre-shock levels are again reached. It seems that the monetary shock causes much larger expectational errors in the complements treatment.

* Insert ***Figure 8*** about here *

Agents also had to indicate, how confident they were that their price expectation would be correct by choosing an integer from 1 to 6.[13] Subjects' confidence in their expectation $\bar{P}^e_{-i}$ can be taken as an indicator of the subjective belief that $\bar{P}^e_{-i}$ will actually be the realization. The confidence rank is therefore a rough measure of how much probability mass subjects put on $\bar{P}^e_{-i}$ . As can be seen from *figure 8*, average confidence (the subjective measure) qualitatively tracks the percentage of actually correct predictions (the objective measure, compare *figure 7*). Note the breakdown of average confidence caused by the *announcement* of the monetary shock from almost 5.5 to about 3. This reduction in subjects' confidence is less pronounced in the substitutes treatment than in the complements treatment. Moreover, it takes 16 periods until the confidence in the complements treatment catches up with the confidence in the substitutes treatment. This suggests that subjects perceived more uncertainty in the complements treatment.

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12. According to a Mann-Whitney-U-test (5%, 2tailed) that uses the median deviation from the best reply in each group as the unit of observation. Due to some large outliers the median deviation is a better measure than the mean deviation.
13. 6 indicates "I am very confident that my expectation on the average price will be correct", whereas 1 indicates "I am not at all confident that my expectation on the average price will be correct".

### 4.4. Loss decomposition

Our data about subjects' expectations and best reply behavior allow to examine the sources of the observed efficiency losses. For this purpose losses are decomposed into three categories: 1. Losses that arise from wrong predictions of $\bar{P}_{-i}$, 2. Losses from a failure to play best reply to $\bar{P}^e_{-i}$, and 3. Losses from an aggregate demand externality.

* Insert ***Figure 9*** about here *

Suppose an agent $i$ expects an average price of $\bar{P}^e_{-i}$ which gives rise to the payoff function $\pi_i(P_i, \bar{P}^e_{-i}, M)$ (see left parabola in *figure 9*). Denote the best reply to $\bar{P}^e_{-i}$ by $P_i(\bar{P}^e_{-i})$. Suppose that agent $i$ is not fully rational for some reason and chooses a price $P_i$ which is not a best reply on her expectation. Therefore, if her expectation turns out to be correct, this agent will get a lower payoff (compare points C and D in the diagram). Now suppose that agent $i$'s expectation is not correct, and that an average price of $\bar{P}_{-i}$ materializes. This gives rise to the bold faced payoff function $\pi_i(P_i, \bar{P}_{-i}, M)$. If agent $i$ had the correct expectation and plays the best reply to this expectation, she receives a profit indicated by point B. In fact, however, she gets a lower payoff indicated by point E because she chooses $P_i$. The loss she incurs (B - E) can be partially attributed to the failure to play best reply (C - D), partially on her failure to correctly predict the average price [(B - E) - (C - D)]. Finally, suppose that the actual average price $\bar{P}_{-i}$ is not equal to the equilibrium price $\bar{P}_{-i}^*$. In equilibrium, agent $i$ would have made a payoff illustrated by point A. The best a fully rational agent can do when the actual average price is $\bar{P}_{-i}$ is to reach a profit indicated by point B, which is smaller than the one in point A. The difference A - B does not arise because the agent made some mistake, but because *other* agents choose prices that are not in equilibrium. They thus constitute an aggregate demand externality.[14]

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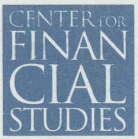
14. In our experiment the losses from aggregate demand externality are relatively small by construction of the decision matrix. The maximum possible loss (after the shock) from the aggregate demand externality is 55% of equilibrium profits for agents of type $x$ and 60% for agents of type $y$. Since the equilibrium is efficient, these losses can by definition only be positive, i.e. gains from aggregate demand externality are excluded by definition.
Losses from failure to play best reply on expected average price arise when an agent fails to choose the strategy which maximizes payoffs given the subjective expectation for the average price in this period. Maximum losses for both types are 100% of equilibrium profit. Since the profit function has unique maximum in the decision variable $p_i$, all deviations from best-reply behavior yield losses, gains are excluded.
Losses from having incorrect expectations arise when the price expectation of an agent differs from actual average prices. Here, losses or gains can occur

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## Mathematical appendix

The real payoff for agent $i$ of type $k = x, y$ is given by:

$$\pi_{ik} = \frac{V \cdot \left[\dfrac{1 + a\left(\dfrac{\bar{P}_{-ik}}{M} - \dfrac{\bar{P}^*_k}{M}\right)^2}{1 + b\left(\dfrac{\bar{P}_{-ik}}{M} - \dfrac{\bar{P}^*_k}{M}\right)^2}\right]}{1 + c\left\{\left(\dfrac{P_{ik}}{M} - \dfrac{P^*_k}{M}\right) - d\left(\dfrac{\bar{P}_{-ik}}{M} - \dfrac{\bar{P}^*_k}{M}\right) + e \cdot \arctan\left[\left(\dfrac{\bar{P}_{-ik}}{M} - \dfrac{\bar{P}^*_k}{M}\right) \cdot f\right]\right\}^2}$$

Each agent of type $k = x, y$ has to choose a price $P_{ik} \in [1, 30]$ in every period $t \in [0, 40]$. The average price for agent $i$ ($\bar{P}_{-ik}$) is the simple average of all prices chosen by *other* agents in his group in period $t$. Specifically, we used groups of $n = 4$ agents, with 2 agents of type $x$ and $y$, respectively. For example, the average price for agent 1 of type $x$ is: $\bar{P}_{1x} = \dfrac{P_{2x} + P_{1y} + P_{2y}}{3}$.

The payoff function is formulated in differences from equilibrium values (i.e. the parameters denoted with *). Equilibrium is attained when all expressions in round brackets () are equal to zero, i.e. when $P_{ik} = P^*_k$ and $\bar{P}_{-ik} = \bar{P}^*_k$ and, consequently, $\pi_{ik}^* = V$ for all $i$ and $k$.

In all periods and all experimental sessions the parameters $a$, $b$, $c$, $f$ and $V$ were the same. They were given by

$a = 0.5$, $b = 0.6$, $c = 27$, $f = 20$ and $V = 40$.

The parameters $d$ and $e$ differed across treatment conditions. They were

$d = 1$ and $e = 0.05$ in the complements treatment, and

$d = -1$ and $e = -0.05$ in the substitutes treatment.

***Properties of the payoff function***

The payoff function obviously is *homogeneous of degree zero* in the quantity of money ($M$), own chosen prices ($P_i$) and average prices ($\bar{P}_{-i}$). That is

$\lambda^r \cdot \pi_i(P_i, \bar{P}_{-i}, M) = \pi_i(\lambda P_i, \lambda \bar{P}_{-i}, \lambda M)$ with $\lambda > 0$, and $r = 0$ for all $i$ and $k$.

The payoff function is more conveniently written as:

$$\pi(p, \bar{p}) = \frac{VA(\bar{p})}{1 + cB^2(p, \bar{p})},$$

with $p \equiv (P_i/M)$, $\bar{p} \equiv \bar{P}_{-i}/M$, $A(\bar{p}) = \frac{1 + a(\bar{p} - \bar{p}^*)^2}{1 + b(\bar{p} - \bar{p}^*)^2}$, and

$$B(p, \bar{p}) = (p - p^*) - d(\bar{p} - \bar{p}^*) + e \cdot \arctan[(\bar{p} - \bar{p}^*) \cdot f]$$

The payoff function is symmetric and quasiconcave in $p$, having a bell-shaped curvature for every given $\bar{p}$. This can be seen by noting that the payoff function is of the type $y(p) = 1/(1 + p^2)$. The necessary first order condition for a maximum is:

$$\frac{\partial \pi(p, \bar{p})}{\partial p} = -\frac{2cVABB_p}{(1 + cB^2)^2} = 0.$$

Which implies that either $A(\bar{p}) = 0$, $B(p, \bar{p}) = 0$, or $B_p(p, \bar{p}) = 0$.

