Leverage and Asset Prices: An Experiment. (Preliminary and Incomplete).

Marco Cipriani Ana Fostel Daniel Houser *

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Abstract

This is the first paper to test the asset pricing implication of leverage in a laboratory. We show that as theory predicts, leverage increases asset prices: when an asset can be used as collateral (i.e., when the asset can be bought on margin), its price goes up. This represents a departure from the Law of One Price. This happens because leverage allows agents who value the asset the most to hold it in equilibrium, thus realizing gains from trade. However, important deviations from the theory arise in the laboratory. In particular, allowing agents to buy on margin shifts their demand for the asset even when they are not on their budget constraint when they are not allowed to borrow. In addition, the spread between collateralizeable and non-collateralizeable assets does not increase during crises as predicted by the theory.

Keywords: Leverage, Asset Pricing, Experiment.

JEL Codes: A10, C90, G12

*Marco Cipriani: International Monetary Fund and New York Federal Reserve Bank (email: marco.cipriani@ny.frb.org); Ana Fostel: George Washington University (email: afostel@gwu.edu). Daniel Houser: George Mason University (email:). We thank Cecilia Chen for outstanding research assistance. We also thank John Geanakoplos and Andrew Schotter for very helpful comments. Ana Fostel thanks the IMF for financial support. The views in this paper should not be interpreted the as reflecting the views of the IMF or its Board of Directors, the Federal Reserve Bank of New York, or the Federal Reserve System. All errors are ours.

Introduction

The recent financial crisis has made clear the impact that leverage has on financial system stability. The crisis was preceded by years in which the amount of leverage in the financial system, both institutionally and with respect to assets, increased dramatically. The crises poster-children, AIG and Lehman, as well as the systemic banking troubles in the US and Europe clearly illustrate the risks margin calls pose for the financial system's liquidity and solvency. As a result, recent academic work has focused on the role of leverage in a financial economy. See for instance, Acharya and Viswanathan (2011), Adrian and Shin (2010), Araujo et al (Forthcoming), Brunnermeier and Pedersen (2009), Cao (2010), Fostel Geanakoplos (2008, 2011 and forthcoming), Garleanu and Pedersen (2011), Geanakoplos (1997, 2003 and 2010), Gromb and Vayanos (2002), and Simsek (2010).

An important strand of this literature has focused on the asset pricing implication of leverage. Two papers develop a formal theory of asset pricing: Fostel-Geanakoplos (2008) in a general equilibrium model with incomplete markets, and Garleanu and Pedersen (2011) in a CAPM model.[1] These papers show that in a world where agents are heterogeneous and markets incomplete, the ability to use an asset as a collateral (i.e., buying on margin) increases its price in equilibrium. This happens because buying on margin makes it possible for a subset of agents who value the asset the most to determine its price. The increase in price represents a deviation from the Law of One Price (LOP), since two assets with the same payoff in all states of the word are priced differently.

When assets can be used as collateral to borrow money, their prices not only reflect future cash flows but also their efficiency as liquidity providers. In fact, in the terminology used in Fostel-Geanakoplos (2008), the price of any asset can be decomposed into two parts: its payoff value and its collateral value. The payoff value reflects the assets owner valuation of the future stream of payments, i.e. it is the value attached to the asset due to its investment role. But assets can also be used as collateral to borrow money. The collateral value reflects the asset owners valuation of this second role. This can theoretically create deviations from Law of One Price since two assets with identical payoffs can be priced differently if they have different collateral values. An example of such deviation is the so-called "CDS-basis," which

[1] Hindi (1994) developed pricing implication of leverage in a partial-equilibrium setup with exogenous leverage.

became more severe during the recent crisis. An investor buying a corporate bond and its CDS creates a synthetic risk-free position if held to maturity. However, the price of this synthetic instrument is usually below that of a treasury, an apparent arbitrage opportunity that can be explained by the fact that treasuries can be used more easily as collateral than the synthetic instrument.

Our paper is the first to test the asset pricing implications of leverage in a controlled laboratory environment. To this purpose, we build a model in which markets are incomplete and agents are heterogenous, which is however amenable to experimental implementation. In our model, agents can trade an asset among themselves. They have heterogenous asset valuations: some agents value the asset more than others in some state of nature. We compare two economies, which are identical except that in one the asset can be used as collateral and in the other it cannot. When the asset can be used as collateral, agents who value the asset the most become the only holders in equilibrium and as a result, its price increases.

When we bring the model to laboratory, we confirm the theory's mains predictions. In particular, leverage increases asset prices: when the asset can be used a collateral, its price goes up. That is, deviations from the LOP arise in the laboratory.

Also, and explaining the previous result, when leverage its possible, agents who value the asset the most end up holding more of it.

However, an important deviation from the theory arise in the laboratory. Allowing agents to buy on margin shifts their demand for the asset even when they did not spend all their cash holding in those sessions when buying on margin was not allowed. In the paper, we suggest two explanations for this deviation. First, we argue that the shift in demand could stem from an aggregation bias. And to some extend we show that this is indeed the case, since leverage is negatively associated to final cash holdings in those treatments in which borrowing is forbidden. Second, we argue that the above explanation, cannot be the whole story since there are subjects who do not spend their cash when borrowing is not allowed, and still borrow when allowed. We suggest, that some sort of "price illusion" affects their behavior. Subjects do not fully internalize that when buying on margin, not only the cash put down at time 0 is lower, but the future net payoff from the asset goes down, as the loan on the asset needs to be repaid.

Finally, we ran a second treatment of the experiment, in which we increased the probability of bad news in the economy and interpret this as a crisis situation. Theory predicts that the spread between assets that can be bought on margin and those that cannot should increase as a result. Fostel and Geanakoplos (2008) called this Flight to Collateral: when the crisis hits, assets that can be used as collateral see their price drop by less than assets that cannot. In the laboratory, we find partial support for the hypothesis. In fact, when looking at aggregate data we do not observe Flight to Collateral in the laboratory. We argue that the key driver of the indeterminacy of Flight to Collateral is the behavior of the empirical supply: the supply in the laboratory is a smooth version of the one predicted by the theory. The observed supply suggests some sort of aversion to losses in the worst-case scenario. So for prices below 190 they want to avoid the worst case scenario in which they keep all the asset and the Low state realizes. On the contrary, for prices higher than 190 they want to avoid the worst case scenario which is selling all the asset and that the High state realizes. Expand...Prospect theory.... However, even with this behavior of the supply curve just discussed, when we look at the disaggregated data round by round we see that in XX cases flight to collateral hold. In fact, in our theoretical model, for implementation purposes, the supply is quite extreme. In fact, with a smooth supply what we need to generate Flight to Collateral is that the ...., which is what we actually observe in the data some of the times....

Section 1 develops the theoretical model. Section 2 describes the experiment design and the experimental procedures. Section 3 presents the results.

1 Theory

1.1 A Model of Leverage and Asset Prices

1.1.1 Time and Assets

We consider a two-period economy, with time $t = 0, 1$. At time 1, there are two states of the nature, $s = High$ and $s = Low$, with probability q and $1 - q$ respectively. In the economy, there is a continuum of risk-neutral agents, of two different types indexed by i.

There are two assets in the economy, cash and a risky asset Y (from now on "the asset") with payoff in units of cash. The payoff of the risky asset is described in Figure 1. In state *Low*, the risky asset pays D_{Low}, which is the same for all agents' types, whereas in state *High* it pays D^i_{High}, which may differ across types.

Nevertheless, for any type i, it is always true that $D_{Low} < D^i_{High}$, that is, the payoff in the high state of the world is always higher than the payoff in the low state of the world.

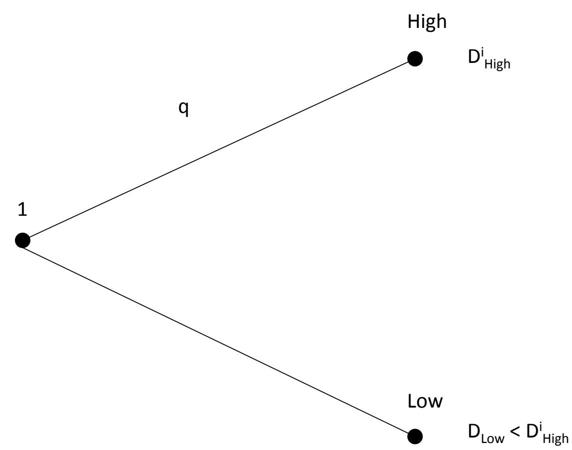

Figure 1: Asset Payoffs.

1.1.2 Agents

At $t = 0$, agents of type i have an endowment of m^i units of cash and of a^i units of the asset. Agents' payoff in each state $s = High, Low$ is given by a linear payoff function:

$$u^i_s(\bullet) = w + D^i_s y - \varphi. \tag{1}$$

In equation (1), w denotes final cash holdings, y refers to final asset holdings, $D^i_s y$ represents the asset payoffs in state s, and φ is debt repayment.[2] The expected payoff to agent of type i is given by

$$U^i = q u^i_{High} + (1 - q) u^i_{Low}. \tag{2}$$

[2]We introduce the debt repayment φ in the payoff function to mimic the way payoffs are explained to the subjects in the laboratory. One could re-write the model having φ in the budget constraint, and having only final cash holdings net of repayment in the payoff function.

In this model, agents are heterogeneous. They disagree on what the asset pays in the high state. Following Fostel-Geanakoplos (2008), we will consider two types of agents: Optimists and Pessimists, denoted by $i = O, P$. Each type of agent has mass 1. Optimists believe that the asset pays more in state $High$ than Pessimists do, that, is $D^O_{High} > D^P_{High}$. In Fostel-Geanakoplos (2008) heterogeneity is modeled as differences in subjective probabilities over the states of the world. In contrast, here, in order to make the experiment easier to implement in the laboratory, heterogeneity is modeled as differences in the asset payoff in the high state of the world.[3] What is really crucial for our results is to have some sort of heterogeneity.[4]

The purpose of this paper is to study the asset pricing implications of collateralized borrowing, in a laboratory financial market. In order to do so, we study two different economies: first, the No-Leverage economy, from now on the NL-economy, where agents cannot borrow. Second, the Leverage economy, from now on the L-economy, where agents are allowed to borrow using the asset as a collateral.

In our model, unlike traditional Arrow-Debreu models, we explicitly take into account the fact that agents may not always honor their promises. Historically, there are basically two types of technologies that can be used to enforce payment in the future: collateral or punishment. In the first one, agents cannot borrow unless they ex-ante post collateral. Usually this consists of some kind of durable good, like a house or a bond. The second one, refers to the fact that agents ex-post face some kind of punishment in the case of default, like prison time. In our model we use the collateral enforcement technology: agents need to hold the asset in order to borrow.[5]

We will now present the theoretical models of the NL and L-economy that we bring to the laboratory.

1.1.3 The NL-Economy

In the NL-economy agents cannot borrow, and therefore $\varphi = 0$. Taking as given the asset price, agents choose asset holdings y and cash holdings w in order to maximize the payoff function (2) subject to their budget constraint:

[3] Quote papers on double auction for this.

[4] Obviously, our model could be re-written as a model with heterogeneous priors and three states of nature, where the assets pays D_{Low}, D^P_{High}, and D^0_{High}. Optimists would give probability q to the state paying D^O_{High} and 0 to the state paying D^P_{High}, whereas Pessimists would .do the opposite.

[5] For models of punishment in general equilibrium see for example Dubey, Geanakoplos and Shubik (1990).

$$w + py \leq m^i + pa^i. \tag{3}$$

An equilibrium in the NL-economy is given by asset price p, cash holdings w, and asset holdings y such that asset market clears and that agents maximize their payoff function (2) subject to the budget constraint (3).

1.1.4 The L-Economy

In the L-economy agents can borrow from a bank using the asset Y as collateral.[6] As explained before, agents cannot borrow unless they post the asset as collateral. We assume that the maximum amount agents can borrow per unit of the asset is D_{Low}, that is, the asset payoff in the low state. In other words, the minimum downpayment to purchase one unit of the asset is $p - D_{Low}$.This condition guarantees that there can never be default in equilibrium, as the loan is equal to the asset payoff in the Low state.

This borrowing constraint is sometimes referred to as *Value at Risk* equal to zero ($VaR = 0$). Restricting to $VaR = 0$ does not change the set of equilibrium prices and payoffs in our economy. As Fostel-Geanakoplos (2011) show, in any binomial model where agents do not get direct utility from the asset, any equilibrium prices and payoffs can be sustained by a $VaR = 0$ contract.[7]

Agents take the asset price p as given and choose asset holdings y, cash holdings w, and borrowing φ in order to maximize (2) subject to the borrowing constraint (4) and budget constraint (5):

$$\varphi \leq D_{Low} y, \tag{4}$$

$$w + py \leq m^i + pa^i + \varphi. \tag{5}$$

An equilibrium in the L-economy is given by asset price p, cash holdings w, asset holdings y, and borrowing φ at $t = 0$ such that the asset market clears and that agents maximize their payoff function (2) subject to constraints (4) and (5).

[6]Since we are not modeling the credit market, we will assume that the interest rate set by the bank is zero. For this reason, the amount borrowed at time 0, φ, is also the amount to be repaid at time 1.

[7]Fostel and Geanakoplos (2011) show that under the conditions mentioned above, for any equilibrium for which $Var > 0$, one can find another equilibrium with the same asset price as the original equilibrium, in which the only contract that agents trade is $VaR = 0$.

The degree of leverage at the security level is measured by the Loan-to-Value ratio, defined as:

$$LTV = \frac{\varphi}{py}, \tag{6}$$

which measures how much an agent can borrow using one unit of asset as collateral as a proportion of the asset price. The Loan-to-Value ratio measures how effective the asset is as collateral, that is, as a liquidity provider that allows agents to borrow. We will show in the remainder of the section that this role as collateral will have profound asset prices implications. In particular, the price of the asset will be higher in the L-economy than in the NL-economy.

1.2 Leverage and Deviations from Law of One Price

1.2.1 Parameter Choice: The Bullish Market

In order to study the asset pricing implications of collateralized borrowing, we calculate the equilibria in both the L and NL-economy. Note that even for this simple model of collateral economy, one cannot solve for the equilibrium price and quantities analytically. For this reason, we solved the model numerically for the set of parameters presented in Table 1. These parameter values were chosen so that the economy is amenable to laboratory implementation. We further discuss this choice in Section 1.2.4 below.