But $A \geq 0$, since $a,b > 0$, and $B_p = 1$. Thus, we must have $B = 0$, i.e. $(p - p^*) - d(\bar{p} - \bar{p}^*) + e \cdot \arctan[(\bar{p} - \bar{p}^*) \cdot f] = 0$.

With $D \equiv (\bar{p} - \bar{p}^*)$ this is more conveniently written as

$$p_i(\bar{p}) = dD - (e \cdot arc\tan(Df)) + p^*$$

which is the *best reply function.*

Differentiating the best reply function with respect to the average price yields

$$\left.\frac{\partial p^{br}(\bar{p}, M)}{\partial \bar{p}}\right|_{\frac{\partial \pi}{\partial p} = 0} = d - \frac{e}{1 + D^2 f}.$$

If $d > e > 0$, the slope of the best reply function is positive (since $f > 0$). If $d < e < 0$, the slope is negative. In the former case, strategic complementarity prevails, in the latter strategic substitutability.

*Table 1:* Experimental design

| | | Complements | Substitutes |
|---|---|---|---|
| All periods and subjects | Slope of reaction function | positive | negative |
| | Choice variable | $P_i \in \{1, 2 \ldots, 30\}$ | $P_i \in \{1, 2 \ldots, 30\}$ |
| | Group size | $n = 4$ | $n = 4$ |
| | Information feedback in period $t$ | $\bar{P}_{-i}, \pi_i$ | $\bar{P}_{-i}, \pi_i$ |
| | Real equilibrium payoff (pre- and post-shock, for both types) | 40 | 40 |
| Pre-shock ($t = 1$ - 20) | Money supply $M_0$ | 42 | 42 |
| | Average equilibrium price $\bar{P}^*$ and average equilibrium expectation for the whole group | 18 | 18 |
| | Equilibrium price for type $x$ | 9 | 9 |
| | Equilibrium expectation $\bar{P}_i^e$ for type $x$ | 21 | 21 |
| | Equilibrium price for type $y$ | 27 | 27 |
| | Equilibrium expectation $\bar{P}_i^e$ for type $y$ | 15 | 15 |
| Post-shock ($t = 21$ - 40) | Money supply $M_1$ | 14 | 14 |
| | Average equilibrium price $\bar{P}^*$ and average equilibrium expectation for the whole group | 6 | 6 |
| | Equilibrium price for type $x$ | 3 | 3 |
| | Equilibrium expectation $\bar{P}_i^e$ for type $x$ | 7 | 7 |
| | Equilibrium price for type $y$ | 9 | 9 |
| | Equilibrium expectation $\bar{P}_i^e$ for type $y$ | 5 | 5 |

*Table 2:* Number of observation above, in, and below the equilibrium (group averages as units of observation)

| | Strategic Complements | | | Strategic Substitutes | | |
|---|---|---|---|---|---|---|
| Period | above | in | below | above | in | below |
| 21 - 25 | 51 | 4 | 0 | 14 | 33 | 13 |
| 26 - 30 | 32 | 23 | 0 | 10 | 39 | 11 |
| 31 - 35 | 23 | 31 | 1 | 6 | 46 | 8 |
| 36 - 40 | 17 | 38 | 0 | 7 | 45 | 8 |

*Table 3:* Loss decomposition (complements in italic)[1]

| Period | Efficiency loss in % of equilibrium real profit ($= L^{Tot}/\pi^*$) | | Efficiency loss due to failure to predict average price ($= L^{Exp}/\pi^*$) | | Efficiency loss due to failure to play best reply ($= L^{BRF}/\pi^*$) | | Efficiency loss due to aggregate demand externality ($= L^{ADE}/\pi^*$) | |
|---|---|---|---|---|---|---|---|---|
| 18 | 0.04 | *0.03* | 0.01 | *0.00* | 0.03 | *0.03* | 0.00 | *0.00* |
| 19 | 0.02 | *0.01* | 0.00 | *0.00* | 0.01 | *0.00* | 0.00 | *0.00* |
| 20 | 0.03 | *0.01* | 0.01 | *0.01* | 0.02 | *0.00* | 0.00 | *0.00* |
| 21 | 0.18 | *0.65* | 0.16 | *0.54* | 0.02 | *0.09* | 0.00 | *0.02* |
| 22 | 0.12 | *0.47* | 0.09 | *0.29* | 0.04 | *0.16* | 0.00 | *0.02* |
| 23 | 0.11 | *0.35* | 0.02 | *0.23* | 0.07 | *0.11* | 0.03 | *0.02* |
| 24 | 0.09 | *0.27* | 0.07 | *0.21* | 0.02 | *0.05* | 0.00 | *0.01* |
| 25 | 0.19 | *0.18* | 0.10 | *0.07* | 0.06 | *0.10* | 0.03 | *0.01* |
| 26 | 0.15 | *0.17* | 0.08 | *0.08* | 0.04 | *0.08* | 0.03 | *0.01* |
| 27 | 0.09 | *0.17* | 0.01 | *0.11* | 0.07 | *0.05* | 0.01 | *0.01* |
| 28 | 0.05 | *0.11* | 0.02 | *0.03* | 0.03 | *0.07* | 0.00 | *0.01* |
| 29 | 0.04 | *0.10* | 0.01 | *0.05* | 0.02 | *0.04* | 0.00 | *0.01* |
| 30 | 0.05 | *0.14* | 0.02 | *0.08* | 0.03 | *0.06* | 0.00 | *0.01* |
| 31 | 0.01 | *0.08* | 0.01 | *0.06* | 0.01 | *0.02* | 0.00 | *0.01* |
| 32 | 0.01 | *0.07* | 0.00 | *0.05* | 0.00 | *0.01* | 0.00 | *0.00* |
| 33 | 0.08 | *0.06* | 0.03 | *0.04* | 0.03 | *0.02* | 0.02 | *0.00* |
| 34 | 0.04 | *0.05* | 0.01 | *0.03* | 0.02 | *0.01* | 0.00 | *0.00* |
| 35 | 0.02 | *0.03* | -0.01 | *0.02* | 0.03 | *0.01* | 0.00 | *0.00* |
| 36 | 0.10 | *0.10* | 0.04 | *0.06* | 0.04 | *0.04* | 0.02 | *0.00* |
| 37 | 0.03 | *0.06* | 0.01 | *0.05* | 0.02 | *0.00* | 0.00 | *0.00* |
| 38 | 0.11 | *0.14* | 0.05 | *0.11* | 0.04 | *0.03* | 0.02 | *0.00* |
| 39 | 0.05 | *0.13* | 0.01 | *0.10* | 0.04 | *0.03* | 0.00 | *0.00* |
| 40 | 0.04 | *0.03* | -0.01 | *0.00* | 0.05 | *0.02* | 0.00 | *0.00* |