Table 1: Parameter Values in the Bullish Market

Parameters	*Values*
D_{Low}	100
D^{O}_{High}	750
D^{P}_{High}	250
q	0.6
m^{O}	15,000
m^{P}	0
a^{O}	0
a^{P}	100

Under this parametrization, the asset's payoff in the low state is $D_{Low} = 100$; in the high state is $D^O_{High} = 750$ for the Optimists and $D^P_{High} = 250$ for the Pessimists. The probability of the state of the world being High is $q = 0.6$. Optimists have initial cash endowments $m^O = 15,000$, whereas pessimists have no cash. In contrast, Pessimists have initial asset endowments, $a^O = 100$, whereas Optimists have no asset endowment. Note that since Optimists have all the cash endowment and Pessimists have all the asset endowment, Optimists are on the demand side of the market, and Pessimists on the supply side. In the remainder of the paper, we will refer to this combination of parameters as the *Bullish market*,[8] since under this parametrization, the High state is more likely than the Low state.

1.2.2 NL-Economy

The equilibrium values are presented in the left column of Table 2. The equilibrium asset price is 190.

Table 2: The Equilibrium in the Bullish Market

	NL-economy		L-economy	
Price	190		250	
	Spread: 60			
	Optimists	Pessimists	Optimists	Pessimists
y	78.95	21.05	100	0
φ	0	0	10,000	0
w	0	15,000	0	25,000
u_U	59,212	20,262	65,000	25,000
u_D	7,895	17,105	0	25,000

Individual decisions are described in the lower part of the table. In equilibrium, the Optimists use all their cash to buy all the assets they can afford; this happens because their expected value of the asset ($0.4(100) + 0.6(750) = 490$) is higher than the price, and the solution to their optimization problem is a corner solution. As a result, they invest their wealth of $15,000$ in buying all the assets they can afford

[8] Note that as a convention, we will use the world "market" to refer to the parametrization (Bullish vs. Bearish) and the word "economy" to refer to whether agents are allowed to leverage on the asset (that is, buy on margin) or not (L and NL-economy).

without borrowing–that is, 78.95 units–at the unit price of 190, so that their final cash holdings are zero.

In contrast, the solution to the Pessimists's optimization problem is not a corner solution: at a price of 190 they are indifferent between holding cash and holding the asset (as their expected value, $0.4(100) + 0.6(250)$, equals the price). In equilibrium, they end up with 21.05 units of Y and $15,000$ of cash.[9] Note that Optimists and Pessimists share the asset in equilibrium, a fact that, as we shall see, will have important implications when we contrast the NL with the L-economy in the model and in the laboratory.

Figure 2 shows the Pessimists' supply schedule, and the Optimists' demand. The supply (gray line) is a step function that becomes horizontal at the Pessimists' expected value (190). The demand (black line) is a decreasing function of the price, determined by the Optimists' budget constraints.[10] Demand intersects supply at the horizontal segment of the supply schedule. As a result, in equilibrium, both types of agents are determining the asset price, the Optimists through their budget constraints and the Pessimists through their asset valuation.

In equilibrium, assets change hands from Pessimists (who value them less) to Optimists (who value them more), thereby realizing gains from trade in the economy. However, due to the Optimists' inability to borrow, gains from trade are not fully exploited. Indeed, in equilibrium Pessimists hold a strictly positive quantity of the asset.

Finally, the payoff resulting from the equilibrium allocation are $59,212$ in the High state and $7,895$ in the Low state for Optimists; $20,262$ in the High state and $17,105$ in the Low state for Pessimists. The higher volatility in the Optimists' payoff is due to the fact that they hold 80% of the risky asset supply, whereas Pessimists hold only 20%.

[9] Of course, in the experiment we will not assume that the asset is perfectly divisible, hence we will use as a theoretical benchmark the closest integer approximation.

[10] The demand drops to zero when the price reaches the Optimists' expected value (490). In our parametrization, this region of the demand curve, however, is irrelevant for the determination of equilibrium price and quantities.

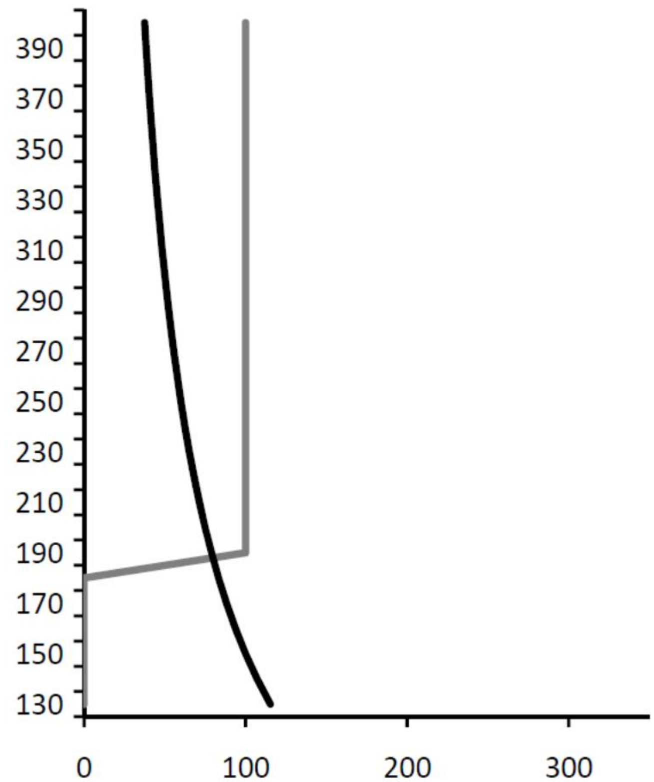

Figure 2: Supply (grey) and Demand (black) in the Bullish NL-economy.

1.2.3 L-economy

The equilibrium values are presented in the right column of Table 2. In equilibrium, the asset price is 250.

Individual decisions are described in the lower part of the table. In the L-economy, the solution to both Optimists' and Pessimists' optimization problem is a corner solution.

Since Optimists' expected value (490) is greater than the equilibrium price, they buy as many units of the risky asset as they can afford (100 units) on margin. That is, for each unit of the asset that they purchase, they borrow the maximum amount allowed, 100 per unit of the asset, and pay a down-payment of 150 to cover the unit price of 250. Hence, Optimists borrow $10,000$ using the assets as collateral and use their initial wealth to cover the total down-payment, i.e., $100(250-100) = 15,000$. They do not save any of their initial cash endowment and leverage to the maximum extent. As a result, the equilibrium asset loan-to-value is $LTV = \frac{\phi}{py} = \frac{10{,}000}{250(100)} = 0.4$. Borrowing allows the Optimists to hold all the assets in the economy in equilibrium.

The solution to Pessimists' optimization problem is also a corner solution, since their expected value of the asset (190) is now lower than the price. As a result, they sell all their endowment of the risky asset at a price of 250 and receive $100(250) = 25,000$ in cash.

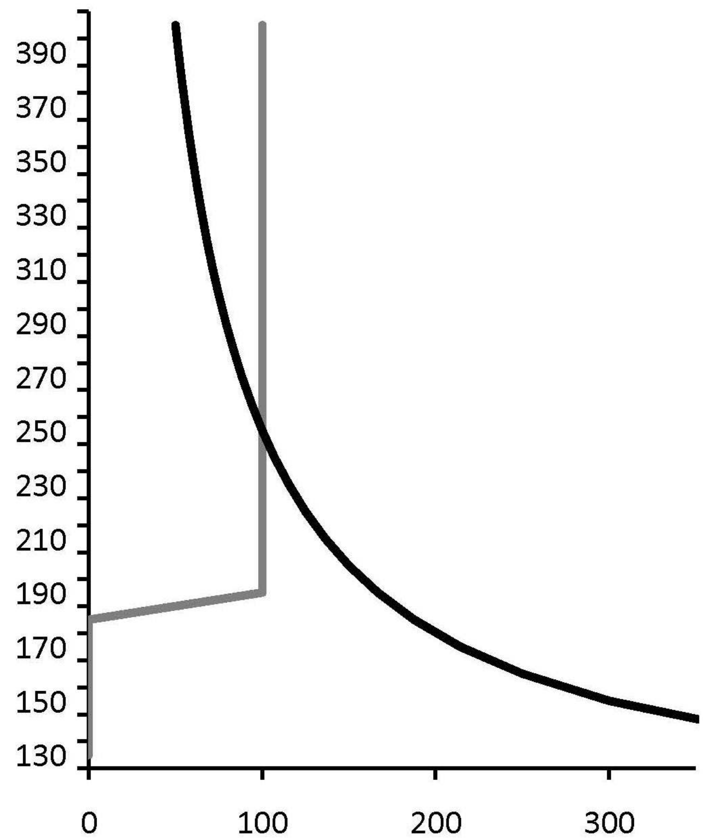

Figure 3: Supply (grey) and Demand (black) in the Bullish L-economy.

In this equilibrium, unlike in the previous one, Optimists alone determine the price through their budget and borrowing constraints. This happens because collateralized borrowing reduces the downpayment to be paid at time 0, from p to $p - \varphi$, thereby shifting demand upward. The supply side of the market is not affected by the change in credit conditions, as in this economy the supply of credit is exogenous and perfectly elastic. As a result, as Figure 3 shows, demand (black line) now intersects supply (gray line) on the vertical segment of the supply curve and, in equilibrium the price is solely demand determined.

Note that unlike in the NL-economy, gains from trade are fully realized in equilibrium: all the assets change hands from the Pessimists to the Optimists. Because of this, Optimists' payoff become very volatile, even more than in the NL-economy. Now the payoff resulting from the equilibrium allocation are $65,000$ in the High state and 0 in the Low state for Optimists; $25,000$ in both states for Pessimists.

1.2.4 Deviation from the Law of One Price

One important feature of our model is that the equilibrium price is higher in the L-economy than in the NL-economy. As we have seen in Sections 1.2.2 and 1.2.3, $p_L = 250 > p_{NL} = 190$, generating a spread of $s = 60$. This spread is a deviation from the Law of One Price: two assets with identical payoffs (i.e., the risky asset in the L-economy and the risky asset in the NL-economy) have different prices in equilibrium.[11]

As we have seen, in the L-economy, the price is higher than in the NL-economy because the asset can be used as collateral. Why does this happen?

In the economy without leverage, even if the Optimists value the asset more than the Pessimists do, they cannot afford to buy all the existing supply; as a result, part of the asset supply ends up in the hands of the less enthusiastic investors (the Pessimists), lowering its price in equilibrium. In contrast when leverage is possible,

[11] The reader may note that we do not have two assets with the same payoffs state by state in the *same* economy. As we explain at the end of this section, for reasons of laboratory implementation we decided to have one asset traded each time. However, since the *only* difference between the two economies is that in one the asset can be used as collateral and in the other not, we still can interpret this as a deviation from the LOP.

Optimists can afford to buy the whole asset supply, whose price is therefore determined only by their budget constraint (i.e., how much they can afford to purchase). This implies that the price is higher.

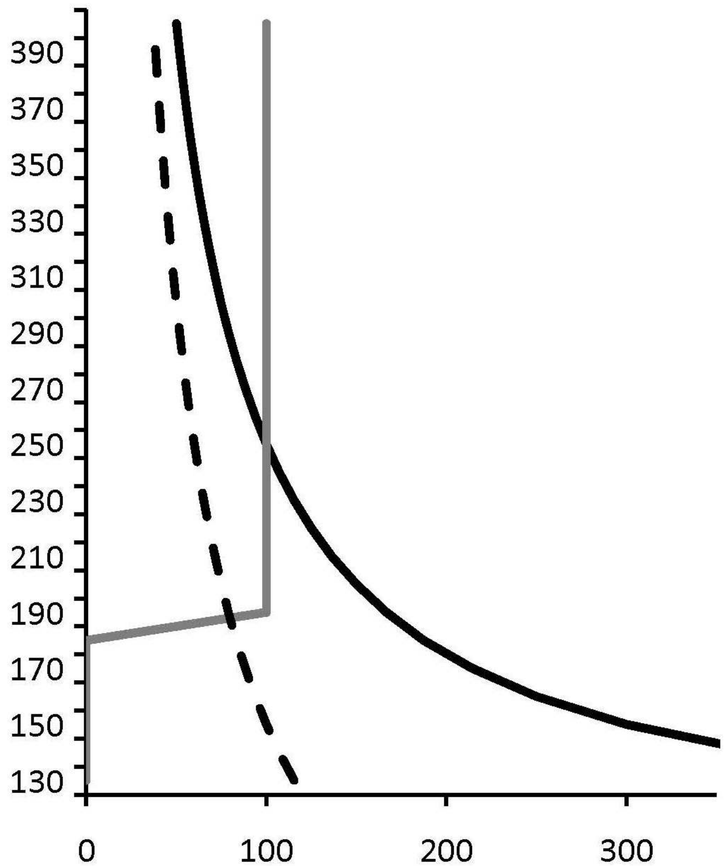

Figure 4: Supply (grey) and Demand (NL-economy: dotted black; L-economy: solid black) in the Bullish Market.

The effect of leverage on the equilibrium price can be seen in Figure 4, which combines Figures 2 and 3, that is, the supply and demand in the L and NL-economy. The gray line is the supply function, which, as we already mentioned, is the same for both economies. The ability to borrow, however, does affect the demand: the demand in the L-economy (black line) is always higher than in the $NL-$economy (black dotted line). Let us pause for a second on this point. As mentioned before, the downpayment, i.e, the money Optimists need to put down to acquire one unit of asset at time 0, is reduced by the amount borrowed per unit of asset. This can be clearly seen from equations (3), (4) and (5). In both L and NL economies, Optimists chose zero cash holdings provided that the price is less than 490 (their expected value); from their budget constraint (equation 3), we have that the demand in the NL-economy is given by

$$p = \frac{m^i}{y}, \tag{7}$$

whereas from equations (4) and (5) the demand in the L-economy is given by

$$(p - D_{Low}) = \frac{m^i}{y}, \tag{8}$$

hence explaining the shift in demand.

Notice, that the effect of collateralized borrowing is different from the effect of an increase in the cash endowment m^i. This is so because the loan repayment affects the actual asset payoffs in the final period. That is, because of buying on margin the net asset payoff is $D^i_{High} - D_{Low}$ in the High state and 0 in the Low state. To put it differently, Optimists when buying one unit of asset on margin are effectively buying the Arrow security that pays 1 in the High state. Finally, the gap between the two demand functions is the bigger the smaller is the downpayment, since the percentage reduction in the downpayment due to borrowing ($\frac{p-D_{Low}}{p}$) is inversely related to the price.