1. Columns 3 to 5 may not sum to entries in column 2 due to rounding errors.

*Figure 1:* Nominal average prices of the median group

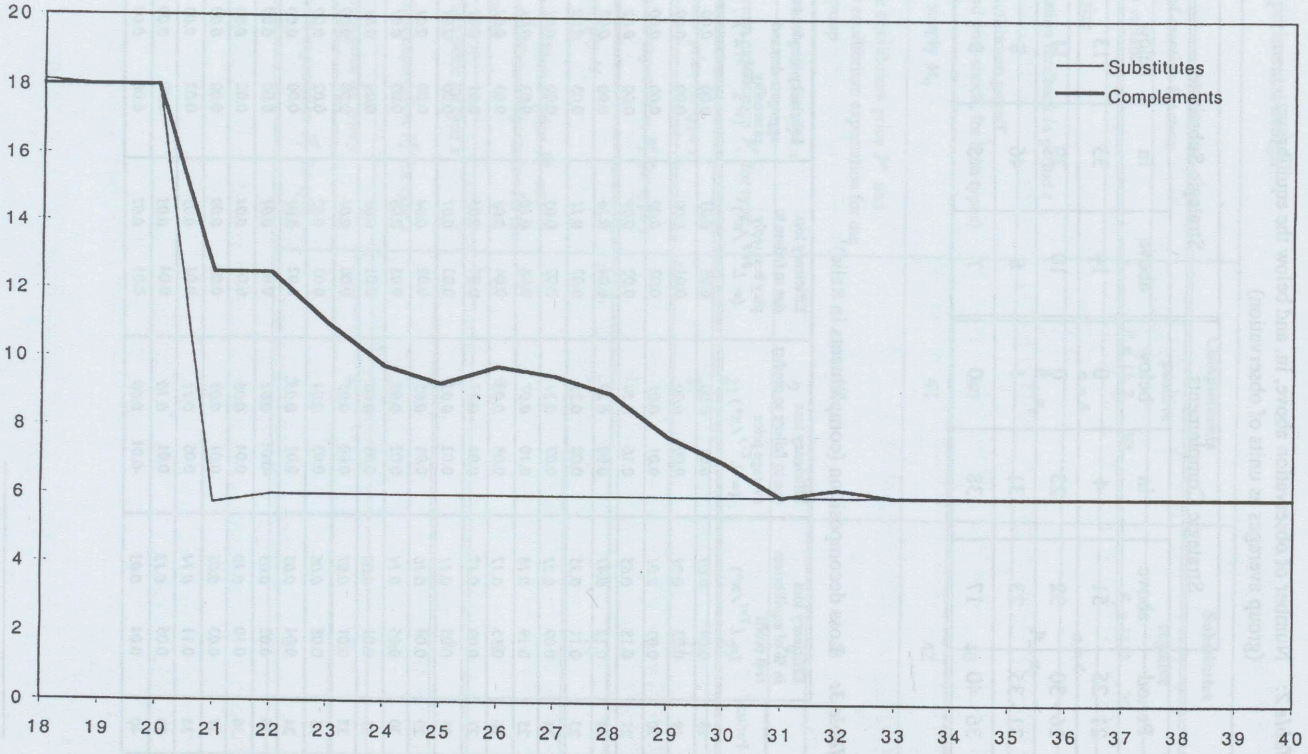


*Figure 2:* Percentage of subjects choosing equilibrium prices

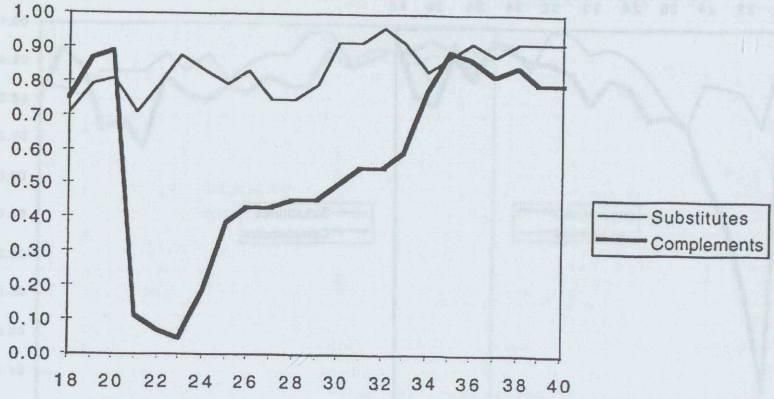



*Figure 3:* Distribution of nominal prices (for agents of type *y*)

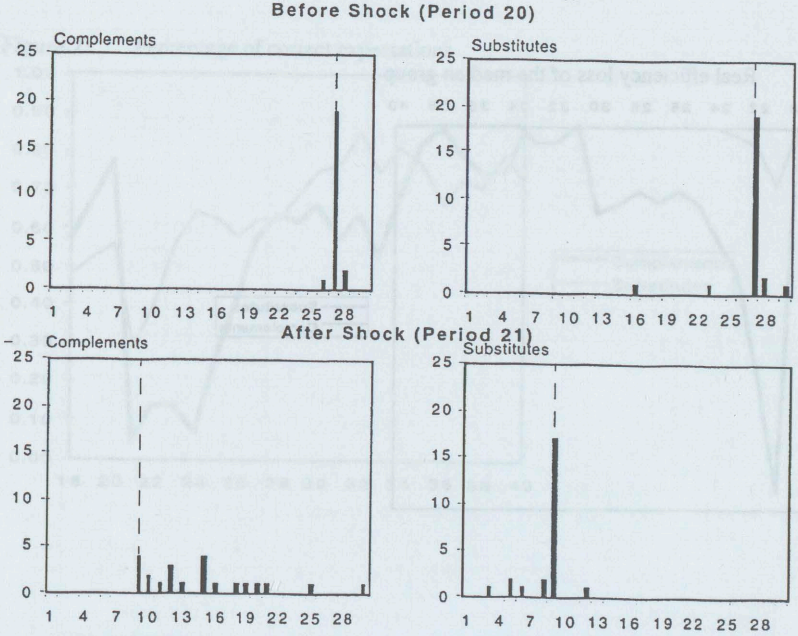


*Figure 4:* Average real losses (percent of equilibrium payoff)

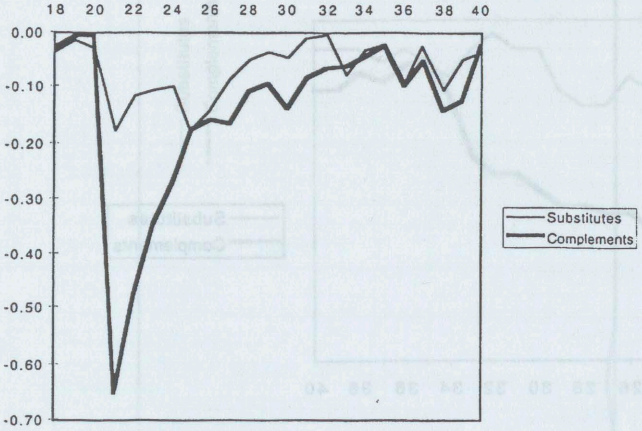



*Figure 5:* Real efficiency loss of the median group

*Figure 6:* Percentage of best replies on price expectation ($P_i = P_i(\overline{P}^e_{-i})$)

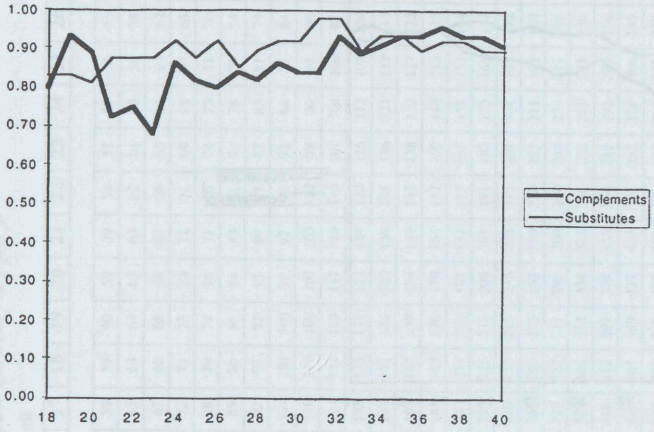



*Figure 7:* Percentage of correct expectations

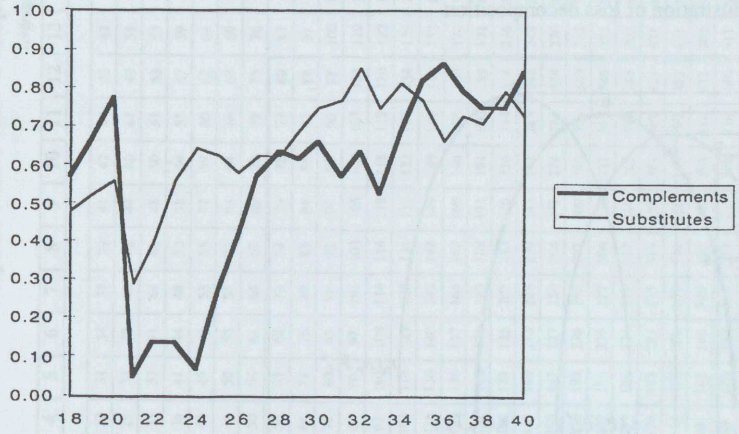


*Figure 8:* Average confidence in price expectation

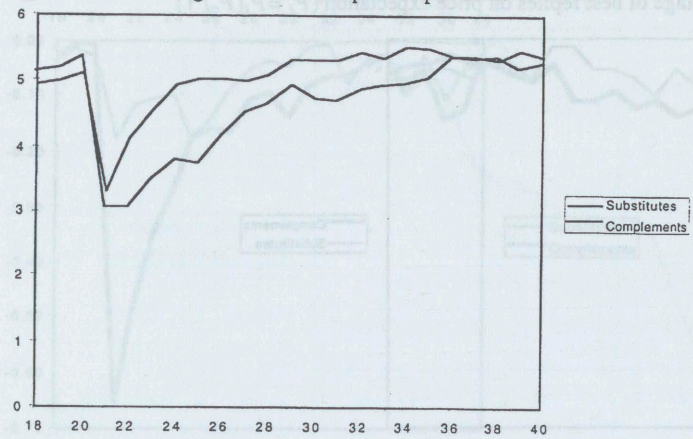
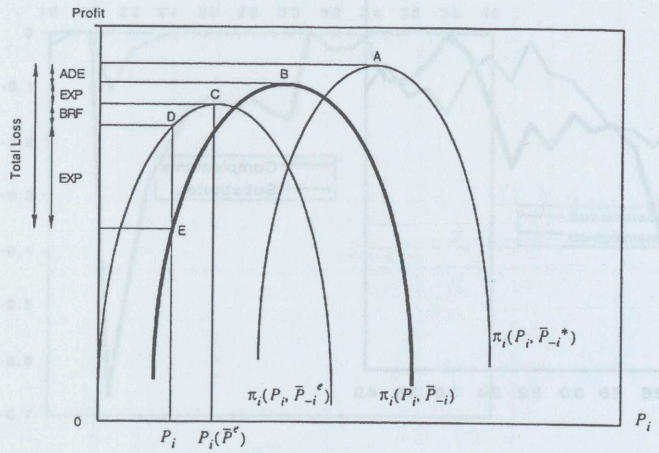