Note that the wedge between demands in the two economies is the only factor generating the deviation from the the Law of One Price. Because of this gap, demand intersects supply in two different segments of the supply function: in the $NL-$economy, the intersection occurs when supply is flat, and as a result Optimists and Pessimists share the asset and jointly determine its price. In the $L-$economy, the curves intersect when supply is vertical at 100; as a result, only Optimists hold the assets and their constraints determine the price. In the $NL-$economy the price needs to be equal to Pessimists' expected value for them to be willing to hold (some units of) it; in the $L-$economy, the price needs to be greater than Pessimists' valuation for them to be willing to sell (all of) it.

Geanakoplos (2003) and Fostel-Geanakoplos (2008) first showed that, when assets can be used as collateral, higher security-based leverage generates higher asset prices. In an economy with collateralized borrowing, assets have a dual role: they are not only investment opportunities (i.e., they give a right to a future cash flow), but also allow investors to borrow money (i.e., they provide a technology to transfer wealth across time). This second role of the asset as a provider of liquidity is priced: as a result, when the asset can be used as collateral (in the L-economy) its price is higher than when it cannot (in the NL-economy), notwithstanding the fact that its cash flow in all states of the word is identical in both economies. Hence, the spread between the asset price in the L and NL-economy can be interpreted as the asset *collateral value.*

When in our model is the spread positive, therefore indicating a departure from the Law of One Price? When the set of agents determining the price is different across economies. As explained before, in the NL-economy both Optimists and Pessimists determine the price, whereas in the L-economy the price is determined by the Optimists' constraints only. A spread would not have been generated in equilibrium if the set of agents determining the price in the two economies were the same. This can happen under two circumstances: i) when Optimists have a large cash endowment m^0 so that they afford to buy all the assets even in the NL-economy, and ii) if the borrowing constraint is very tight (i.e., D_{Low}, which is the maximum agents can borrow, is small), so that even if the Optimists borrow as much as they can, they are still not be able to afford all the supply of the asset. The choice of parameters described in Table 1 ensures that the set of agents determining the price is different across economies.

Note that in our model, we do not have two assets with the same payoff and different prices in the *same* economy. However, the L and the NL-economy only differ because in the first one the asset can be used as collateral, whereas in the second it cannot; therefore, the increase in the price between NL and L represents a deviation from the LOP. Indeed, in the Appendix, we show how a deviation from the LOP would arise in a two-asset economy with the same parameter values as in the Bullish market where one asset can be used as collateral and the other cannot. In the laboratory, we implemented the NL and L-economy sequentially, as opposed to the two-asset economy, because doing otherwise would have been unfeasible.[12]

[12] As we describe in the Procedures (Section 2) and in the Instructions (Appendix), the game implemented in the laboratory is already very complicated, especially the explanation of how buying on margin works. An extension to a two-asset case, in which only one asset can be bought on margin, would have been extremely difficult to explain to the subjects.

1.3 The Bearish Market

In this section, we consider a parametrization identical to the Bullish market, where however q is lowered to 0.4. We refer to this as the *Bearish Market*, as the probability of the High state is now lower than that of the Low state.

Table 3 shows the equilibrium outcomes when $q = 0.4$ for both the NL and $L-$economy.

Table 3: The Equilibrium in the Bearish Market

	NL-economy		L-economy	
Price	160		250	
	Spread: 90			
	Optimists	Pessimists	Optimists	Pessimists
y	93.75	6.25	100	0
φ	0	0	10,000	0
w	0	15,000	0	25,000
u_U	70,312	16,562	65,000	25,000
u_D	9,375	15,625	0	25,000

Note that the equilibrium price of the NL-economy drops from 190 in the Bullish market to 160 in the Bearish market. In contrast, in the $L-$economy, the equilibrium price stays put at 250. As a result, the spread between NL and L-economy increases to 90 from 60 in the Bullish market. The increase in spread after bad news)is what Fostel and Geanakoplos (2008) interpreted as *Flight to Collateral:* during a crisis, assets that can be used as a collateral become relatively more valuable.

In the Bearish market, the equilibrium regime is the same as the one described before: that is, in the NL-economy the price is jointly determined by Optimists and Pessimists, whereas in the $L-$economy it is determined by the Optimists alone. The supply and demand curves for both the L and NL-economies are showed in Figure 5. In both L and NL-economies, the Optimists' demand function does not shift with respect to the Bullish Market, as their behavior is determined by their budget and borrowing constraints and is not affected by the decrease in probability of the high state of the world.[13] In contrast, the Pessimists' supply function shifts downward, as their expected value of the asset decreases. Because of this downshift in supply, the price in the NL-economy decreases.

The question is why the downward shift in price does not occur in the L-economy. In the L-economy the price is only determined by the Optimists, for demand intersects the vertical segment of the supply schedule. Since demand does not change as q changes, the price does not change either. Because the decrease in q lowers the price only in the NL economy, the spread between the L and NL case (i.e., the deviation from the law of one price) increases when we move from the Bullish to the Bearish Market.

2 The Experiment

2.1 The Experiment Design

The experiment was run at the Interdisciplinary Center for Economic Science, ICES, at George Mason University. We recruited subjects in all disciplines at George Mason University using the ICES online recruiting system. When the number of students willing to participate was larger than the number needed, we chose the subjects randomly in order to reduce the chance that the students in the experiment knew each other. Subjects had no previous experience with the experiment. The experiment was programmed in z-tree[14].

The experiment consisted of five sessions. Twelve students participated in each session for a total of 60 students. Each session consisted of four treatments, corresponding to the four economies described in Section 1:

1. The Bullish Market in the Non-Leverage Economy: the *Bull-NL Treatment*.

2. The Bullish Market in the Leverage Economy: the *Bull-L Treatment*.

3. The Bearish Market in the Non-Leverage Economy: the *Bear-NL Treatment*.

[13]Strictly speaking, this is true only for the region of prices below the Optimists' new expected value (360), which, however, is the relevant region for price determination given the Pessimists' supply function.

[14]See Fischbacher (2007).

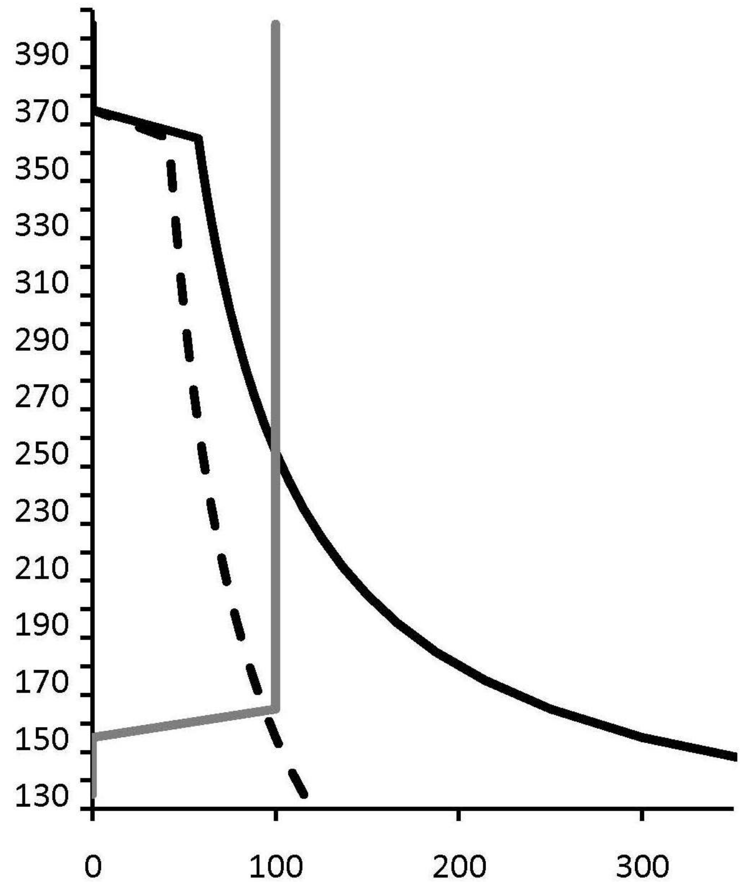

Figure 5: Supply (grey) and Demand (NL: dotted black; L: solid black) in the Bearish Economy.

4. The Bearish Market in the Leverage: *Bear-L Treatment*.

Note that in each session the same group of students played all the four treatments, thus allowing as to study the difference in behavior across treatments with one-sample statistical techniques.

For each of the five sessions, we ran the experiment over two days. In Sessions 1, 2 and 3, we ran $Bull-NL$ and $Bear-NL$ the first day, and $Bull-L$ and $Bear-L$ the second day. In Sessions 4 and 5, we ran $Bear-L$ and $Bull-L$ in the first day, and $Bear-NL$ and $Bull-NL$ in the second day. Therefore, in Sessions 4 and 5 we inverted both the ordering of *Bull* vs. *Bear* and of NL vs. L, thus allowing us to control for order effects in the data.

In each treatment of each session, we ran fifteen rounds of the same economy. The first four rounds of each treatment (both in treatments played in day one and those played in day two) were used for practice and did not determine students' payments. The experiment lasted on average 2.5 hours each day. Students were paid at the end of the second day. They received on average \$40, including a \$10 show-up fee paid at the end of the first day.

2.2 The Procedures

We first describe the procedures for the $Bull - NL$ treatment in those sessions (1 to 3) when the NL treatment is played first. Later we will describe the procedures for the other treatments and sessions.

1. At the beginning of the experiment, we gave written instructions to all subjects.[15] We read the instructions aloud in order to make the structure of the experiment common knowledge. Then, we gave the subjects time to ask questions, which were answered in private by the experimenters.

2. All payoffs were denominated in an experimental currency called $E\$$. The risky asset was referred to as a "widget." Optimists and Pessimists were referred to as Buyers and Sellers. This was done because, in our economy, Optimists hold all the cash (and have to decide how much to buy) and Pessimists all the assets (and have to decide how much to sell); the terms Buyers and Sellers were easier for subjects to understand as they characterized what their role was in the experiment.[16] Nevertheless, in the remainder of the paper, when describing the empirical results, we will continue use the terminology of the theoretical model (i.e., Optimists and Pessimists).

3. At the beginning of the round, each subject was randomly assigned to be either an Optimist or a Pessimist. In every round, there were six Optimists and six Pessimists. Subjects could see their role in the left corner of their computer (see screen shot in the Appendix). Subjects had the same role in all the four

[15] The Instructions are included in the Appendix.

[16] Moreover, we wanted to avoid using the terms Optimist and Pessimist so as not to bias their behavior.

treatment they played: that is, if a subject was a Pessimist in the first round of the $Bull - NL$ treatment and an Optimist in the second round, he was also a Pessimist and Optimist in the first and second round of the other three treatments. We did so in order to increase the statistical power of our tests (see footnote xx).

4. Next, the demand by Optimists and the supply by Pessimists were elicited by presenting them with a list of ten prices and asking them how many units of the asset they wanted to buy (Optimists) or sell (Pessimists) at each price.[17] For each of the 10 prices, Optimists were informed of the maximum number of assets that they could afford to buy. The computer mechanically enforced (weakly) upward sloping supply, and downward sloping demand. That is, if an Optimist demanded x^1 at a price p^1, he was only allowed to demand $x^2 \leq x^1$ at a price $p^2 > p^1$.[18]

5. The list of ten prices was taken from a pre-determined matrix and varied from round to round.[19] Note that the matrix was the same (for each round) across sessions and treatments (i.e., we used the same matrix in the same round of each session and each treatment). We let prices vary slightly from round to round in order to avoid habituation.

6. After all the subjects had made their choices, the computer calculated the price at which trading occurred. The price was determined by minimizing the excess supply over the ten prices for which we elicited subjects' choices. Subjects then learned about the price from the computer screen and the trades were automatically realized. If excess supply was positive (negative) at the equilibrium price, supply (demand) was proportionally reduced for all Optimists (Pessimists).

7. After trading occurred, the state of the world was realized. In front of all the subjects, an experimenter extracted a ball from an urn with 6 red balls and 4 green balls in the Bullish market, 4 and 6 in the Bearish market. If the ball

[17] See screenshot in the Appendix.

[18] Since the payoff is defined in terms of final cash only, no rational agent would chose an inverted demand or supply function. Moreover, without the above choice restriction in the experiment, mistakes by even a small number of subjects could have created inversions in some segments of demand or supply. As a result, there could have been multiple prices, far away from each other, for which the distance between demand and supply is low. Given our price-selection rule, this would have generated large changes in the equilibrium price for small changes in subjects' choices, thus making the equilibrium price less meaningful.

[19] See Appendix.

extracted was red (green), the state of the world was High (Low). The outcome of the extraction was shown to all subjects.

8. After the state of the world was realized, subjects could see in the computer screen their final per-round payoff. In order to avoid zero-payoff, a $E\$10,000$ bonus was paid to each subject at the end of each round in addition to their payoff.

9. After round 1 ended, a new round started. The session continued until all 15 rounds were played. Each round was independent from the previous one: subjects were not allowed to carry on endowments of cash or assets from one round to the next.

After the 15 rounds were played, students were given the instructions for the $Bear-NL$ treatment, which was played right after. We followed the same procedure described in points 1 to 9.

The same group of students were gathered the following day to play the two L-economy treatments (i.e., the $Bull-L$ treatment and the $Bear-L$ treatment), following the same procedures outlined in points 1 to 9. In the Instructions, subjects were explained in detail how borrowing worked: the maximum amount of borrowing allowed, its effect on subjects' budget constraint and the impact of loan repayment on their final payoff. During the experiment, the Optimists' screenshots indicated how much they needed to borrow to afford a given number of assets at a given price.[20] Finally, after trading decisions were made, the screenshots indicated how much Optimists had borrowed and had to repay at the trading price determined by the computer.

After the end of the second treatment of the second day of the experiment, five rounds were extracted out of the last 11 rounds of each treatment (the first four rounds were for practice only). Payoffs were summed up and converted into US$ at the rate of $E\$20,000$ per US$. Identical procedures were followed in Sessions 4 and

[20]For each price, Optimists were told how many assets they could afford if: a) they did not want to borrow, b) if they wanted to borrow the maximum of 100 per asset, c) if they wanted to borrow only 30 per asset, and d) if they wanted to borrow only 60 per asset. In the Instructions, Optimists were told that this information was for reference only and that they were not restricted to borrow the quantities indicated in the screen.

5, with the exception that the sequence in which the treatments were played was altered.