*Figure 9:* Illustration of loss decomposition



# Payoff Table A1: Complements, pre-shock, Type *y*

Average price of other firms

| selling price | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 16 | 22 | 27 | 31 | 34 | 37 | 39 | 41 | 42 | 44 | 45 | 47 | 50 | 53 | 56 | 58 | 59 | 60 | 59 | 59 | 58 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 |
| 2 | 10 | 18 | 24 | 29 | 34 | 37 | 40 | 42 | 44 | 46 | 47 | 49 | 51 | 53 | 57 | 60 | 63 | 63 | 64 | 63 | 63 | 62 | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 |
| 3 | 11 | 20 | 27 | 33 | 37 | 41 | 44 | 46 | 48 | 50 | 51 | 53 | 55 | 57 | 61 | 65 | 67 | 68 | 68 | 68 | 67 | 66 | 65 | 64 | 63 | 62 | 60 | 59 | 58 | 57 |
| 4 | 12 | 22 | 30 | 36 | 41 | 44 | 48 | 50 | 52 | 54 | 55 | 57 | 59 | 62 | 66 | 70 | 72 | 73 | 73 | 73 | 72 | 71 | 69 | 68 | 67 | 65 | 64 | 63 | 61 | 60 |
| 5 | 14 | 24 | 33 | 40 | 45 | 49 | 53 | 55 | 57 | 59 | 60 | 62 | 64 | 67 | 71 | 76 | 78 | 79 | 79 | 78 | 77 | 76 | 74 | 73 | 71 | 70 | 68 | 66 | 65 | 63 |
| 6 | 16 | 28 | 37 | 45 | 50 | 55 | 58 | 61 | 63 | 64 | 66 | 67 | 69 | 73 | 77 | 82 | 85 | 86 | 85 | 84 | 83 | 81 | 79 | 78 | 76 | 74 | 72 | 70 | 69 | 67 |
| 7 | 18 | 31 | 42 | 50 | 56 | 61 | 64 | 67 | 69 | 70 | 72 | 73 | 76 | 79 | 84 | 89 | 92 | 93 | 92 | 91 | 89 | 87 | 85 | 83 | 81 | 79 | 77 | 75 | 73 | 71 |
| 8 | 20 | 36 | 47 | 56 | 63 | 68 | 72 | 74 | 76 | 78 | 79 | 80 | 83 | 86 | 92 | 97 | 101 | 101 | 100 | 99 | 97 | 94 | 92 | 89 | 87 | 84 | 82 | 80 | 78 | 76 |
| 9 | 23 | 40 | 54 | 64 | 71 | 76 | 80 | 83 | 84 | 86 | 87 | 88 | 91 | 95 | 101 | 107 | 110 | 110 | 109 | 107 | 105 | 102 | 99 | 96 | 93 | 90 | 88 | 85 | 83 | 80 |
| 10 | 26 | 46 | 61 | 72 | 80 | 86 | 90 | 92 | 94 | 95 | 96 | 97 | 100 | 104 | 111 | 117 | 121 | 121 | 119 | 117 | 114 | 110 | 107 | 104 | 100 | 97 | 94 | 91 | 88 | 86 |
| 11 | 29 | 51 | 69 | 81 | 90 | 97 | 101 | 103 | 105 | 106 | 107 | 108 | 110 | 115 | 122 | 129 | 133 | 133 | 131 | 128 | 124 | 120 | 116 | 112 | 108 | 104 | 101 | 97 | 94 | 91 |
| 12 | 32 | 58 | 77 | 92 | 102 | 109 | 114 | 116 | 118 | 118 | 119 | 120 | 122 | 127 | 135 | 143 | 147 | 147 | 144 | 140 | 136 | 131 | 126 | 121 | 117 | 113 | 109 | 105 | 101 | 98 |
| 13 | 35 | 64 | 87 | 104 | 116 | 123 | 128 | 131 | 132 | 133 | 133 | 134 | 136 | 141 | 150 | 159 | 163 | 162 | 159 | 154 | 149 | 143 | 138 | 132 | 127 | 122 | 117 | 113 | 109 | 104 |
| 14 | 37 | 70 | 96 | 116 | 130 | 140 | 145 | 148 | 149 | 149 | 149 | 149 | 152 | 157 | 167 | 177 | 181 | 180 | 176 | 170 | 164 | 157 | 150 | 144 | 138 | 132 | 127 | 122 | 117 | 112 |
| 15 | 39 | 74 | 105 | 129 | 146 | 157 | 164 | 168 | 169 | 168 | 168 | 168 | 170 | 176 | 187 | 198 | 203 | 201 | 196 | 189 | 181 | 173 | 165 | 158 | 151 | 144 | 138 | 132 | 126 | 121 |
| 16 | 40 | 78 | 113 | 141 | 162 | 176 | 185 | 189 | 191 | 191 | 190 | 189 | 191 | 198 | 210 | 223 | 227 | 225 | 218 | 209 | 201 | 191 | 182 | 173 | 165 | 157 | 150 | 143 | 136 | 130 |
| 17 | 39 | 79 | 117 | 151 | 177 | 195 | 207 | 213 | 216 | 216 | 214 | 214 | 216 | 223 | 237 | 251 | 256 | 253 | 245 | 235 | 223 | 212 | 201 | 191 | 181 | 172 | 163 | 155 | 148 | 141 |
| 18 | 37 | 78 | 119 | 157 | 189 | 213 | 229 | 239 | 243 | 244 | 243 | 242 | 244 | 252 | 268 | 283 | 289 | 285 | 275 | 263 | 250 | 236 | 223 | 211 | 199 | 189 | 179 | 170 | 161 | 153 |
| 19 | 35 | 74 | 117 | 159 | 197 | 227 | 250 | 264 | 272 | 274 | 274 | 274 | 276 | 285 | 303 | 321 | 327 | 322 | 311 | 296 | 280 | 264 | 249 | 234 | 221 | 208 | 196 | 186 | 176 | 167 |
| 20 | 32 | 69 | 112 | 156 | 199 | 236 | 266 | 287 | 300 | 306 | 308 | 309 | 312 | 323 | 343 | 363 | 370 | 364 | 351 | 334 | 315 | 296 | 278 | 261 | 245 | 230 | 216 | 204 | 192 | 182 |
| 21 | 29 | 63 | 104 | 149 | 195 | 239 | 277 | 306 | 326 | 337 | 343 | 346 | 351 | 364 | 387 | 409 | 418 | 412 | 397 | 378 | 356 | 334 | 312 | 292 | 273 | 256 | 240 | 225 | 211 | 199 |
| 22 | 25 | 57 | 95 | 139 | 186 | 234 | 279 | 317 | 346 | 365 | 377 | 385 | 393 | 408 | 434 | 459 | 470 | 465 | 449 | 427 | 403 | 377 | 352 | 328 | 306 | 285 | 266 | 249 | 233 | 219 |
| 23 | 23 | 50 | 85 | 126 | 173 | 223 | 273 | 319 | 357 | 387 | 407 | 421 | 434 | 453 | 482 | 511 | 524 | 521 | 506 | 483 | 456 | 426 | 397 | 369 | 343 | 319 | 297 | 276 | 258 | 241 |
| 24 | 20 | 45 | 76 | 113 | 158 | 206 | 259 | 311 | 358 | 398 | 429 | 452 | 471 | 495 | 527 | 559 | 578 | 579 | 566 | 544 | 515 | 483 | 450 | 417 | 387 | 358 | 332 | 308 | 287 | 267 |
| 25 | 18 | 40 | 67 | 101 | 142 | 188 | 240 | 295 | 349 | 398 | 439 | 472 | 500 | 530 | 565 | 601 | 625 | 633 | 627 | 608 | 579 | 545 | 509 | 472 | 437 | 403 | 373 | 345 | 320 | 297 |
| 26 | 16 | 35 | 60 | 89 | 126 | 169 | 219 | 273 | 330 | 386 | 436 | 480 | 517 | 552 | 591 | 629 | 660 | 679 | 682 | 671 | 646 | 613 | 574 | 534 | 494 | 456 | 420 | 387 | 358 | 331 |
| 27 | 14 | 31 | 53 | 79 | 112 | 151 | 196 | 248 | 305 | 364 | 421 | 473 | 519 | 560 | 600 | 640 | 678 | 709 | 727 | 727 | 712 | 683 | 645 | 603 | 559 | 516 | 475 | 437 | 402 | 370 |
| 28 | 12 | 28 | 47 | 70 | 99 | 134 | 175 | 223 | 277 | 335 | 395 | 452 | 505 | 550 | 591 | 631 | 676 | 720 | 753 | 771 | 770 | 751 | 719 | 677 | 631 | 583 | 537 | 493 | 453 | 416 |
| 29 | 11 | 24 | 41 | 62 | 87 | 118 | 155 | 198 | 248 | 304 | 363 | 422 | 478 | 526 | 565 | 605 | 654 | 708 | 758 | 795 | 814 | 811 | 790 | 754 | 708 | 658 | 607 | 558 | 512 | 469 |
| 30 | 10 | 22 | 37 | 55 | 77 | 104 | 137 | 175 | 221 | 272 | 328 | 386 | 442 | 490 | 527 | 565 | 616 | 677 | 741 | 796 | 836 | 855 | 851 | 827 | 788 | 739 | 686 | 631 | 579 | 530 |

Use an integer number from 1 to 6 to indicate how confident you are that the average price you expect will actually be realized