Notice that our procedure to determine the equilibrium price is different from that of a standard double auction or of a call auction since we are eliciting the whole demand and supply schedule for each subject and in each round, with a methodology reminiscent of the "strategy method." We did so because eliciting the whole demand and supply schedules will be crucial for our understanding of the mechanism generating deviation from the Law of One Price. Additionally, implementing a double auction in our economy would have been very difficult. In our simplest setup, the NL-treatment, we would have had to departure from a standard double auction by having subjects chose quantities in addition to prices (since subjects could not have traded 100 units of the asset in a reasonable amount of time).[21] In the L-treatment, the departure from the double auctions would have been even more severe, as subjects would have had to choose prices, quantities and borrowing per asset at the same time.

In the remainder of the paper we will confront the equilibrium price and quantities of the theoretical model with those that arise in the laboratory. Note that having a finite number of subjects does not modify the equilibrium, as long as they behave as price takers, which is a reasonable assumption given the large number of subjects in the experiment.

3 Results

3.1 The Bullish Market

We start by analyzing the equilibrium results in the Bullish market, comparing the equilibrium prices in the Leverage (L) and in the Non-Leverage (NL) treatments. Table 4 shows the average equilibrium prices across the five sessions of the experiment and in each session separately.[22]

[21] The reason why we parametrized the model with large cash and asset endowments is to generate differences in behavior across treatments that are detectable in the laboratory. For instance, with our parameter values, if subjects had only 10 units of the asset and $1,500$ in cash, optimists equilibrium holding in the L and NL-economies would have been 9 and 10 units respectively. As a result, even small amount of noise would have masked the effect of leverage in the laboratory.

[22] We restrict ourselves to the last 11 rounds of each session, over which subjects were paid. The results for all 15 rounds are reported in the Appendix.

Table 4: Average Equilibrium Prices in the Bullish Market

	Average	S1	S2	S3	S4	S5
NL	216	213	210	219	210	228
L	254	241	263	260	241	263
Spread	38	28	54	42	32	35

As theory predicts, across s and in each session, the average equilibrium price is higher in the L versus the NL-treatment, with an average spread of 38 across sessions. Deviations from the Law of One Price arise in the laboratory as a result of subjects' heterogeneity and the ability to use the asset as a collateral. The difference in prices is statistically significant ($p - value = 0.001$),[23] and robust to order effects. Moreover, it is consistent even across rounds of the experiment: as shown in Table 5, out of 55 rounds (11 for each session), the spread between the L and the NL-treatment is zero in only 14, and it is never negative.

Table 5: Per-round Equilibrium Prices across Sessions in the Bullish Market

	S1			S2			S3		
Round	NL	L	S	NL	L	S	NL	L	S
5	210	240	30	210	300	90	240	300	60
6	220	220	0	200	220	20	200	250	50
7	200	230	30	200	320	120	230	230	0
8	225	255	30	175	255	80	205	225	20
9	195	285	90	195	225	30	225	285	60
10	195	245	50	245	245	0	245	305	60
11	205	235	30	235	295	60	205	235	30
12	240	240	0	240	240	0	210	300	90
13	200	250	50	200	250	50	220	250	30
14	230	230	0	230	290	60	200	230	30
15	225	225	0	175	255	80	225	255	30

[23] We regressed the per-round changes in the equilibrium price between L and NL-economy against a constant (remember that in each round of the two treatments the same subjects act as Optimists and Pessimists, and face the same price vector). We tested whether the regression constant is significantly different from zero, correcting the standard errors with by-session clustering and obtaining the p-value reported in the main text of the paper. Note that we obtain a similar result if we run a non-parametric sign test on per-round price differences (p-value=0.000).

	S4			S5		
Round	NL	L	S	NL	L	S
5	210	240	30	240	300	60
6	200	250	50	220	220	0
7	230	230	0	200	290	90
8	175	255	80	225	225	0
9	195	285	90	225	285	60
10	215	245	30	245	245	0
11	235	235	0	235	235	0
12	240	240	0	240	300	60
13	200	220	20	220	250	30
14	200	230	30	230	290	60
15	205	225	20	225	255	30

Moreover, as predicted by theory, as we move from the NL to L-treatment, the equilibrium level of transactions increases, that is, a larger number of assets is sold by the Pessimists to the Optimists. As Table 6 indicates, the average quantity traded per subject increases from 56 to 69 assets, a difference that is statistically significant and robust to order effects.[24] Therefore, the relaxation of the collateral constraint between NL and L-treatment allows gains from trade to be exploited in the laboratory market to a greater extent.

Table 6: Per-Subject Average Transactions in the Bullish Market

	Average	S1	S2	S3	S4	S5
NL	56	57	46	63	64	49
L	69	75	59	70	76	66

Although the experimental results are broadly in line with the theoretical predictions of Section 1, important departures from theory arise:

1. in both NL and L-treatments, the quantities traded per subject (56 in NL and 69 in L) are lower than what theory predicts (78 and 100 respectively);

[24]The p-value is 0.000.

2. whereas in the L-treatment the average price is very close to its theoretical counterpart, the equilibrium price in the NL-treatment (216) is above the theoretical one (190).

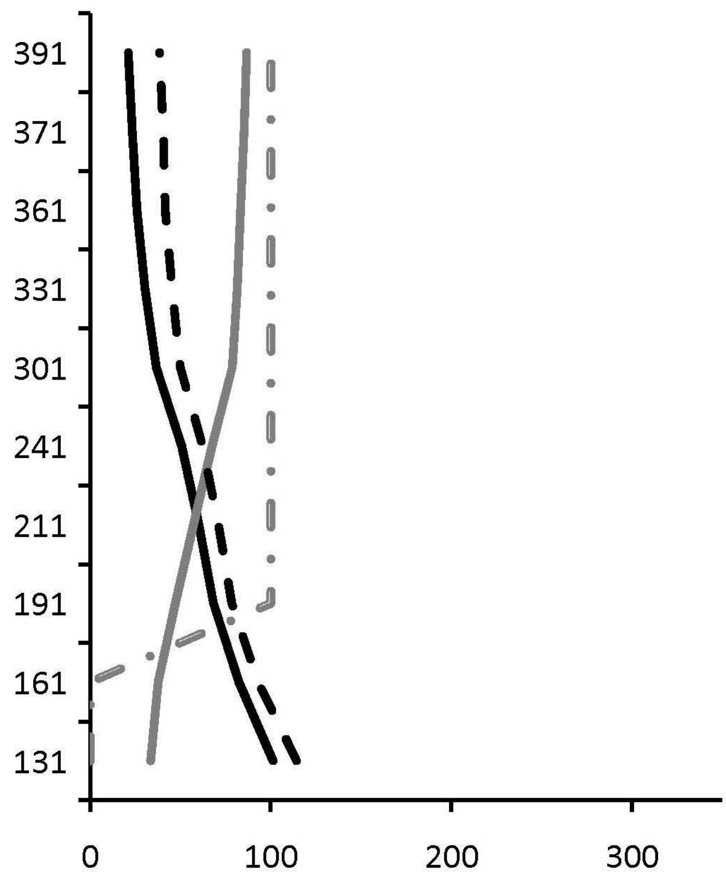

Figure 6: Supply (grey) and Demand (black) in the $Bull - NL$ Treatment. Solid lines are the experimental results; dotted lines the theoretical functions.

In order to explain these departures, let us first focus on the NL-treatment. Figure 6 shows the theoretical (thick lines) and the empirical (dotted lines) demand (black) and supply (grey) curves in the NL-economy; the empirical curves are averaged across subjects, rounds and sessions. Two observations are in order. First, the empirical demand is to the left of the theoretical one: in particular, the Optimists' demand, although downward sloping, is not determined by the budget constraint as theory predicts. Indeed, as column 1 of Table 7 shows, Optimists' average final cash holdings–which theoretically should be zero–are on average around $E\$3,000$ (out of an initial endowment of $E\$15,000$).

Second, the average empirical supply is a smoother version of the theoretical one. According to the model, Pessimists should sell 0 assets at a price below their expected value ($E\$190$), and sell all their holdings, 100, at a price above its expected value. Instead, in the experiment, Pessimists offer positive quantities for prices below 190 (that is, the empirical supply is to the right of the theoretical one), and supply less than 100 units for prices above 190 (that is, the empirical supply is to the left of the theoretical one). Although supply monotonically increases in the price, it never reaches 100 units.[25]

Table 7: Optimists' Final Cash Holding and Borrowing in the Bullish Market

	Final Cash	Borrowing per Widget	Aggregate Loan to Value Ratio
NL	$3,065$	-	-
L	$1,555$	45	0.23

Because the empirical supply is a smooth version of the theoretical one, the price is higher than theory predicts, and the quantity traded is lower. The leftward shift in the empirical demand with respect to theory amplifies the effect of the empirical supply on quantities and dampens the effect on prices. Nevertheless, since the departure of supply from the theoretical one is larger than that of the demand, the price in the laboratory is higher than theory predicts.

Let us now turn our attention to the L-treatment. The upper portion of Figure 7, compares the empirical supply and demand in the L-treatment (solid line) with those of the NL-treatment (dotted line). The bottom portion instead compares the empirical supply and demand in L-treatment (solid line) with their theoretical counterparts (dotted line).

As the upper portion of Figure 7 shows, the empirical supply in the L-treatment overlaps with that in the NL-economy (dotted and solid gray lines overlaps). This

[25]Note that for a price higher than 250 (Pessimist's value in the High state), supply is very close to 100, which reassures us that Pessimists understood the model. We will discuss more extensively the supply behavior in the next section.

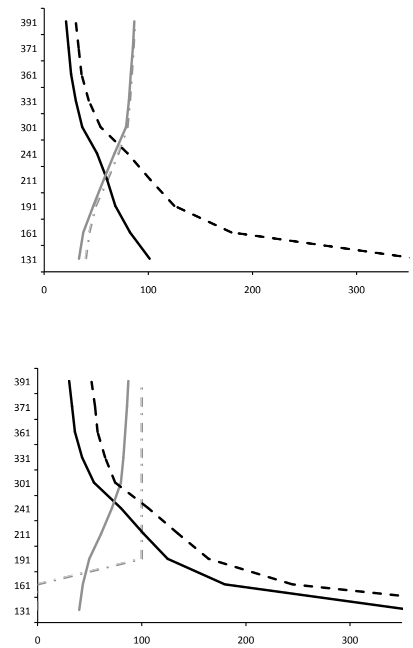

Figure 7: Upper: Supply (grey) and Demand (black) in the $Bull - NL$Treatment (Solid lines) and $Bull - L$ Treatment (Dotted lines). Bottom: Supply (grey) and Demand (black) in the $Bull - L$Treatment. Solid lines are the experimental results; dotted lines the theoretical functions.

is a good check that subjects understood the experiment since the problem that Pessimists face is the same in the two treatments. The empirical demand (solid black line) shifts rightwards with respect to that of the NL-treatment (dotted black line), as now subjects are allowed to borrow. This rightward shift is what generates the spread between the price in the NL and the L-treatment, and as a result, the deviation form the Law of One Price in the laboratory.

Note however that, as the lower portion of Figure 7 shows, the empirical demand is in the L-treatment (solid black line) is still to the left of its theoretical counterpart (dotted black line). That is, subjects do not exhaust all the collateral value of the assets. As the second column of Table 7 shows, each Optimist borrows on average $E\$45$ per unit of the asset he buys, whereas in the theoretical equilibrium they borrow $E\$100$. Nevertheless, because in the region determining the price, the empirical supply is to the left of the theory, the price in the L-treatment is very close to the theoretical one (although quantity is lower).

To summarize the previous discussion, the increase in price due to leverage stems from the fact that Optimists' demand shift to the right when we move from the NL to the L-treatment.

This rightward shift in demand is puzzling. In the NL-treatment, the demand curve was not determined by the Optimists' budget constraint, that is, Optimists were not spending all their cash endowment. One would expect that in such circumstances allowing subjects to borrow should not affect their behavior; instead, we observe the opposite.[26]Two explanations come to mind:

First, the shift in demand could stem from an aggregation bias. This would be the case if the shift in demand primarily stems from subjects who are at (or close to) the budget constraint in the NL-treatment, and use the leverage technology to buy more assets in the L-treatment. To some extent, this is indeed the case. As figure 8 shows, the Loan to Value in the L-treatment is negatively associated with the Optimists' final cash holdings in the NL-treatment.[27]

Second, the above explanation, however, cannot be the whole story: there are subjects who are far away from the budget constraint in the NL-treatment and still borrow when allowed. One possible interpretation is that some sort of "price illusion" affects their behavior. Subjects do not fully internalize that when buying on margin, not only the cash put down at time 0 is lower (i.e., the downpayment is smaller than the un-leveraged price), but the future net payoff from the asset goes down (as the loan on the asset needs to be repaid). That is, subjects do not realize that when buying on margin they are effectively buying a different asset, the Arrow security that pays in the high state.

3.2 The Bearish Market

In this section, we analyze the experimental results when we lower the value of q to 0.4 (i.e., in the Bearish Market). Let us recall what the theory predicts should

[26]This shift in demand cannot be explained by risk aversion either. It is simple to show that under very general conditions on utility functions, the only way for an agent to be interior in both economies is at the same point in which borrowing is zero.

[27]The slope of the regression line (in the chart) is negative and significant (p-value 0.01, after correcting for session clusters).

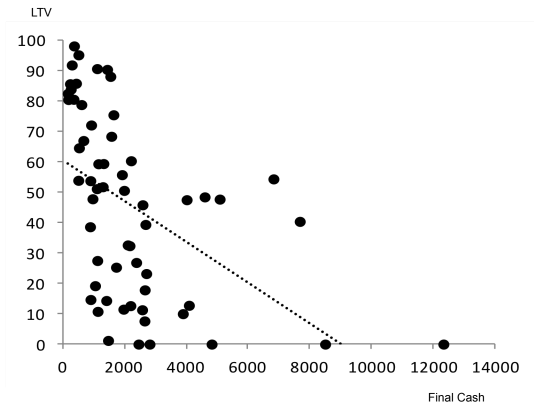

Figure 8: LTV regressed on Final Cash holding in NL-Treatment.

happen by looking at how demand and supply functions move when q goes from 0.6 to 0.4 (as we had showed on Figure 5). In both L and NL-economies, the Optimists' demand function does not shift with respect to the Bullish Market. In contrast, the Pessimists' supply function shifts downward. As we mentioned in the theoretical section of the paper, in the NL-economy because of the downward shift in supply, the price decreases. In the $L-$economy, in contrast, the downward shift in supply leaves equilibrium price unaffected. As a result, the spread between the L and NL economies (i.e., the deviation from the law of one price) increases when we move from the Bullish to the Bearish Market.

Let us now turn our attention to whether the data bear out the theory's predictions. As theory predicts, the empirical supply curve (both in L and in NL-treatments), averaged across rounds and across sessions, shifts rightward, reflecting the decrease in the asset's expected value (see Figure 9).[28]

In contrast, Optimists' demand does not shift significantly as q changes (i.e., with respect to the Bullish market), in accordance to what theory predicts: i.e., the movement in demand between L and NL-treatment is unaffected by the change in probability (see Figure 10).

Table 8: Average Equilibrium Prices in the Bearish Market Treatments

[28]Moreover, as theory predicts (and as was the case in the Bullish Market), there is no significant difference in the empirical supply curve between the NL and the L-treatment, which is to be expected as subjects face exactly the same decision problem.

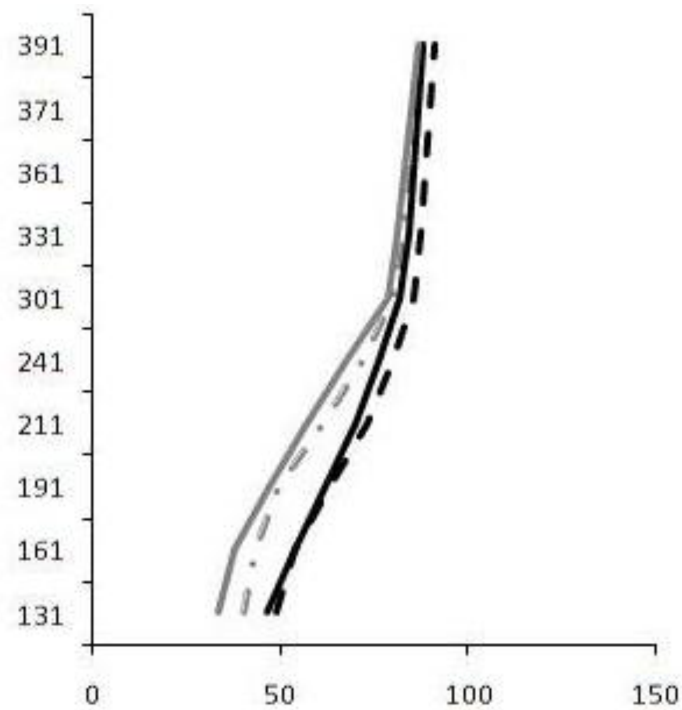

Figure 9: Supply curves in the *Bull* (gray) and *Bear* (black) Treatments. Solid lines are the results in the NL-economies; dotted lines in the L-economies.

	Average	S1	S2	S3	S4	S5
NL	188	182	187	203	195	175
L	230	228	236	230	230	227
Spread	42	46	49	27	35	52

Therefore, as in the Bullish Market, the relaxation of the collateral constraint from NL to L shifts demand upwards, and the price is higher in the L than in the NL-treatment. As Table 8 shows, the average equilibrium price is 188 in NL, and 230 in L. That is, we observe a deviation from the Law of One Price due to the collateral value of the asset being traded. As in the Bullish treatment, the difference

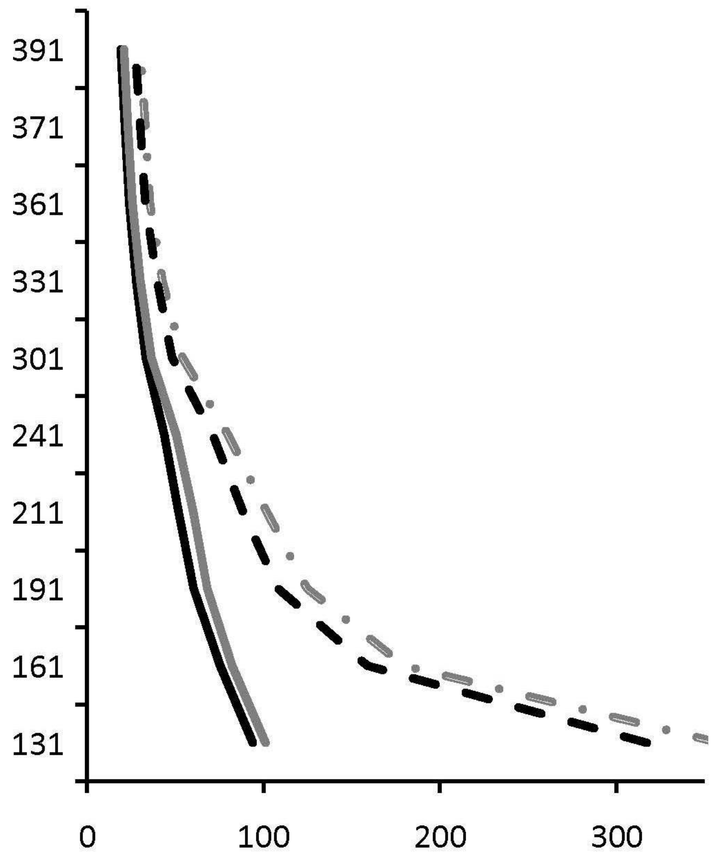

Figure 10: Demand curves in the *Bull* (gray) and *Bear* (black) Treatments. Solid lines are the results in the NL-economies; dotted lines in the L-economies.

in price between L and NL is statistically significant (p-value= 0.00)[29] and robust to order effects.[30]

Nevertheless, in contrast to what theory predicts, in the L-treatment the price is lower than it was in the Bullish L-treatment– it decreases from 253 to 230. As a result, the spread between NL and L-treatment does not increase when we move from the Bullish to the Bearish treatment, i.e., when q goes from 0.6 to 0.4 (the spread moves from 38 to 42, a statistically insignificant difference).[31]

[29]See footnote 20 for a description of the test.

[30]The p-value is 0.000.

[31]When regressing the per-round spread on a constant, the p-value is 0.61 (correcting for by-

Why does the spread between NL and L not increase in the Bearish Market treatments? As we mentioned in the theory section, the spread between L and NL increases as we move from Bullish to Bearish because the price in the L-economy does not change with q. This occurs because the supply function is a step function, which crosses demand in its vertical segment; as the function shifts downward, equilibrium prices and quantities are unaffected. In the laboratory, however, the supply function is not a step function: as we commented before, supply increases smoothly as the price goes up. As a result, when we move from Bullish to Bearish, the equilibrium price decreases even in the L-treatment–and the equilibrium quantity increases. This decrease in the price for the L-treatment implies that the behavior of the $L - NL$ spread is not obvious. In fact, at the aggregate level in the laboratory, the spread is constant across Bullish and Bearish Market treatments. That is, we do not observe "*Flight to Collateral*" in the laboratory.

To summarize the previous discussion, the key driver of the indeterminacy of Flight to Collateral is, as we just mentioned, the behavior of the empirical supply. This behavior of the empirical supply curve is clearly not consistent with expected utility maximization by Pessimists. This is because, ... In fact, The observed supply suggests some sort of aversion to losses in the worst-case scenario. So for prices below 190 they want to avoid the worst case scenario in which they keep all the asset and the Low state realizes. On the contrary, for prices higher than 190 they want to avoid the worst case scenario which is selling all the asset and that the High state realizes. Expand...Prospect theory....

However, even with this behavior of the supply curve just discussed, when we look at the disaggregated data round by round we see that in XX cases flight to collateral hold. In fact, in our theoretical model, for implementation purposes, the supply is quite extreme. In fact, with a smooth supply what we need to generate Flight to Collateral is that the ...., which is what we actually observe in the data some of the times....

[to be completed]

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Appendix A: A Two-Asset Economy.

We consider a two-period financial economy, with time $t = 0, 1$. At time 1, there are two states of the nature, $s = High$ and $s = Low$, with probability q and $1 - q$.

There are three assets in economy, cash and two risky assets X and Y with payoffs in units of cash. Assets X and Y have the same payoff as in our benchmark model, and are independently distributed. All the other features of the model hold. In particular, agents payoff function is given by

$$u_s^i(\bullet) = w + D_{y,s}^i y + D_{x,s}^i x - \varphi \tag{9}$$

Agents cannot borrow using asset X as a collateral, whereas they can use asset Y as collateral with $\varphi \leq Dy, Low$. Taking as given the asset price, agents choose asset holdings y, x and cash holdings w in order to maximize the payoff function subject to their budget constraints :

$$w + px + py \leq m^i + pa_x^i + pa_y^i + \varphi \tag{10}$$

$$\varphi \leq D_{y,Low} y \tag{11}$$

We find the equilibrium for the same parameter values as in the Bullish market described in Table 1. The equilibrium is described in Table 9:

Table 9: The Equilibrium in the Two-Asset Economy

	Optimists	Pessimists
p_y	250	
p_x	190	
y	100	0
x	0	100
u_{High}	$75,000$	$40,000$
u_{Low}	$10,000$	25000

Appendix B: Full Data Set.

The following tables incorporate data from all fifteen rounds of experimentation and can be compared with tables 4, 6, 7, and 9, respectively.

Table 10: Average Equilibrium Prices in the Bullish Market

	Average	S1	S2	S3	S4	S5
NL	216	223	205	215	208	230
L	251	244	254	260	242	256
Spread	33	21	49	45	34	26

Table 11: Per-Subject Average Transactions in the Bullish Market

	Average	S1	S2	S3	S4	S5
NL	55	54	45	62	66	49
L	70	73	61	70	78	69

Table 12: Optimists' Final Cash Holding and Borrowing in the Bullish Market

	Final Cash	Borrowing per Widget	Aggregate Loan to Value Ratio
NL	$3,156$	-	-
L	$1,535$	44	0.23

Table 13: Average Equilibrium Prices in the Bearish Market

	Average	S1	S2	S3	S4	S5
NL	190	185	186	207	191	181
L	235	232	234	233	238	237
Spread	45	47	48	26	47	56

Table 15: Per-Subject Average Transactions in the Bearish Market

	Average	S1	S2	S3	S4	S5
NL	59	53	54	61	69	59
L	71	77	60	75	76	70

The following graphs show the implicit supply and demand curves generated from each round of the experiment (aggregated across the five sessions).

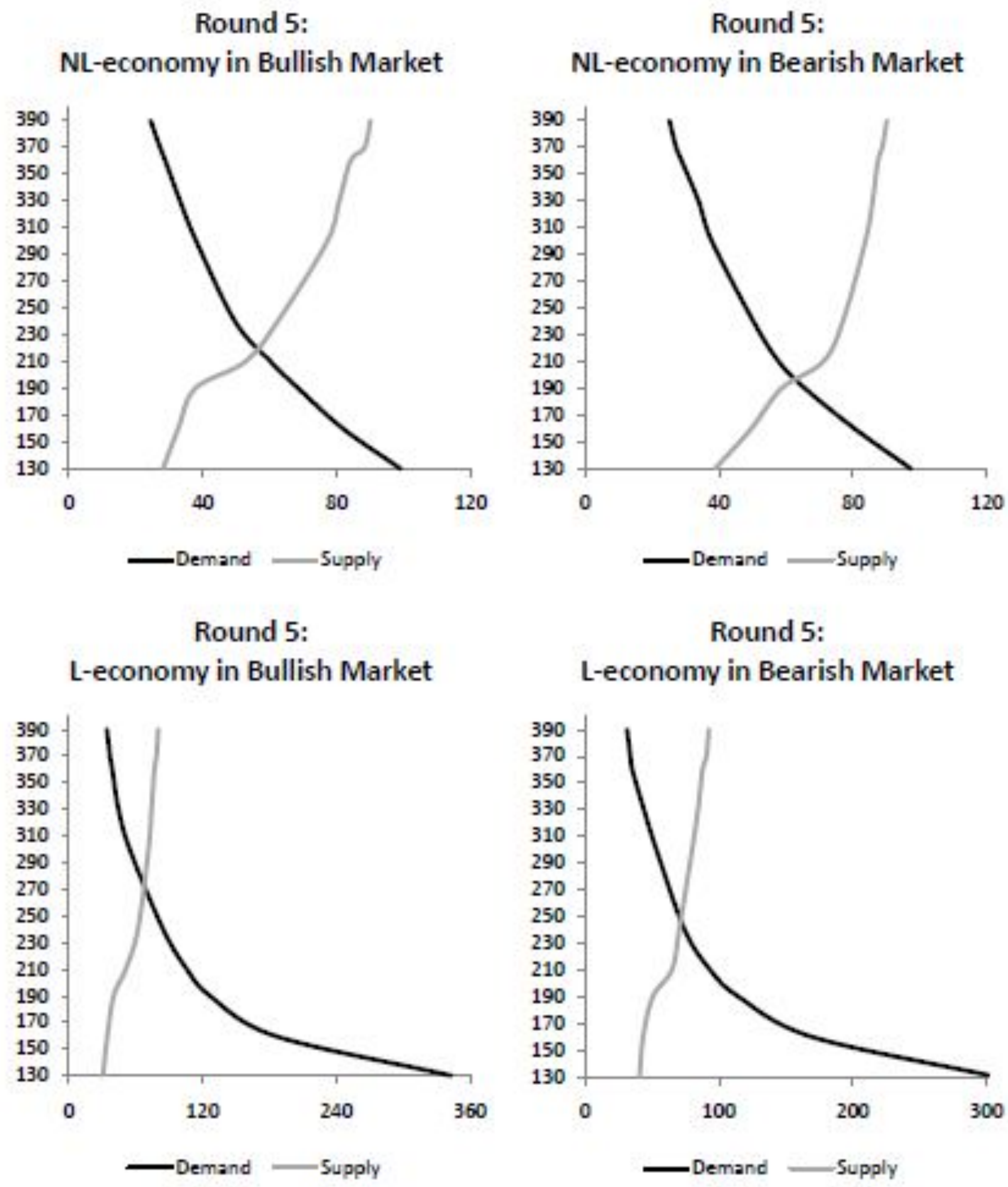
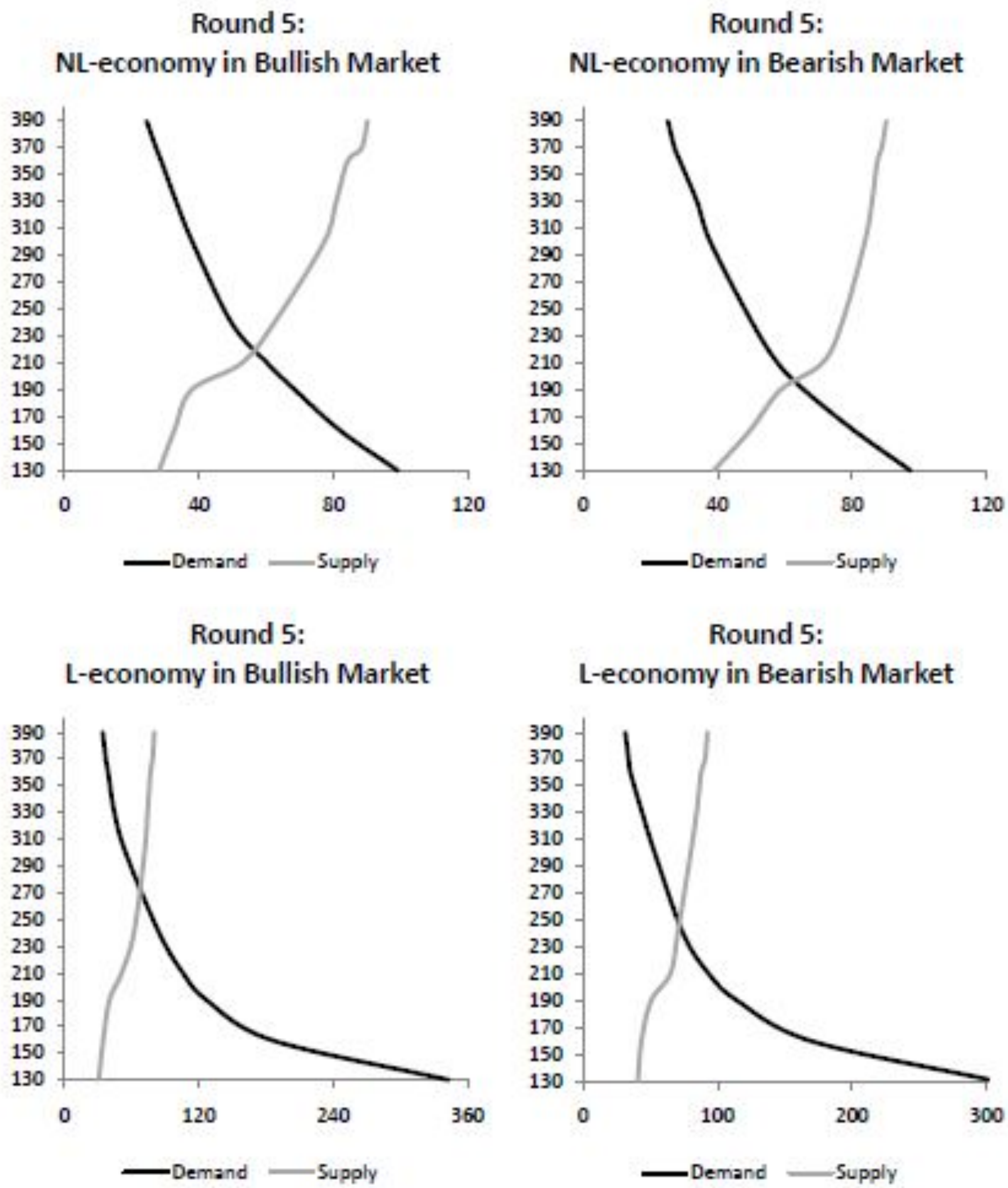