1 = I am *not* at all confident that my expectation will be correct

2 = I am *not* very that my expectation will be correct

3 = I am *not* quite confident that my expectation will be correct

4 = I am quite confident that my expectation will be correct

5 = I am very confident that my expectation will be correct

6 = I am absolutely confident that my expectation will be correct

# Payoff Table A3: Substitutes, pre-shock, Type *y*

Average price of other firms

| selling price | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 4 | 6 | 8 | 11 | 14 | 18 | 21 | 25 | 30 | 34 | 40 | 45 | 49 | 53 | 57 | 62 | 68 | 76 | 85 | 95 | 107 | 121 | 136 | 154 | 175 | 199 | 227 | 259 | 296 |
| 2 | 2 | 4 | 6 | 9 | 12 | 15 | 19 | 23 | 27 | 32 | 37 | 42 | 48 | 53 | 57 | 61 | 66 | 73 | 82 | 92 | 103 | 116 | 131 | 149 | 169 | 192 | 219 | 251 | 287 | 330 |
| 3 | 2 | 4 | 7 | 9 | 13 | 16 | 20 | 24 | 29 | 34 | 40 | 45 | 51 | 57 | 61 | 66 | 71 | 79 | 88 | 99 | 112 | 127 | 144 | 163 | 186 | 212 | 243 | 279 | 321 | 370 |
| 4 | 2 | 4 | 7 | 10 | 13 | 17 | 21 | 26 | 31 | 36 | 42 | 49 | 55 | 61 | 66 | 71 | 77 | 85 | 96 | 108 | 122 | 138 | 157 | 179 | 205 | 235 | 270 | 311 | 359 | 415 |
| 5 | 2 | 4 | 8 | 11 | 14 | 18 | 23 | 27 | 33 | 39 | 46 | 53 | 60 | 66 | 71 | 77 | 84 | 93 | 104 | 118 | 133 | 152 | 173 | 198 | 227 | 261 | 301 | 348 | 403 | 468 |
| 6 | 2 | 5 | 8 | 11 | 15 | 19 | 24 | 30 | 36 | 42 | 49 | 57 | 65 | 72 | 77 | 83 | 91 | 101 | 113 | 128 | 146 | 167 | 191 | 219 | 252 | 291 | 337 | 391 | 454 | 529 |
| 7 | 3 | 5 | 9 | 12 | 16 | 20 | 26 | 32 | 38 | 46 | 53 | 62 | 71 | 78 | 84 | 90 | 99 | 110 | 124 | 141 | 161 | 184 | 212 | 244 | 282 | 326 | 379 | 441 | 513 | 599 |
| 8 | 3 | 6 | 9 | 13 | 17 | 22 | 28 | 34 | 41 | 49 | 58 | 67 | 77 | 85 | 92 | 99 | 108 | 121 | 136 | 155 | 178 | 204 | 235 | 272 | 315 | 366 | 427 | 498 | 581 | 677 |
| 9 | 3 | 6 | 10 | 13 | 19 | 24 | 30 | 37 | 45 | 54 | 63 | 74 | 84 | 93 | 101 | 108 | 118 | 132 | 150 | 171 | 197 | 227 | 263 | 305 | 354 | 413 | 482 | 563 | 657 | 764 |
| 10 | 3 | 6 | 10 | 15 | 20 | 26 | 33 | 40 | 49 | 58 | 69 | 81 | 92 | 103 | 111 | 119 | 130 | 146 | 166 | 190 | 219 | 253 | 294 | 342 | 400 | 467 | 546 | 637 | 741 | 857 |
| 11 | 3 | 6 | 11 | 16 | 22 | 28 | 35 | 43 | 53 | 64 | 76 | 89 | 102 | 113 | 122 | 131 | 144 | 162 | 184 | 212 | 245 | 284 | 331 | 386 | 452 | 528 | 617 | 719 | 832 | 952 |
| 12 | 3 | 7 | 12 | 17 | 23 | 30 | 38 | 48 | 58 | 70 | 83 | 98 | 112 | 125 | 135 | 145 | 160 | 180 | 205 | 237 | 274 | 319 | 373 | 436 | 511 | 597 | 696 | 806 | 923 | 1042 |
| 13 | 4 | 8 | 13 | 19 | 25 | 33 | 42 | 52 | 64 | 77 | 92 | 108 | 125 | 139 | 150 | 161 | 177 | 200 | 229 | 265 | 309 | 360 | 422 | 494 | 578 | 674 | 781 | 895 | 1010 | 1117 |
| 14 | 4 | 8 | 14 | 20 | 28 | 36 | 46 | 57 | 70 | 85 | 102 | 120 | 139 | 155 | 167 | 180 | 198 | 224 | 258 | 299 | 348 | 407 | 477 | 558 | 652 | 755 | 866 | 978 | 1083 | 1168 |
| 15 | 4 | 9 | 15 | 22 | 30 | 39 | 50 | 63 | 78 | 94 | 113 | 134 | 155 | 173 | 187 | 201 | 222 | 252 | 290 | 337 | 394 | 461 | 539 | 630 | 730 | 838 | 947 | 1048 | 1131 | 1186 |
| 16 | 5 | 10 | 17 | 24 | 33 | 43 | 55 | 70 | 86 | 104 | 126 | 150 | 174 | 195 | 210 | 226 | 250 | 284 | 327 | 381 | 445 | 521 | 608 | 705 | 810 | 915 | 1014 | 1094 | 1148 | 1168 |
| 17 | 5 | 11 | 18 | 26 | 36 | 48 | 61 | 77 | 96 | 117 | 142 | 169 | 196 | 220 | 237 | 255 | 282 | 321 | 370 | 431 | 503 | 587 | 681 | 781 | 884 | 979 | 1057 | 1110 | 1130 | 1118 |
| 18 | 6 | 12 | 20 | 29 | 40 | 53 | 68 | 86 | 107 | 132 | 159 | 190 | 221 | 248 | 268 | 288 | 319 | 363 | 419 | 487 | 567 | 657 | 754 | 852 | 944 | 1020 | 1072 | 1092 | 1081 | 1043 |
| 19 | 6 | 13 | 22 | 32 | 44 | 59 | 76 | 96 | 120 | 148 | 180 | 215 | 250 | 281 | 303 | 326 | 361 | 410 | 473 | 548 | 634 | 726 | 821 | 910 | 983 | 1033 | 1053 | 1044 | 1008 | 953 |
| 20 | 7 | 14 | 24 | 35 | 49 | 65 | 85 | 107 | 135 | 167 | 203 | 243 | 283 | 317 | 343 | 369 | 408 | 463 | 532 | 612 | 700 | 790 | 875 | 946 | 994 | 1014 | 1006 | 973 | 921 | 858 |
| 21 | 7 | 16 | 27 | 39 | 55 | 73 | 95 | 121 | 153 | 189 | 230 | 275 | 319 | 358 | 387 | 416 | 459 | 520 | 593 | 675 | 760 | 841 | 909 | 955 | 975 | 968 | 937 | 888 | 829 | 765 |
| 22 | 8 | 18 | 30 | 44 | 61 | 82 | 107 | 137 | 173 | 214 | 260 | 310 | 359 | 402 | 434 | 466 | 514 | 577 | 652 | 731 | 807 | 871 | 916 | 936 | 930 | 901 | 855 | 799 | 739 | 678 |
| 23 | 9 | 20 | 33 | 49 | 69 | 92 | 121 | 155 | 195 | 242 | 293 | 348 | 401 | 447 | 482 | 517 | 567 | 632 | 703 | 774 | 834 | 876 | 896 | 891 | 864 | 822 | 769 | 712 | 655 | 599 |
| 24 | 10 | 22 | 37 | 55 | 77 | 104 | 137 | 175 | 221 | 272 | 328 | 386 | 442 | 490 | 527 | 565 | 616 | 677 | 741 | 796 | 836 | 855 | 851 | 827 | 788 | 739 | 686 | 631 | 579 | 530 |
| 25 | 11 | 24 | 41 | 62 | 87 | 118 | 155 | 198 | 248 | 304 | 363 | 422 | 478 | 526 | 565 | 605 | 654 | 708 | 758 | 795 | 814 | 811 | 790 | 754 | 708 | 658 | 607 | 558 | 512 | 469 |
| 26 | 12 | 28 | 47 | 70 | 99 | 134 | 175 | 223 | 277 | 335 | 395 | 452 | 505 | 550 | 591 | 631 | 676 | 720 | 753 | 771 | 770 | 751 | 719 | 677 | 631 | 583 | 537 | 493 | 453 | 416 |
| 27 | 14 | 31 | 53 | 79 | 112 | 151 | 196 | 248 | 305 | 364 | 421 | 473 | 519 | 560 | 600 | 640 | 678 | 709 | 727 | 727 | 712 | 683 | 645 | 603 | 559 | 516 | 475 | 437 | 402 | 370 |
| 28 | 16 | 35 | 60 | 89 | 126 | 169 | 219 | 273 | 330 | 386 | 436 | 480 | 517 | 552 | 591 | 629 | 660 | 679 | 682 | 671 | 646 | 613 | 574 | 534 | 494 | 456 | 420 | 387 | 358 | 331 |
| 29 | 18 | 40 | 67 | 101 | 142 | 188 | 240 | 295 | 349 | 398 | 439 | 472 | 500 | 530 | 565 | 601 | 625 | 633 | 627 | 608 | 579 | 545 | 509 | 472 | 437 | 403 | 373 | 345 | 320 | 297 |
| 30 | 20 | 45 | 76 | 113 | 158 | 206 | 259 | 311 | 358 | 398 | 429 | 452 | 471 | 495 | 527 | 559 | 578 | 579 | 566 | 544 | 515 | 483 | 450 | 417 | 387 | 358 | 332 | 308 | 287 | 267 |

Use an integer number from 1 to 6 to indicate how confident you are that the average price you expect will actually be realized

1 = I am *not* at all confident that my expectation will be correct

2 = I am *not* very that my expectation will be correct

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6 = I am absolutely confident that my expectation will be correct

# Payoff Table A2: Complements, post-shock, Type *y*

Average price of other firms

| selling price | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 14 | 16 | 17 | 20 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 8 |
| 2 | 12 | 18 | 21 | 22 | 26 | 29 | 28 | 26 | 24 | 22 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 8 | 8 |
| 3 | 18 | 25 | 28 | 29 | 34 | 37 | 35 | 32 | 29 | 27 | 25 | 23 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 11 | 11 | 10 | 10 | 10 | 9 | 9 | 9 |
| 4 | 26 | 36 | 39 | 40 | 45 | 49 | 45 | 40 | 36 | 33 | 29 | 27 | 24 | 22 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 11 | 11 | 11 | 10 | 10 | 10 | 9 |
| 5 | 35 | 52 | 56 | 56 | 62 | 67 | 60 | 53 | 46 | 40 | 36 | 32 | 29 | 26 | 24 | 22 | 20 | 19 | 18 | 16 | 15 | 15 | 14 | 13 | 12 | 12 | 11 | 11 | 10 | 10 |
| 6 | 40 | 71 | 81 | 81 | 89 | 95 | 83 | 70 | 60 | 51 | 44 | 39 | 34 | 31 | 28 | 25 | 23 | 21 | 20 | 18 | 17 | 16 | 15 | 14 | 14 | 12 | 12 | 12 | 11 | 11 |
| 7 | 35 | 80 | 109 | 115 | 129 | 137 | 119 | 97 | 80 | 66 | 56 | 48 | 42 | 37 | 33 | 30 | 27 | 24 | 22 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 11 |
| 8 | 25 | 68 | 119 | 151 | 176 | 193 | 172 | 139 | 111 | 89 | 73 | 61 | 52 | 45 | 39 | 35 | 31 | 28 | 26 | 24 | 22 | 20 | 19 | 17 | 16 | 15 | 14 | 13 | 13 | 12 |
| 9 | 18 | 50 | 102 | 157 | 200 | 236 | 237 | 201 | 158 | 123 | 98 | 79 | 66 | 56 | 48 | 42 | 37 | 33 | 30 | 27 | 25 | 23 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 |
| 10 | 12 | 34 | 74 | 129 | 176 | 226 | 279 | 275 | 229 | 177 | 136 | 107 | 86 | 71 | 59 | 51 | 44 | 39 | 35 | 31 | 28 | 26 | 23 | 22 | 20 | 19 | 17 | 16 | 15 | 14 |
| 11 | 9 | 24 | 51 | 92 | 129 | 173 | 253 | 318 | 312 | 255 | 195 | 148 | 115 | 92 | 75 | 63 | 54 | 46 | 41 | 36 | 32 | 29 | 27 | 24 | 22 | 21 | 19 | 18 | 17 | 16 |
| 12 | 7 | 18 | 36 | 63 | 89 | 121 | 189 | 284 | 357 | 348 | 281 | 212 | 160 | 124 | 98 | 80 | 67 | 57 | 49 | 43 | 38 | 34 | 30 | 28 | 25 | 23 | 21 | 20 | 19 | 17 |
| 13 | 5 | 13 | 26 | 45 | 62 | 84 | 131 | 210 | 316 | 395 | 382 | 305 | 229 | 172 | 132 | 104 | 84 | 70 | 59 | 51 | 45 | 39 | 35 | 32 | 29 | 26 | 24 | 22 | 21 | 19 |
| 14 | 4 | 10 | 19 | 33 | 45 | 60 | 91 | 145 | 232 | 347 | 433 | 416 | 331 | 246 | 183 | 140 | 110 | 89 | 74 | 62 | 53 | 46 | 41 | 36 | 33 | 30 | 27 | 25 | 23 | 21 |
| 15 | 3 | 8 | 15 | 25 | 34 | 44 | 66 | 102 | 161 | 254 | 379 | 470 | 449 | 355 | 262 | 194 | 148 | 116 | 93 | 77 | 65 | 56 | 48 | 43 | 38 | 34 | 31 | 28 | 26 | 24 |
| 16 | 3 | 6 | 12 | 19 | 26 | 34 | 49 | 73 | 112 | 176 | 277 | 410 | 506 | 481 | 378 | 278 | 206 | 156 | 122 | 98 | 81 | 68 | 58 | 50 | 44 | 39 | 35 | 32 | 29 | 26 |
| 17 | 2 | 5 | 10 | 15 | 20 | 26 | 37 | 54 | 81 | 123 | 192 | 300 | 440 | 541 | 513 | 402 | 294 | 217 | 164 | 127 | 102 | 84 | 70 | 60 | 52 | 46 | 41 | 36 | 33 | 30 |
| 18 | 2 | 4 | 8 | 12 | 16 | 21 | 29 | 42 | 60 | 89 | 134 | 207 | 322 | 471 | 576 | 544 | 425 | 310 | 227 | 171 | 133 | 107 | 87 | 73 | 62 | 54 | 47 | 41 | 37 | 34 |
| 19 | 2 | 4 | 7 | 10 | 14 | 17 | 24 | 33 | 46 | 66 | 97 | 145 | 223 | 344 | 500 | 611 | 575 | 448 | 326 | 238 | 179 | 139 | 111 | 91 | 76 | 64 | 56 | 49 | 43 | 39 |
| 20 | 1 | 3 | 6 | 9 | 11 | 14 | 19 | 27 | 37 | 51 | 72 | 105 | 156 | 238 | 365 | 530 | 645 | 606 | 470 | 341 | 249 | 186 | 144 | 115 | 94 | 79 | 67 | 58 | 50 | 44 |
| 21 | 1 | 2 | 5 | 7 | 10 | 12 | 16 | 22 | 30 | 40 | 56 | 78 | 112 | 166 | 253 | 386 | 559 | 679 | 636 | 492 | 357 | 259 | 194 | 150 | 119 | 97 | 81 | 69 | 59 | 52 |
| 22 | 1 | 2 | 4 | 6 | 8 | 10 | 14 | 18 | 24 | 32 | 44 | 60 | 84 | 120 | 177 | 267 | 407 | 588 | 712 | 666 | 514 | 372 | 270 | 202 | 156 | 124 | 101 | 84 | 71 | 61 |
| 23 | 1 | 2 | 4 | 5 | 7 | 8 | 12 | 15 | 20 | 27 | 35 | 48 | 65 | 90 | 128 | 187 | 282 | 428 | 616 | 745 | 695 | 536 | 387 | 280 | 209 | 161 | 128 | 104 | 87 | 73 |
| 24 | 1 | 2 | 3 | 5 | 6 | 8 | 10 | 13 | 17 | 22 | 29 | 38 | 51 | 69 | 95 | 135 | 197 | 296 | 449 | 645 | 778 | 725 | 558 | 402 | 291 | 217 | 167 | 132 | 108 | 89 |
| 25 | 1 | 2 | 3 | 4 | 6 | 7 | 9 | 11 | 15 | 19 | 24 | 32 | 41 | 55 | 73 | 101 | 143 | 207 | 311 | 469 | 673 | 811 | 754 | 580 | 417 | 301 | 224 | 172 | 136 | 111 |
| 26 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 13 | 16 | 21 | 26 | 34 | 44 | 58 | 78 | 107 | 150 | 218 | 325 | 490 | 701 | 843 | 783 | 601 | 432 | 312 | 232 | 178 | 141 |
| 27 | 1 | 1 | 2 | 3 | 4 | 5 | 7 | 9 | 11 | 14 | 18 | 22 | 28 | 36 | 47 | 61 | 82 | 112 | 157 | 227 | 339 | 510 | 728 | 875 | 813 | 623 | 447 | 322 | 239 | 183 |
| 28 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 15 | 19 | 24 | 30 | 39 | 50 | 65 | 86 | 117 | 164 | 237 | 353 | 530 | 755 | 908 | 842 | 644 | 461 | 332 | 247 |
| 29 | 1 | 1 | 2 | 3 | 4 | 4 | 6 | 7 | 9 | 11 | 13 | 17 | 21 | 26 | 32 | 41 | 52 | 68 | 90 | 123 | 171 | 247 | 367 | 550 | 784 | 940 | 870 | 666 | 477 | 343 |
| 30 | 0 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 15 | 18 | 22 | 27 | 34 | 43 | 55 | 72 | 95 | 128 | 179 | 257 | 381 | 570 | 811 | 972 | 899 | 687 | 491 |

Use an integer number from 1 to 6 to indicate how confident you are that the average price you expect will actually be realized

1 = I am *not* at all confident that my expectation will be correct

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6 = I am absolutely confident that my expectation will be correct

# Payoff Table A4: Substitutes, post-shock, Type *y*

Average price of other firms

| selling price | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 5 | 10 | 15 | 20 | 26 | 37 | 54 | 81 | 123 | 192 | 300 | 440 | 541 | 513 | 402 | 294 | 217 | 164 | 127 | 102 | 84 | 70 | 60 | 52 | 46 | 41 | 36 | 33 | 30 |
| 2 | 3 | 6 | 12 | 19 | 26 | 34 | 49 | 73 | 112 | 176 | 277 | 410 | 506 | 481 | 378 | 278 | 206 | 156 | 122 | 98 | 81 | 68 | 58 | 50 | 44 | 39 | 35 | 32 | 29 | 26 |
| 3 | 3 | 8 | 15 | 25 | 34 | 44 | 66 | 102 | 161 | 254 | 379 | 470 | 449 | 355 | 262 | 194 | 148 | 116 | 93 | 77 | 65 | 56 | 48 | 43 | 38 | 34 | 31 | 28 | 26 | 24 |
| 4 | 4 | 10 | 19 | 33 | 45 | 60 | 91 | 145 | 232 | 347 | 433 | 416 | 331 | 246 | 183 | 140 | 110 | 89 | 74 | 62 | 53 | 46 | 41 | 36 | 33 | 30 | 27 | 25 | 23 | 21 |
| 5 | 5 | 13 | 26 | 45 | 62 | 84 | 131 | 210 | 316 | 395 | 382 | 305 | 229 | 172 | 132 | 104 | 84 | 70 | 59 | 51 | 45 | 39 | 35 | 32 | 29 | 26 | 24 | 22 | 21 | 19 |
| 6 | 7 | 18 | 36 | 63 | 89 | 121 | 189 | 284 | 357 | 348 | 281 | 212 | 160 | 124 | 98 | 80 | 67 | 57 | 49 | 43 | 38 | 34 | 30 | 28 | 25 | 23 | 21 | 20 | 19 | 17 |
| 7 | 9 | 24 | 51 | 92 | 129 | 173 | 253 | 318 | 312 | 255 | 195 | 148 | 115 | 92 | 75 | 63 | 54 | 46 | 41 | 36 | 32 | 29 | 27 | 24 | 22 | 21 | 19 | 18 | 17 | 16 |
| 8 | 12 | 34 | 74 | 129 | 176 | 226 | 279 | 275 | 229 | 177 | 136 | 107 | 86 | 71 | 59 | 51 | 44 | 39 | 35 | 31 | 28 | 26 | 23 | 22 | 20 | 19 | 17 | 16 | 15 | 14 |
| 9 | 18 | 50 | 102 | 157 | 200 | 236 | 237 | 201 | 158 | 123 | 98 | 79 | 66 | 56 | 48 | 42 | 37 | 33 | 30 | 27 | 25 | 23 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 |
| 10 | 25 | 68 | 119 | 151 | 176 | 193 | 172 | 139 | 111 | 89 | 73 | 61 | 52 | 45 | 39 | 35 | 31 | 28 | 26 | 24 | 22 | 20 | 19 | 17 | 16 | 15 | 14 | 13 | 13 | 12 |
| 11 | 35 | 80 | 109 | 115 | 129 | 137 | 119 | 97 | 80 | 66 | 56 | 48 | 42 | 37 | 33 | 30 | 27 | 24 | 22 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 11 |
| 12 | 40 | 71 | 81 | 81 | 89 | 95 | 83 | 70 | 60 | 51 | 44 | 39 | 34 | 31 | 28 | 25 | 23 | 21 | 20 | 18 | 17 | 16 | 15 | 14 | 14 | 12 | 12 | 12 | 11 | 11 |
| 13 | 35 | 52 | 56 | 56 | 62 | 67 | 60 | 53 | 46 | 40 | 36 | 32 | 29 | 26 | 24 | 22 | 20 | 19 | 18 | 16 | 15 | 15 | 14 | 13 | 12 | 12 | 11 | 11 | 10 | 10 |
| 14 | 26 | 36 | 39 | 40 | 45 | 49 | 45 | 40 | 36 | 33 | 29 | 27 | 24 | 22 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 11 | 11 | 11 | 10 | 10 | 10 | 9 |
| 15 | 18 | 25 | 28 | 29 | 34 | 37 | 35 | 32 | 29 | 27 | 25 | 23 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 11 | 11 | 10 | 10 | 10 | 9 | 9 | 9 |
| 16 | 12 | 18 | 21 | 22 | 26 | 29 | 28 | 26 | 24 | 22 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 8 | 8 |
| 17 | 9 | 14 | 16 | 17 | 20 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 8 |
| 18 | 7 | 10 | 13 | 14 | 16 | 18 | 18 | 18 | 17 | 16 | 15 | 15 | 14 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 7 | 7 |
| 19 | 5 | 8 | 10 | 12 | 14 | 15 | 15 | 15 | 15 | 14 | 14 | 13 | 12 | 12 | 11 | 11 | 11 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 |
| 20 | 4 | 6 | 8 | 9 | 11 | 13 | 13 | 13 | 13 | 12 | 12 | 12 | 11 | 11 | 10 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 6 | 6 |
| 21 | 3 | 5 | 7 | 8 | 10 | 11 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 |
| 22 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 |
| 23 | 2 | 4 | 5 | 5 | 7 | 8 | 9 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 |
| 24 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 |
| 25 | 2 | 2 | 4 | 5 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 26 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 27 | 1 | 2 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 6 | 5 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 |
| 28 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 |
| 29 | 1 | 2 | 2 | 3 | 4 | 4 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 30 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

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