Round 5:
NL-economy in Bullish Market
Round 5:
NL-economy in Bearish Market
Round 5:
L-economy in Bullish Market
Round 5:
L-economy in Bearish Market
Demand
Supply

Figure 11:



Round 5:
NL-economy in Bullish Market
Round 5:
NL-economy in Bearish Market
Round 5:
L-economy in Bullish Market
Round 5:
L-economy in Bearish Market
390
370
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200
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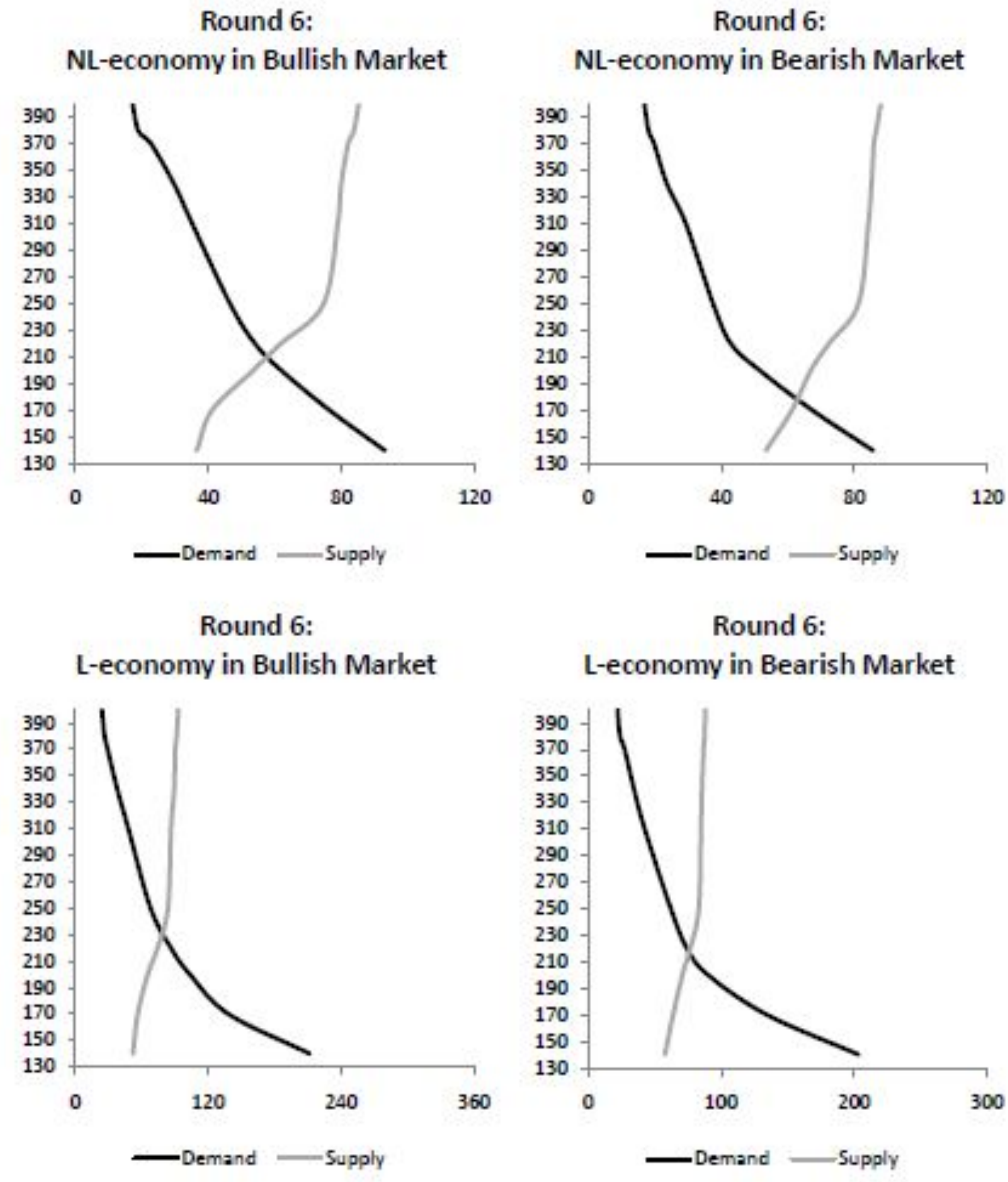
Demand
Supply

Figure 12:


Round 6:
NL-economy in Bullish Market
390
370
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Demand
Supply
Round 6:
NL-economy in Bearish Market
390
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Demand
Supply
Round 6:
L-economy in Bullish Market
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Demand
Supply
Round 6:
L-economy in Bearish Market
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Demand
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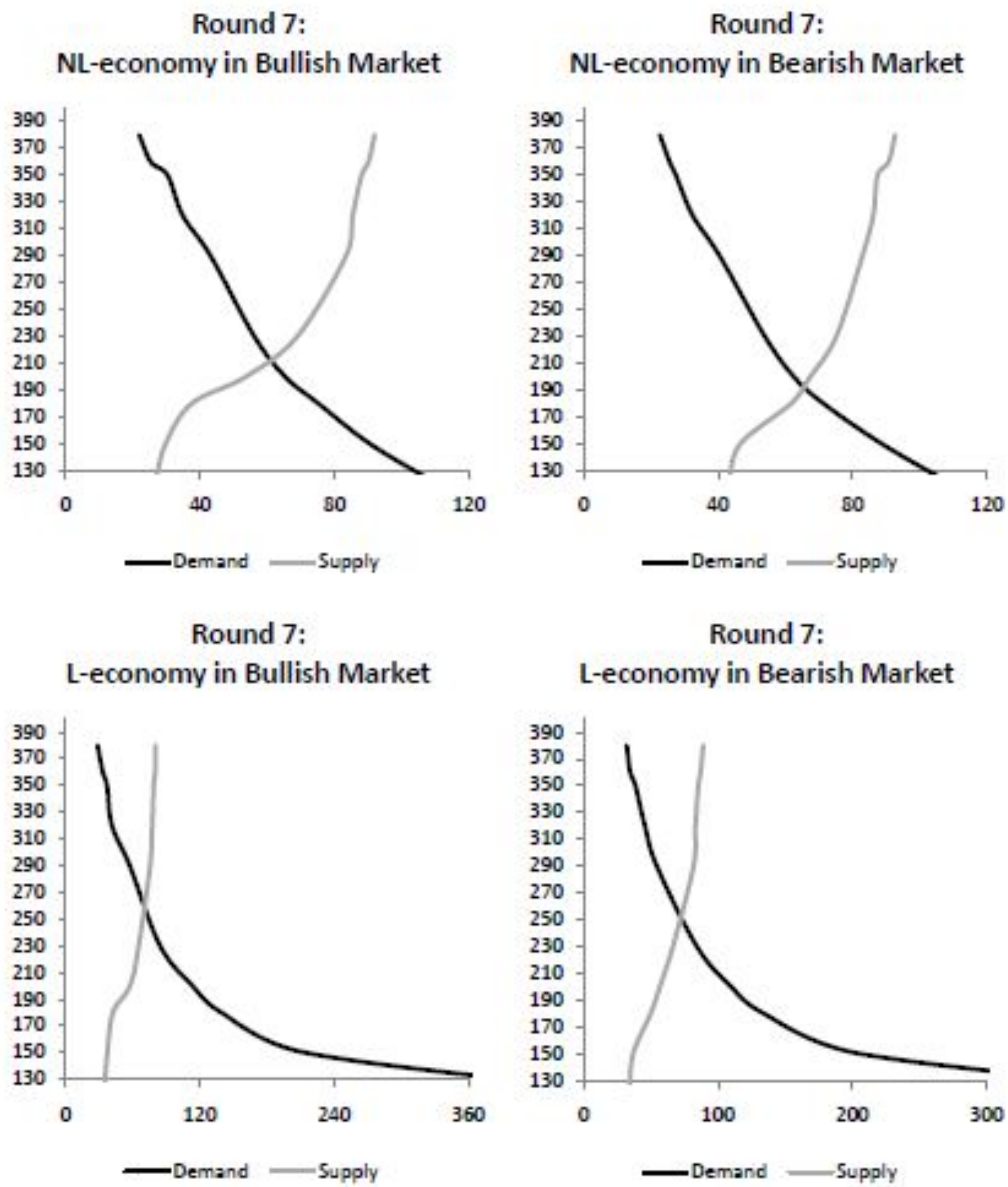
Figure 13:


Round 7:
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Round 7:
NL-economy in Bearish Market
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Round 7:
L-economy in Bullish Market
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Round 7:
L-economy in Bearish Market
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Demand
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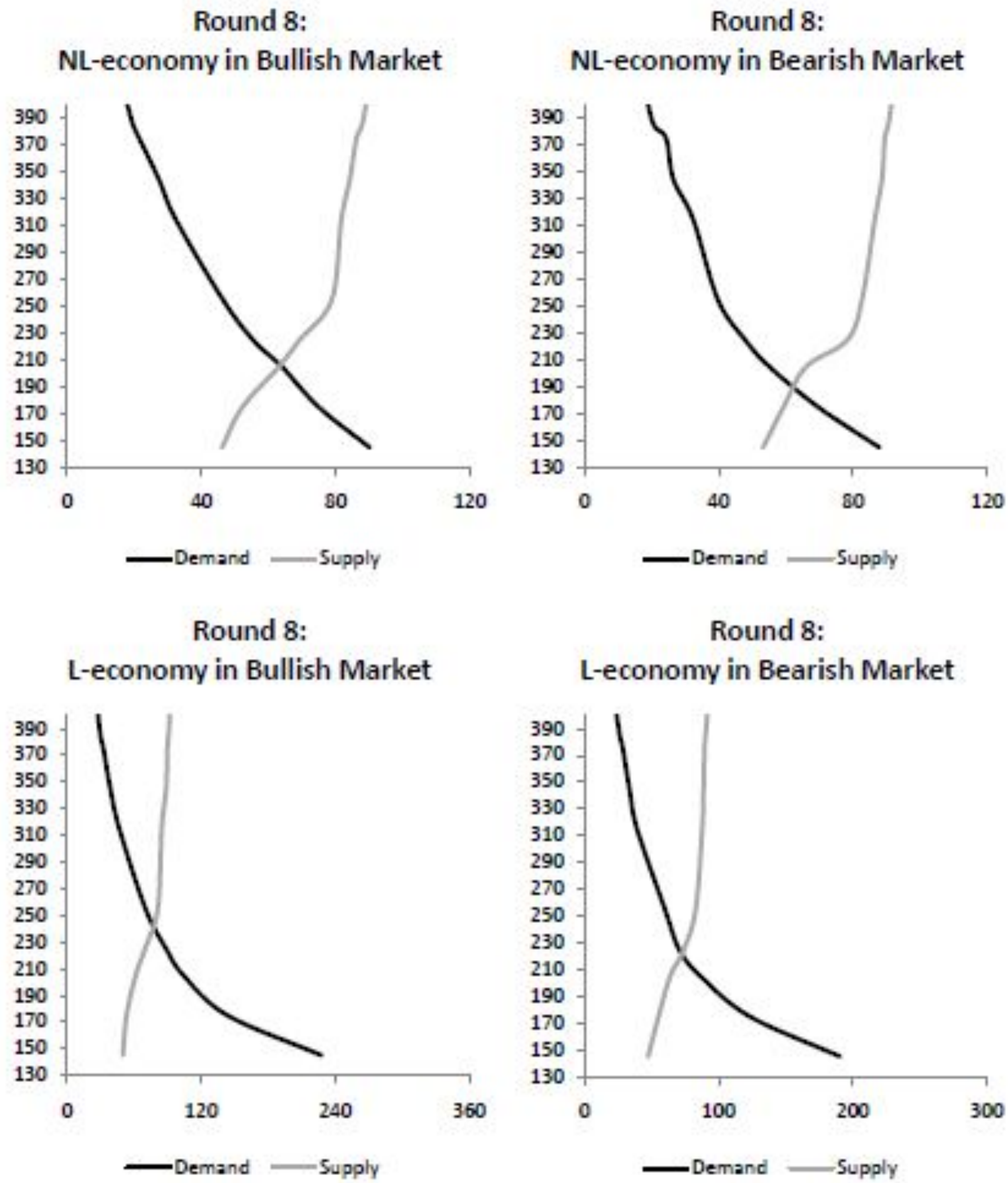
Figure 14:


Round 8:
NL-economy in Bullish Market
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Round 8:
NL-economy in Bearish Market
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Round 8:
L-economy in Bullish Market
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Round 8:
L-economy in Bearish Market
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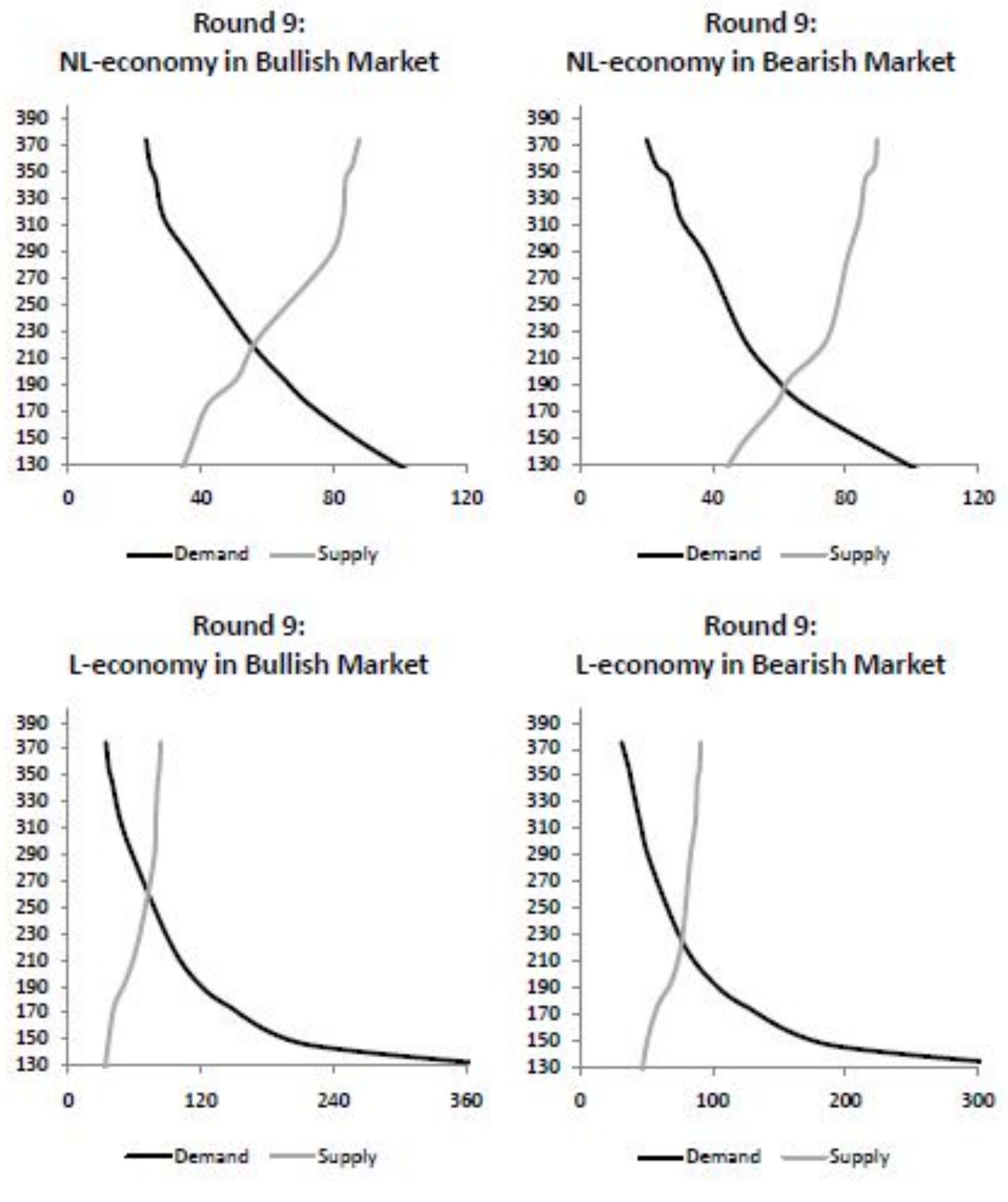
Figure 15:


Round 9:
NL-economy in Bullish Market
Round 9:
NL-economy in Bearish Market
Round 9:
L-economy in Bullish Market
Round 9:
L-economy in Bearish Market
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Demand
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Figure 16:

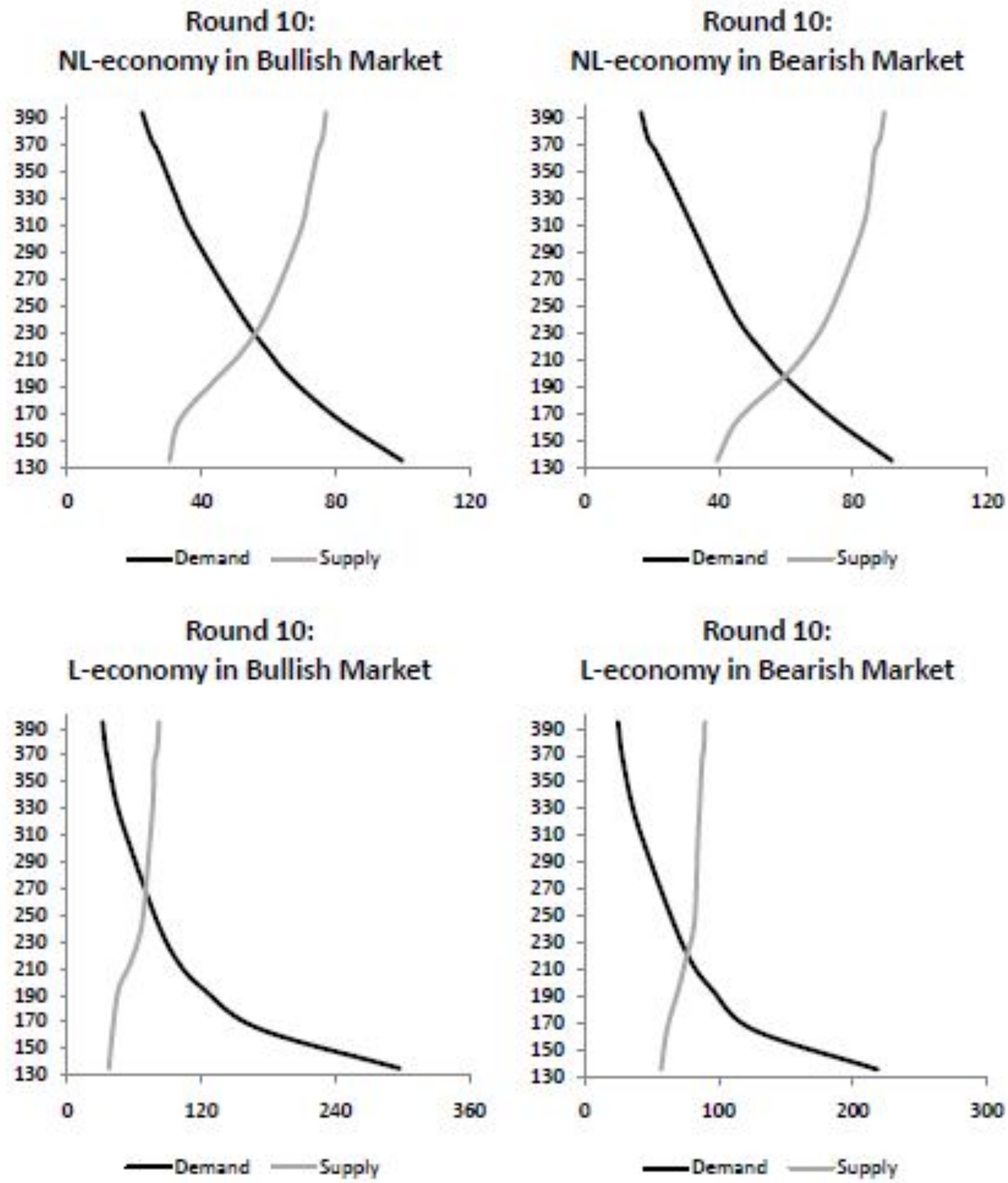
Round 10:
NL-economy in Bullish Market
Round 10:
NL-economy in Bearish Market
Round 10:
L-economy in Bullish Market
Round 10:
L-economy in Bearish Market
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Figure 17:

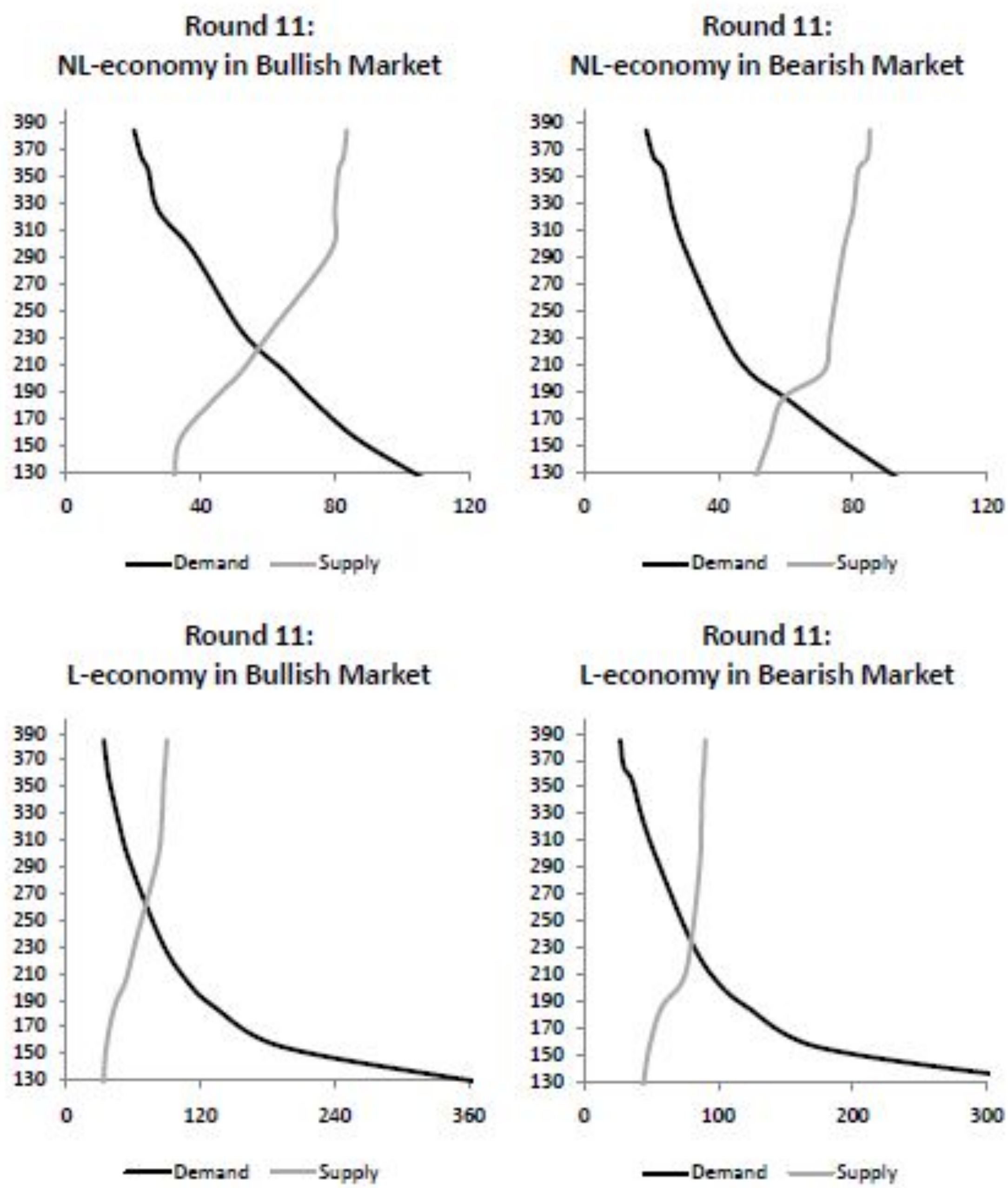
Round 11:
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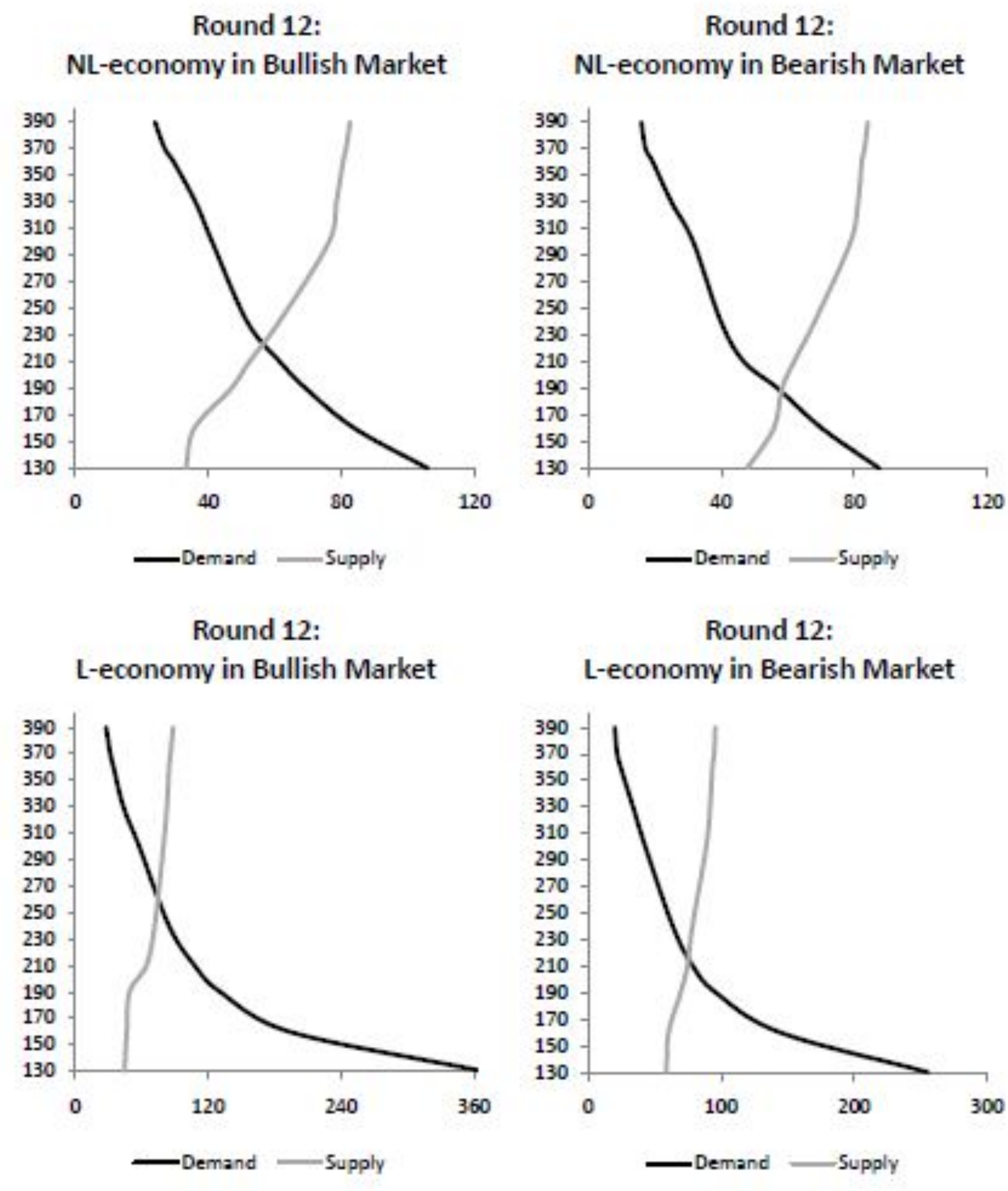
Figure 18:


Round 12:
NL-economy in Bullish Market
390 370 350 330 310 290 270 250 230 210 190 170 150 130
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Round 12:
NL-economy in Bearish Market
390 370 350 330 310 290 270 250 230 210 190 170 150 130
0 40 80 120
Demand Supply
Round 12:
L-economy in Bullish Market
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Demand Supply
Round 12:
L-economy in Bearish Market
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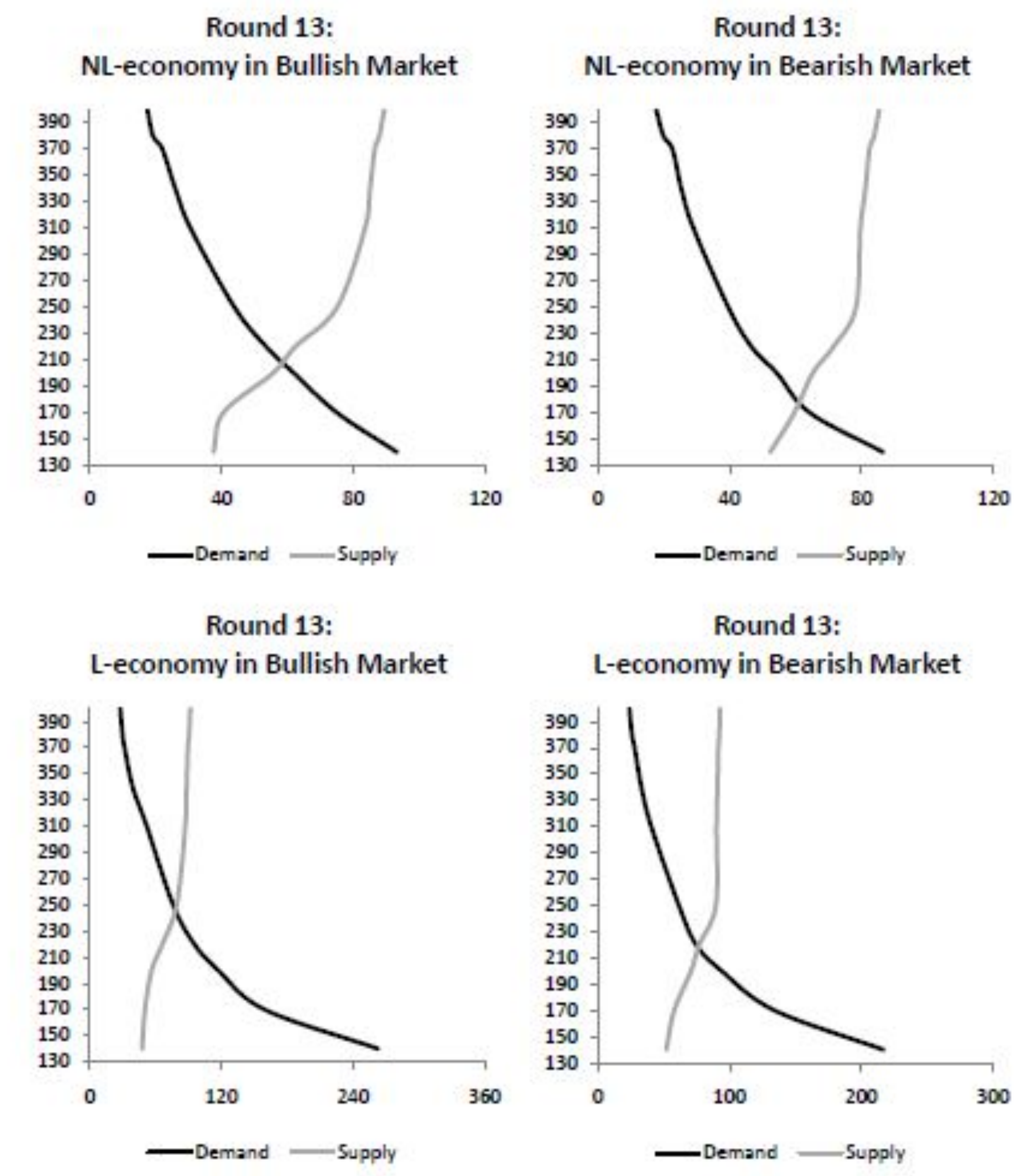
0 100 200 300
Demand Supply

Figure 19:


Round 13:
NL-economy in Bullish Market
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Demand Supply
Round 13:
NL-economy in Bearish Market
390 370 350 330 310 290 270 250 230 210 190 170 150 130
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Demand Supply
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L-economy in Bullish Market
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Round 13:
L-economy in Bearish Market
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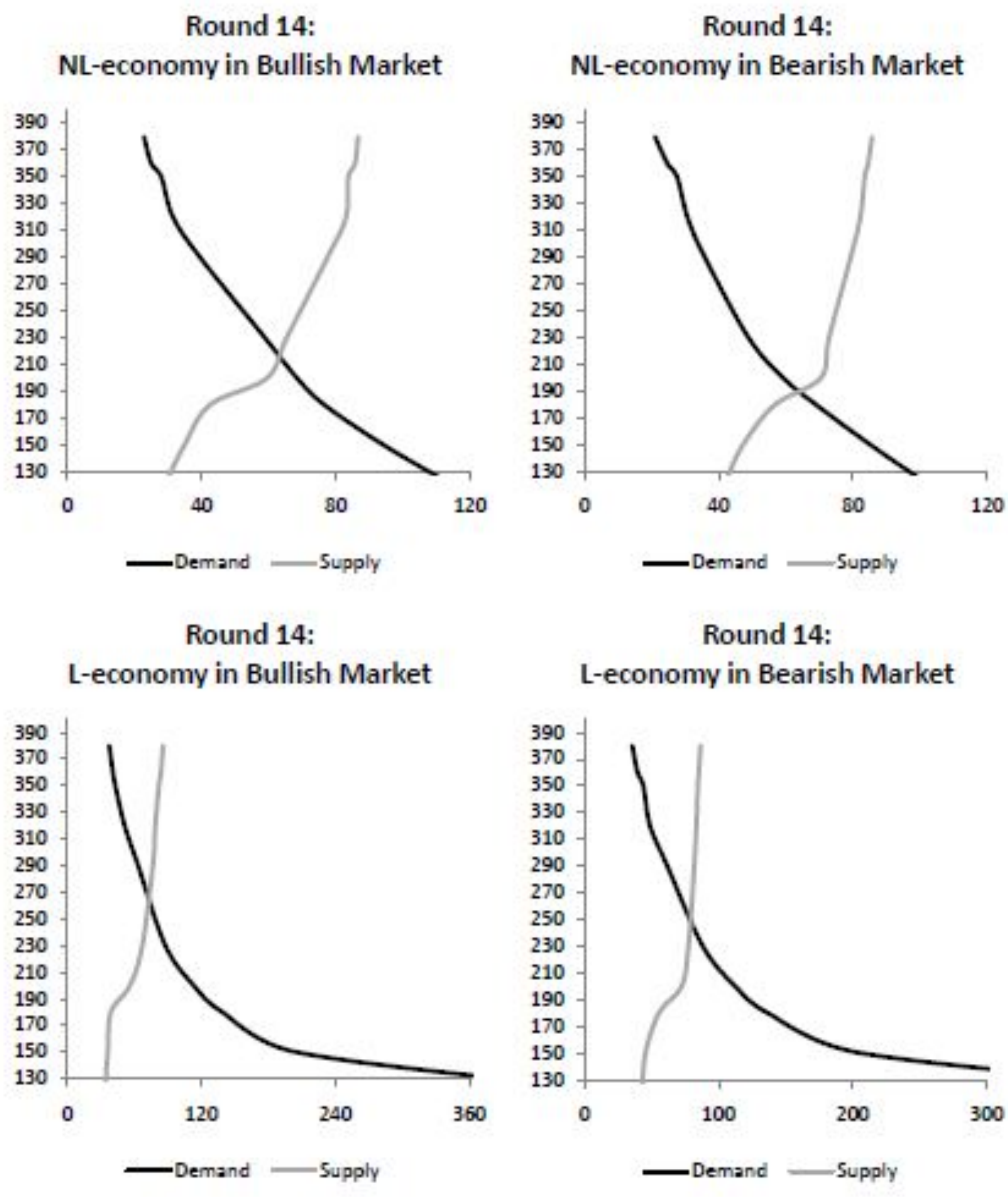
Demand Supply

Figure 20:


Round 14:
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Round 14:
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Figure 21:

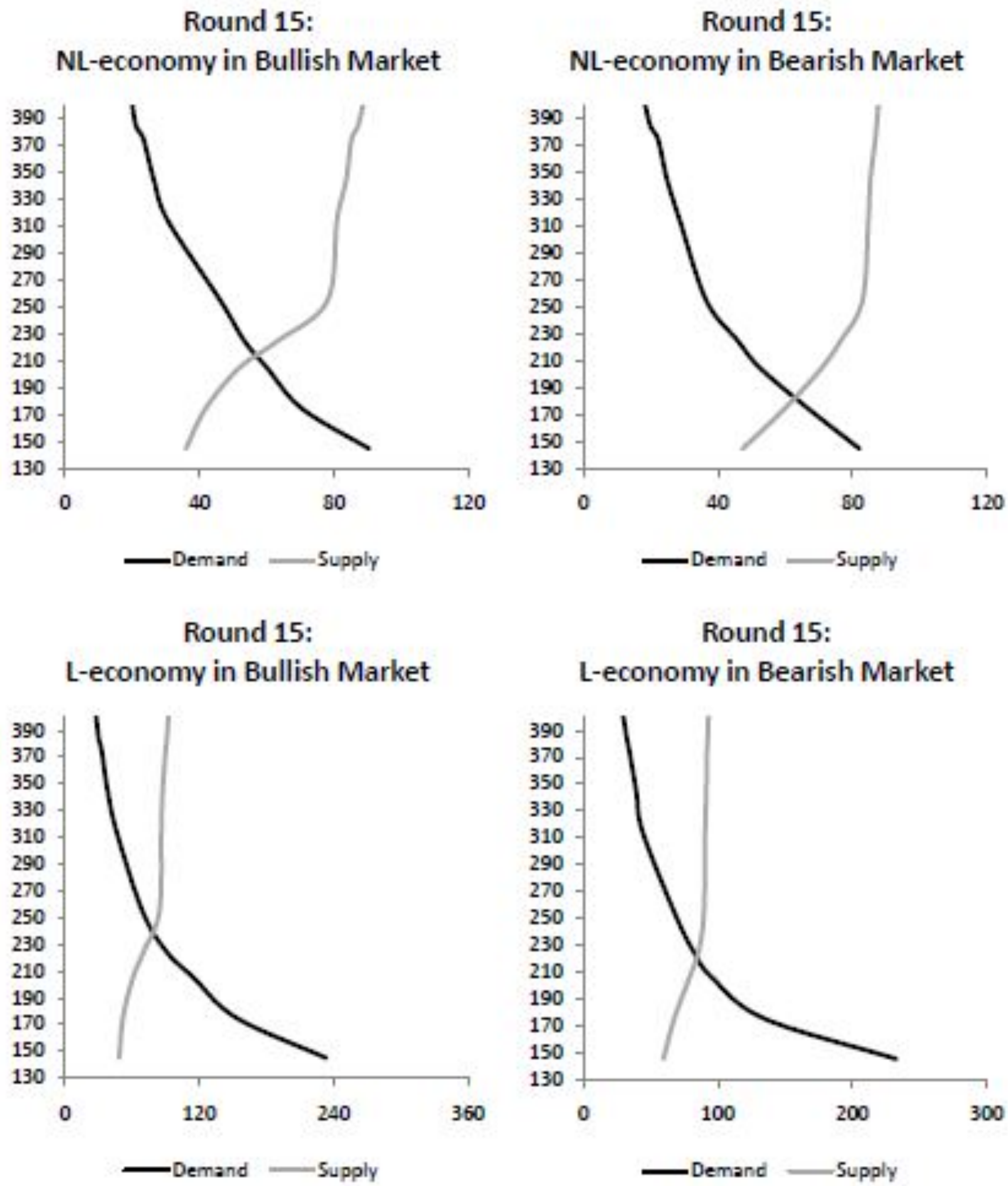
Round 15:
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Figure 22: