

Informational Content of Prices Set Using Excess Demand: The Natural Experiment of Czech Voucher Privatization

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Abstract

The natural experiment of voucher privatization in the Czech Republic is used to test whether prices that were adjusted in a limited number of discrete steps based primarily on the extent of excess demand or supply are able to fully reflect both public and private information. Early in the process, when prices reflected primarily book values determined from communist-era accounts, neither public nor private information was reflected in prices. Such information, however, did affect players' bids. As the process continued and prices were adjusted in response to excess demand and supply, the market price reflected all available information, both public and private. This finding provides strong evidence supporting the conclusions of previous limited laboratory experiments that markets provide efficient price signals, even in the presence of a large number of both informed and uninformed traders.

JEL classification: G14

Keywords: Markets; Efficiency; Auctions; Privatization

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1. Introduction

A cornerstone of economic reasoning holds that markets respond to signals from excess demand or supply to establish prices that reflect all available public and private information. Because all information is reflected in prices, this single indicator can fully inform the actions of individual agents. Every student of economics is taught the principle that “Prices convey information. They reflect all the information available to all members of society.... [Planners], no matter how benevolent, can never gather more than a fraction of the information that may be relevant to their decision - but *all* of that information is reflected in the price. (Landsburg, 1995, p. 306).”

Tests of the ability of markets to incorporate information have typically taken the form of studies of the time pattern of equity price reaction to events that might be expected to affect their prices. This literature is too extensive to summarize here (see Fama, 1991, 1998), although results tend to indicate that information is rapidly and fully incorporated into prices. Greene and Watts (1996), for example, find that market responses to earnings announcements are almost entirely reflected in the first post-announcement trade on the NASDAQ and in the first few trades on the NYSE (or the opening trade alone if the announcement was made during non-trading hours). Chen et. al. (1999) find that equity prices have fully responded to unanticipated changes in discount rates within the trading period/hour after the information is released.

Evaluation of the incorporation of private information into prices is made more difficult by the fact that such information is inherently unobservable to the researcher. Holthausen et. al. (1990) report that prices adjust quickly to large block trades (which they take as an indication of actors reacting to private information). Meulbroek (1992) finds a rapid adjustment to

(subsequently revealed) illegal insider trading.¹ Lin and Rozeff (1995) rely on the autocorrelation of daily variances in stock prices to provide an estimate of the speed of incorporation of information into prices and report that for NYSE/AMEX shares, 88.3 per cent of the eventual response to the arrival of new private information takes place within a single day while 98.6 per cent of the value of private information is reflected within two days.

Despite this research, the fact that “control over supply and demand conditions and the information provided to traders is impossible in the field” (Bronfman et. al., 1996), has meant that much research regarding the workings of price-setting mechanisms has been conducted in the laboratory.² While possessing the obvious advantage of full knowledge of each participant’s information set, laboratory studies have their own limitations. In general such studies are small scale (in terms of number of participants or assets involved), use simple rules, and have short durations (see Sunder, 1995).

Voucher privatization of state assets in the former Czechoslovakia, and later the Czech Republic, following the abrupt end of communism in 1989 provides a unique environment in which to test whether markets rapidly reflect both public and private information in prices. The voucher process was a real world natural experiment that possessed many of the advantages and few of the disadvantages of laboratory experiments. Among its advantages for a study of the ability of markets to incorporate information into prices are the following.

¹Rozeff and Zaman (1988), on the other hand, find that abnormal returns tend to cumulate for months after insider trades.

²See, for example, Joyce (1984), Friedman (1984), Copeland and Friedman (1992), Sunder (1992), Davis et. al. (1993), Friedman (1993), Friedman and Ostroy (1995), Bloomfield (1996), Bronfman et. al. (1996), Schnitzlein (1996), Cason and Friedman (1996, 1997), Lamoreaux and Schnitzlein (1997), Davis and Williams (1997), Guth et. al. (1997), Joyce (1998), Bloomfield and O’Hara (1999), and Flood et. al. (1999).

- The voucher process was a closed system with a non fungible pseudo-currency (voucher points) that could not be used to purchase anything other than shares in enterprises being privatized.
- The workings of the market were simple, i.e. one-sided (fixed supply) with limited but widely known public information and knowable (at least *ex post*) price adjustment rules.
- Initial prices were far from their equilibrium values.
- The scheme involved a large number of participants (1.5 million adult citizens plus 250 to 350 mutual funds).
- These participants differed widely in their degree of sophistication, with some being uninformed noisy traders, while others were true insiders who could be presumed to know a great deal about the companies on offer.
- Rewards were large enough to motivate participants.³
- The rapid development of equity markets following the end of voucher privatization provided an easy way of evaluating the performance of participants in the voucher bidding. It is these market prices (i.e. what participants could actually obtain for their shares) rather than any abstract, unmeasurable, concept of underlying fundamental value that we use to measure successful bidding.

The results are quite striking. We find that initial relative prices were far from their equilibrium relationship and that firm-specific financial and other information was a significant predictor of future market price. After two to three price adjustments based on a relatively simple excess demand rule, however, for all but the smallest shares on offer public data contained

³In return for a nominal investment of about \$40 (about one week's wages), plus time and energy spent in acquiring information, the typical individual who participated in the voucher scheme acquired securities worth approximately \$1,300, more than four months' wages for the average Czech worker in each of the two waves of voucher privatization.

no information about future share value beyond what was incorporated in voucher prices. Even more impressively, we find that during the first round of bidding almost all professional bidders knew which shares were undervalued at the announced prices. Once again, after two to three price adjustments, even the most sophisticated bidders, with extensive analytical capabilities and presumed inside information regarding Czech firms, were not able to identify undervalued shares. The obvious implication is that the pseudo-market had generated ‘correct’ prices in the sense that there were no remaining undervalued shares to be identified.

Section 2 presents the institutional details of the Czech voucher process. This material is presented both because it is necessary to understand the framework in which we test markets’ ability to reflect information and because some readers may be interested in this innovative privatization mechanism. We must reiterate, however, that our focus is not on Czech voucher privatization *per se*. Rather, we use this unique large-scale natural experiment to evaluate fundamental workings of markets. At the same time, it is important to recognize that we only analyze the informational efficiency of the quasi-market that involved in the voucher privatization process. We are unable to say anything from this analysis about the efficiency of the Czech stock market itself. Section 3 examines formally the extent to which even the relatively crude market mechanism underlying the voucher privatization process was able to fully reflect both public and private information in prices.

2. The voucher process

Early in 1991, slightly over a year after the fall of communism, the Czechoslovak⁴ government began the process of privatizing large companies.⁵ The distribution of former state assets to citizens relied extensively on a unique pseudo-market mechanism that came to be known as ‘voucher privatization.’

2.1. Selection of firms to participate

The first step in the process involved determining the method of privatization. Managers of firms included in large-scale privatization submitted ‘basic projects’ outlining their preferred methods of privatization from among direct sale, public auction, insider buyout, and participation in the voucher privatization scheme. Proposals could involve more than one method. These basic projects could be challenged by any interested party who could submit a competing proposal. On average between five and six proposals were received for each firm undergoing large scale privatization. Perhaps reflecting superior information regarding the prospects of their firms, management proposals were more than twice as likely to be accepted as those from other

⁴Voucher privatization began under the Czechoslovak federal government and initially applied to the entire former Czechoslovakia. Following the split of the country on January 1, 1993, voucher privatization continued in the Czech Republic only. Records were kept independently for both firms and participants in the two halves of the country and we examine only the Czech data. In addition, in early 1993 the former Czechoslovak crown (abbreviated Kčs) was replaced by the Czech crown (Kč). Since their value relative to the dollar was the same, crown will be used interchangeably to refer to the currency in use on a particular date.

⁵Other programs not discussed here privatized small and medium-sized enterprises, housing, and agricultural land (see Kotrba and Svejnar (1994), Kotrba (1995), and Valbonesi (1995) for a summary of these programs). Given the concentration in communist Czechoslovakia, the bulk of the country's assets were involved in large scale privatization.

sources, constituting 20 percent of proposals but over 50 percent of those accepted. The possibility that an alternative proposal could be chosen, however, served to limit managements' ability to design privatization projects that served their own interests rather than those of the public.

More than 7,000 units (firms or parts of firms) were privatized during large-scale privatization. The successful plans for more than three-quarters of these involved either sale at auction, sale to a specific bidder, transfer to local government or restitution to former owners. However, with an average unit value of about \$800,000,⁶ the units transferred via these mechanisms were typically small and accounted for only 14 percent of the value in the program.

The remaining 1,777 enterprises, with an average book value of \$17 million, were turned into joint stock companies. Of these, 1,664 (94 percent) had some or all of their equity included in voucher privatization. The total book value of the equity privatized through vouchers was more than \$14 billion, about 10 per cent of the Czech Republic's national wealth. The largest firm involved in the first wave of voucher privatization was ČEZ, the national electricity monopoly, which had 30 per cent of its equity with a book value of almost \$600 million included. The second largest stake in the first wave was in Škoda Plzeň, a large engineering firm which included 49 per cent of its equity with a book value of slightly less than \$200 million. In the second wave, the mining company OKD (Ostrava) had the largest book value included (about \$450 million), followed by a 26 per cent stake in the telephone company (SPT Telecom), with a book value of about \$250 million.

⁶All values are based on the book value under local accounting rules and are converted at 25 crowns per dollar, approximately the value of the crown throughout the privatization process. As we will see below, these book values should be taken as only very rough indications and often bear little resemblance to actual market values once ownership stakes could be freely traded.

2.2. *The voucher bidding process*

Voucher privatization took place in two waves, each involving several bidding rounds. To prevent strategic end game behavior, the exact number of rounds was not announced until just prior to the final round (round 5 in the first wave and round 6 in the second wave). The first wave involved shares in 988 firms. The second included shares in an additional 676 firms plus unsold shares in 185 firms carried over from the first wave. Table 1 presents a chronology of the key events in each wave. Every citizen over the age of 18 could purchase a book of 1,000 voucher points for 1,000 crowns, about one week's average wage. Approximately 6 million Czechs (about 75 percent of those eligible) participated in each wave, making the book value of the shares available slightly more than 35,000 crowns (\$1,400) per participant in the first wave and 25,000 crowns (\$1,000) in the second wave.

Participants could bid for shares themselves or assign their voucher points to an investment privatization fund (IPF) in return for a share in the fund.⁷ In the first wave 72.2 percent of participants turned their points over to one of 265 IPFs. In the second wave a somewhat smaller 63.5 percent of participants assigned their points to one of 349 funds. The legal structure of IPFs resembled closed-end mutual funds. The funds were administered and the points bid by fund management companies founded by local and foreign financial institutions as well as individuals. It was common for a management company to establish several funds.

In each wave the number of shares to be sold in a firm was established by dividing the book value of the firm's equity in the voucher scheme by a fixed initial 'price' (33.3 points per

⁷Any fraction of an individual's points (in multiples of 100 points) could be turned over to a fund but this transaction had to be done prior to the start of the first round of bidding. See Allen and Smidkova (1998) for a discussion of households' optimal behavior.

share in the first wave and 50 points in the second). A common set of information on each firm was assembled and verified by the Ministry of Privatization and the Voucher Privatization Agency. This information was published in booklet form, reprinted in newspapers, and made available to bidders on diskette. It included sales, employees, debt and profit for the years 1990 through the last year prior to the bidding, the eventual ownership structure of the firm,⁸ and information regarding the firm's basic industry and region of operations. Given that firms had only recently been corporatized, there were no annual reports, disclosure statements or other additional public information available. Thus, the set of information produced by the voucher authorities can be assumed to comprise all information generally available to bidders.

Individuals and funds announced how many shares they would like to purchase (subject to their endowment of points and a restriction that the number of shares demanded for any given firm must cost at least 100 points) at the announced prices. At the end of each round, shares were allocated and prices were adjusted for the following round based on the ratio of demand to available shares in the round just completed (excess supply or demand).

Shares were allocated in each round according to the following set of principles.

- 1) If demand were less than supply, all demands were satisfied and the unsold shares were carried forward to the next round.
- 2) If demand were greater than supply, but less than 125 percent of supply, all bids from individuals were satisfied, while bids from investment funds were satisfied on a pro rata basis, provided that the funds were allocated at least 80 percent of their bid amount. The firm was then completely sold out and not available in future rounds.

⁸Recall that most firms allocated only a portion of their shares to the voucher process.

- 3) In all other cases, no shares were sold and all shares were carried over until the following round.⁹

Between rounds the public information was updated by providing revised prices and the total demand for each stock by individuals and investment funds in the previous round.¹⁰

Although in theory every share in round 1 represented an equal book value, it was clear that these

⁹We do not consider strategic behavior on the part of bidders. There are two such behaviors that could potentially be important. The first is the issue of the ‘winner’s curse’ whereby bidders who overvalued shares (thereby entering a large bid when other who assigned a proper value were not demanding the share) ended up with their misperceived demands satisfied (see Rock (1986) for a discussion of this issue in the related market for initial public offerings). The voucher scheme is more complicated in that the bidding currency cannot be invested elsewhere or used for consumption, so its only possible use is to bid on shares that may be misvalued. Indeed, the possibility of the winner’s curse would be greatest for shares that a bidder felt were seriously undervalued, yet for such shares bidders would most likely find themselves budget constrained and not able to exercise their full desired purchases, thereby rendering the issue of shaving demand to avoid winner’s curse moot. Finally, we use bidders’ behavior only in our study of inside (private) information. As Kagel and Levine (1999) have shown, in auctions with asymmetric information it is uninformed outsiders who are likely to suffer from a winner’s curse. Thus, any strategic behavior based on knowledge of the winner’s curse should be greater for outsiders than insiders, reinforcing the connection between private information and share demand. A more serious potential area for strategic behavior involves the allocation rules for shares in excess demand. In theory bidders who suspect that a share is seriously undervalued face a trade-off between bidding on that share, with a low probability of success (since there is likely to be significant excess demand) but a high payoff if successful, or bidding on less undervalued shares with a lower payoff but higher probability of success. In practice such behavior should be a function of public information, when many bidders would know that shares are undervalued but much less affected by private information known only to a particular bidder. While interesting theoretical possibilities, neither discussions with individuals involved in the process nor subsequent econometric investigation has provided any evidence of strategic behavior designed to avoid winner’s curse effects or the possibility of exceeding the 125 per cent threshold. In general, it appears as if bidders behaved as autonomous units in a competitive market.

¹⁰Czech voucher privatization thus resembled, but was not identical to, any classical market mechanism design. It was not, as some have claimed, a Walrasian tâtonnement (see Hillion and Young, 1996), since demands were satisfied prior to determination of the equilibrium price and there was no recontracting. It bears some resemblance to a multi-unit Dutch auction, although there were several key differences including the fact that the initial price was set at a supposed approximation of the true equilibrium price rather than a price higher than the reservation price of any individual bidder.

accounting values did not represent the actual attractiveness of the firms. Thus, at the announced price of 33.3 points per share, the ratio of demand to available supply in round 1 of the first wave ranged from less than 1 percent to 14,540 percent. The lowest demands were for regional units of the bus network as well as for the aircraft manufacturer Aero (which developed serious financial problems before being sold to Boeing at a nominal price). The highest demands were for five-star hotels in Prague and western Bohemian spas.

Clearly, if equilibrium were to be established in this market, the updating of prices between rounds was critical. By round 2 of the first wave, prices ranged from 10 points per share for the bus companies, Aero, and ČKD Praha, a large and financially troubled engineering company, to 400 points per share for the Palace Hotel in Prague. By the final round prices varied from 1.67 points per share for two of the bus companies to 1000 points per share for several hotels.¹¹ A similar pattern can be seen in the second wave, where, after the second round, prices ranged from 4 points per share to 500 points per share, while by the end of the process the share price ranged from 3.7 points for various bus companies to 1000 points for Sativa, a large agricultural supplier of seeds which attracted numerous bids from farmers. In general, the firms with the greatest excess demand and the highest final price were heavily demanded by individual investors rather than investment funds.

¹¹The upper limit of 1,000 points per share resulted from a policy decision that no share should be priced so high that an individual did not have a theoretical possibility of bidding for this share given that the number of points available to an individual was limited to 1,000. One can argue whether this was a wise policy since it may have induced individuals to bid on shares condemned to be in excess demand at an artificially low price, thereby wasting their points entirely. In any case, it affected shares in only eight companies.

2.3. *Repricing strategies*

A Pricing Commission in the Ministry of Finance adjusted prices between each round. The announced goal of this commission was to adjust prices so that by the end of the process citizens had used all their points while distributing as many shares as possible.¹² Although the Pricing Commission did not announce its decision rules in advance and retained considerable discretion in actually adjusting prices, it has been possible ex post to discover the basic algorithms both through release of internal documents and econometric analysis (see Krcmar, 1992; Svejnar and Singer, 1994; Hillion and Young, 1996; Hlavsa, 1996; Hingorani et. al., 1997).

A simplified version of the price adjustment rules goes as follows. In each round the Commission established a new baseline price by dividing the total remaining points by the number of unsold shares. It then established four intervals based on relative demand, defined as the ratio of shares demanded to shares supplied. The four intervals were based on two endogenous break points as well as a third break point where demand equaled supply (so the relative demand was equal to 1): $(0, \rho_{\min})$, $(\rho_{\min}, \rho_{\max})$, $(\rho_{\max}, 1)$, $(1, \infty)$. Shares with relative demand below ρ_{\min} were offered at a lower relative price (e.g., a lower fraction of the baseline than in the previous round), with the degree of reduction such that if the price elasticity of demand were unitary all shares would be sold in the subsequent round. Firms where the relative demand was between ρ_{\min} and ρ_{\max} were offered at the same price relative to the baseline in the following round. This involved an adjustment in the absolute price per share since the number of voucher points remaining per share changed between rounds depending on what was bought in the previous round. Thus, in round 2 of the first wave, firms with demand

¹²There is some evidence, however, that the authorities created a general overvaluation of shares to leave the government holding some unsold shares, allowing it to raise funds through future sales in the secondary market (see Hillion and Young, 1996).

to supply ratios of less than ρ_{\min} (0.20 for this round) were offered for between 10 and 12 points per share as opposed to 33.3 points per share in round 1, while those between ρ_{\min} and ρ_{\max} (0.2 and 0.67) were offered at 14.28 points per share. Firms with relative demand above 1 (assuming that they were not completely sold out) were offered at a higher relative price in the following round, again with an assumption of unitary elasticity of demand used to set the degree of increase. The interval that at first may appear strange is between ρ_{\max} and 1, where relative prices were increased even though there was excess supply. Recall, however, that all orders for shares in excess supply were filled in the prior round. Thus, if only a very few shares carried over into the subsequent round, a relative price increase might be needed to prevent this stock from facing excess demand in the next round. A stylized representation of the price adjustment rule is given in Fig. 1.

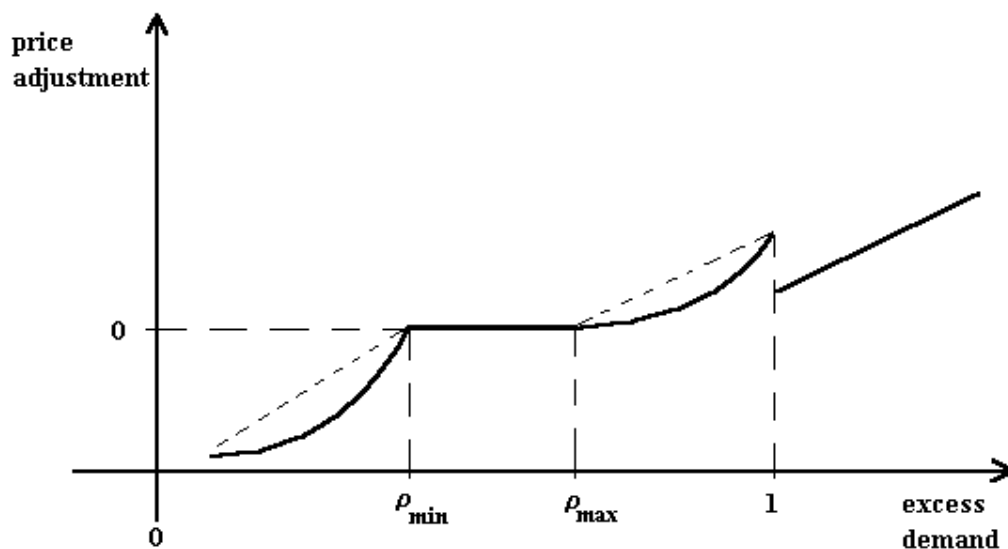


Fig. 1. Price adjustment mechanism

In later rounds the basic rule was augmented by also considering the number of shares remaining as well as the entire history of excess demand and supply. Minor weight was also placed on region and industry. The key role played by the extent of excess demand in price adjustment process can easily be seen in Table 2, which presents the pattern of price changes between rounds.

Econometric results confirm the importance of excess demand. Working before the full pricing rules were widely known, Svejnar and Singer (1994) were able to predict share prices in each round of the first wave with an adjusted R^2 of between .92 and .99 using an equation containing only lagged share prices, number of shares remaining and a cubic in excess demand from the previous round. Thus, even though the utility function of the pricing commission may have included arguments other than getting relative prices right, in practice they relied heavily on the one signal economic theory argues is all that is required for markets to obtain proper relative prices - the extent of excess supply or demand.

2.4. *Public trading after voucher privatization*

Once shares from voucher privatization were distributed, vigorous secondary markets developed. The Prague Stock Exchange (PSE) began in the spring of 1993 with weekly trading sessions that rapidly increased in frequency, so that by October 1994 trading was conducted daily. Volume increased from \$3.1 million in October 1993 to \$92.3 million in March 1994. Once stocks from the second wave were introduced in the spring of 1995, volume increased again so that by the end of 1995 monthly trading reached \$1.2 billion.¹³ Participants in the secondary

¹³Trading on the PSE actually represents a minority of total transactions. A smaller number of sales take place on the parallel RM System that arose out of the centers that processed voucher purchases and mainly serves small investors. The majority of trades take place directly
(continued...)

market included not only the IPFs from voucher privatization (who consolidated and rearranged their holdings) but also both domestic and international individual and institutional investors. These market-determined share values provide a benchmark that enables analysis of whether the voucher prices reflected both public and private information.

It must be made clear, however, that we make no assertion about the efficiency of these secondary markets (for discussions of this issue see Filer and Hanousek (1999) and Hanousek and Filer (1999a)). Rather, we make the much more limited assertion that a major goal of the participants in the voucher privatization auction was to assemble the highest-valued portfolio possible.¹⁴ In this context, since the secondary market reflects the prices at which participants could eventually sell the shares acquired in the voucher process, it represents the appropriate value at which to evaluate this process. In effect, we simply accept that, for participants in voucher privatization, the value of shares is what they could sell those shares for later rather than some abstract fundamental value that they are unable to realize.

3. The role of information

Information can be of two types, public or private. Public information is known (or knowable) to every market participant while private information is available to only one

¹³(...continued)
between buyers and sellers and are registered at the central Securities Register without going through either of the formal exchanges.

¹⁴To the extent that participants had other goals as well, the impact will be to lower the predictive value of our estimated equations.

participant in the market.¹⁵ It is important to note that private information does not have to be illegal or improper. Indeed, as used here, private information refers not only to facts about firms and their future prospects unknown to other bidders, but also to idiosyncratic abilities to interpret public information.

3.1. Methodology

As discussed above, one of the unique features of the Czech voucher privatization process is that a common set of public information was freely provided by the privatization agency to all bidders and is, therefore, easily observable to the researcher. Meanwhile, given the centralized administration of the voucher process, complete records of the bids of every participant for every firm in every round are available, providing a reasonable proxy for the extent of private information. If possessors of such information use it to inform their bidding, then, conditional on the public information, voucher price, and number of shares available, bidders with private information that the current voucher price undervalues a firm should allocate more of their available points to that firm.¹⁶ Private information that the voucher price overvalues a firm, on the other hand, should result in bidders allocating fewer points (probably none) to that firm.

¹⁵These are obviously limiting cases, with most information being neither totally public nor totally private. One might call information known to some but not all market participants ‘semi-private’ (or ‘semi-public’).

¹⁶Note that participants may have had goals other than maximizing the value of their portfolio. In particular they may have sought controlling interests in firms. Some funds (although not typically the larger funds analyzed here) may also have sought specific situations favorable to asset appropriation or other illegal or quasi-legal maneuvers. Thus, private information may not be the only determinant of investment funds’ demand for individual shares. As long as portfolio value is an argument of the funds’ objective function, however, we would still expect to see a positive correlation between demand and eventual price.

The extent to which the prices established in voucher privatization reflect all available information is analyzed using three equations. Each starts with the assumption that the price established in the secondary market after trading has begun reflects the value of these shares to those who acquired them during the privatization process. This price, therefore, can be used as a benchmark for evaluating the information content of voucher prices. With respect to public information, we compare the predictive ability of an equation that includes *only* information generated during voucher privatization (e.g. voucher prices) to the predictive ability of equations that also include measures of public information. The test of whether such information has any value is whether it produces a significant increase in explanatory power over the naive equation conditional on the fact that the naive equation includes voucher prices, and, therefore, the information incorporated in these prices. These estimated equations are:

$$\ln MP_i = \sum_{r=1}^R \beta_r \ln VP_{ir} + \sum_{r=1}^R \delta_r \ln S_{ir} + \epsilon_{iR} \quad (1)$$

and

$$\ln MP_i = \alpha_R + \sum_{r=1}^R \beta_r \ln VP_{ir} + \sum_{r=1}^R \delta_r \ln S_{ir} + PI_i \gamma_{iR} + \epsilon_{iR}. \quad (2)$$

Each equation was estimated separately for each round and predicts the market price (*MP*) of shares in firm *i* in round *R*¹⁷ as a function of the series of voucher prices (*VP*) for that stock and the series of the number of shares remaining (*S*). Remaining shares are included because, as was shown in Fig. 1, the Pricing Commission deliberately mispriced shares that had almost completely sold in previous rounds in order to reduce the probability of excess demand for these firms. Eq. (2) adds to these predictors a vector of public information variables (*PI*) regarding the firm. Eq. (2) also includes a constant term which was omitted from Eq. (1). This constant term, which should serve to improve the predictive accuracy of the equation, is also a measure of

¹⁷Note that although we estimate Eqs. (1) through (3) separately by round (*R*), there is only one market price (*MP*) for each firm, established on the PSE after trading began.

public information. Recall that the number of shares in each firm was set to give a constant book value per share across firms. Since the book value is properly a part of the public information set, inclusion of a constant term in Eq. (1) would be equivalent to including substantial public information in that equation.

In order to investigate the presence of private information, we assume that firms possessing such information will use it to inform their bids. We therefore estimate

$$B_{jir} = \alpha_{jR} + \sum_{r=1}^R \theta_{jr} \ln MP_j + \sum_{r=1}^R \beta_{jr} \ln VP_{ir} + \sum_{r=1}^R \delta_{jr} \ln S_{ir} + PI_i \gamma_{jiR} + \epsilon_{jiR} \quad (3)$$

independently for each bidder j , where B indicates the demand by that bidder for shares in the individual firm. Our assertion is that, conditional on public information (including the voucher price), private information about the future market price will lead to a positive relationship between $\ln MP$ and B .

Because the final voucher prices were partially used to establish initial prices for shares on the PSE and the exchange limited daily moves in each share to five percent, market prices (MP) were observed four months after trading began for shares from each wave. By this time relative prices appear to have stabilized in an equilibrium relationship.¹⁸ Given that the market prices used to evaluate bidding performance were observed several months after the end of the voucher process, they will at best be only partially predicted by voucher prices and information available during the voucher process. In addition, the market prices will also reflect any new

¹⁸The average price for shares between the start of trading and the end of 1996 was also used as a dependent variable. Results reported below were unaffected by the use of the alternative measure of market value.

information since voucher bidding ended.¹⁹ Indeed, the correlation between stock prices in January 1994 (our evaluation date) and those in January 1995 is 0.80, while the correlation with January 1996 is only 0.60.

3.2. *The role of public information*

The value of public information is determined by analyzing whether it adds to the ability of voucher prices to predict future market prices, i.e., whether Eq. (2) better predicts the eventual market price than Eq. (1). As discussed above, the public information available about each firm consisted of its eventual ownership structure, region and industry of operations, and figures on sales, employment, debt and profitability for the previous three years. The only modification we make to the raw data as produced and verified by the Privatization Ministry is to reduce the dimensionality of the problem by extracting common factors. For estimation purposes, the public information set was replaced by orthogonal factors extracted from within each subset of the data (ownership structure, region and industry, and economic variables). In each wave we used any factor with an eigenvalue greater than 1.0. Together these factors accounted for approximately 75 percent of the variation within each group of data.²⁰ While the use of factors was primarily to reduce the scale of the equations estimated, it also assisted in dealing with missing values in

¹⁹The arrival of new information since the end of the bidding process cannot negate our results. Suppose that the new information at least partially determines the market price. There are two possibilities with respect to how this might influence our results. If the recently arrived information is uncorrelated with prior information, it cannot affect the estimated coefficient in a regression of current price on previously available information. On the other hand, if recently arrived information is correlated with prior information, the effect of omitting it will be to make the old information look more valuable than it actually was, biasing results against the hypothesis that voucher prices incorporated all information available at the time of the auction.

²⁰Since our interest here is not in the evaluation of the public information *per se* (for a discussion of this see Shafik (1995), Hingorani et. al (1997), and Hanousek and Kroch (1998)), we do not report the specifics of these factors here. Their exact specification is available at http://home.cerge.cuni.cz/hanousek/voucher_bids.

the data that were likely to have been known to investors even though not available for research purposes.²¹

Table 3a presents F-tests of the additional explanatory power provided by adding public information to Eq. (1).²² Several results stand out. First, there is a strong relationship between the voucher price and the market price in every round after the first. Even though the market price is measured from 12 to 18 months after the voucher rounds ended, and can, therefore, be expected to reflect numerous subsequent developments as well as the entry of significant additional players to the market, voucher prices alone are able to explain between 50 and 60 percent of the variation in market prices. This predictive power increases between round 2 and round 3 in each wave, but basically remains constant for the remaining rounds, indicating that two price-adjustment iterations based on excess demand were sufficient to stabilize the market.

Public information, on the other hand, clearly plays a much less important role. In round 1, when there was no variation in voucher prices, public information regarding the firms was able to explain only 12 to 24 percent of the eventual variation in these firms' value. In later rounds, while public information provides a statistically significant addition to the ability of voucher prices to predict market values, the additional fraction of the variation explained is, in practical terms, quite small, ranging from 2.5 to 4.3 percent of the total market value, less than 10 percent

²¹There is no gain or loss of information from orthogonalizing the factors. We did so because initially we had hoped to be able to say something about the determinants of eventual voucher prices and hoped that making the factors orthogonal would aid in this analysis. In the end, however, any analysis of this type was too speculative for our tastes and we decided not to pursue this line of research.

²²As discussed above, we are interested in the aggregate ability of the full set of information to add to our ability to predict future market prices, not in any individual coefficient (e.g. the apparent influence of a particular factor on price). Because of this (and because of space limitations) we do not report the full set of 297 estimated equations (11 variants of Eqs. (1) and 2 (5 rounds in Wave I and 6 rounds in Wave II) and 275 variants of Eq. (3) (25 bidders times 11 total rounds) on which our analysis is based, The full set of estimated equations is available for inspection at http://home.cerge.cuni.cz/hanousek/voucher_bids.

of the proportion of market value explained by the voucher prices. Thus, it would appear that the voucher prices successfully incorporated the vast bulk of public information about firms.

There are several possible reasons why a small amount of explanatory power from public information may not have been reflected in the voucher prices. Perhaps most importantly, it is widely acknowledged that efficient markets will only incorporate information to the extent that the cost of analyzing it can be recouped through the excess returns to be earned. Some firms involved in Czech voucher privatization were quite small,²³ while others had only a small share of their total value available in voucher privatization. The frequency of small stakes included in the voucher process can be seen by comparing the mean book value of the portion of each firms' assets included in voucher privatization (\$286,000 in the first wave and \$360,000 in the second wave) to the median book value of those assets (\$110,000 in the first wave and \$135,000 in the second wave).

To investigate whether the voucher process more accurately priced firms with significant value being privatized, we divided the firms in each wave into three groups. The division points between groups were arbitrarily chosen to be the multiples of 100,000 shares that resulted in subgroups consisting approximately of the 100 firms with the largest value privatized through vouchers, the 200 firms with the next largest stakes, and the balance of the firms in each round. This division produced groups of firms with a book value sold through vouchers of more than \$800,000 in the first wave (\$1,600,000 in the second wave), between \$300,000 and \$800,000 (between \$600,000 and \$1,600,000), and less than \$300,000 (\$600,000).

Table 3b presents the results of repeating the analysis of the value of public information for these three subgroups of firms. Clearly, the voucher process did a better job in each wave of

²³Recall that the *average* book value of firms involved in voucher privatization was only about \$17,000,000. Since some firms were substantially larger than this average, some firms must have been well below this average.

predicting the market price of the large and medium capitalization stakes than it did of predicting the value of the firms with fewer shares involved. Public information not reflected in voucher prices is restricted to firms with low equity value in the process. There is little, if any, evidence that public information is not fully reflected in prices by round 2 in each wave for the firms with the greatest value in the voucher process, or by the final round for medium capitalization enterprises. Since the large capitalization firms represent the vast majority of value included in the voucher process,²⁴ the obvious conclusion is that these simple pricing adjustment rules based on excess demand enabled all relevant public information to be rapidly and fully reflected in prices, provided only that sufficient reward existed to motivate investors to analyze this information.

3.3. *The role of private information*

The relatively low R^2 values for round 1 of each wave in Tables 3a and 3b indicate that the available public data did not fully reflect the true value of firms in the voucher process. This finding is not surprising since performance prior to privatization should be only loosely related to a firm's potential for success once restructured and reoriented to world (or significantly changed domestic) markets. Presumably participants in the voucher process possessed additional, private information about the future potential of the firms on offer. Indeed, the design of the privatization mechanism meant that an individual or group with private information

²⁴These firms comprised 63 percent of the book value and 76 percent of the market capitalization (as determined by prices four months after trading began) included in the first wave and 68 percent of the book value and 85 percent of the market capitalization in the second wave. When the medium capitalization firms are included, the total fraction of book value and market capitalization in firms where voucher prices fully reflected public information rises to 84 percent and 92 percent for the first wave and 86 percent and 95 percent for the second wave.

could only take advantage of that information by forming an investment fund and bidding for shares rather than bidding for all or part of a firm directly.

The presence of superior (i.e. non-common or private) information (either in terms of factual knowledge or analytical ability) by bidder j in any round should be revealed by a positive coefficient $\theta_{j r}$ on future market price in Eq. (3) for that bidder and round.

It should be noted that this test of the existence of private information is not identical to a conventional test of whether markets are efficient (i.e., whether it is possible to earn an excess return by using private information). In particular, the design of the voucher bidding process meant that even individuals who acted on private information to demand undervalued shares might be unable to purchase them and, therefore, benefit from their private information due to excess demand for these desirable shares. The test of whether investment funds possessed private information is also not a test of whether individuals would have done better investing with such funds than they could do investing on their own.²⁵

Eq. (3) was estimated separately by round for each of the 25 largest privatization fund managers in each wave.²⁶ We also estimated a similar equation for all individual investors, taken as a group. Even in the first round of each wave, the coefficient on the market price in the

²⁵In results not reported here we have found that because of private information in the early rounds, the market value of the portfolio actually purchased by IPFs on average exceeded that purchased by the typical individual investor (or a random bidding process) although by the later rounds randomly allocating points to the remaining shares was able to do as well as the actual performance of funds. Because IPFs in the Czech Republic have typically traded at a substantial discount from their net asset values, however, investors who purchased stocks on their own may have ended up with a more favorable cash position if they exchanged equity for cash before 1998. In early 1998 Czech law was amended to require funds to convert to open ended status if their discounts exceeded a fixed and falling level so that investors who remained in funds until this conversion took place would generally have done better than if they invested their points themselves.

²⁶These 25 largest fund managers (in terms of points assigned to funds they ran) controlled 87 funds and 83 percent of all voucher points assigned to funds in the first wave. The 25 largest fund managers in the second wave (with 74 funds) controlled 78 percent of the points assigned to the funds.

equation predicting the share demand of individual investors was identically equal to zero (and very precisely estimated), indicating that these investors had no private information regarding which shares were undervalued. Table 4 shows the number of the twenty-five largest fund managers in each round where future market price significantly determines share demand after controlling for public information. The results show that funds possessed private information at the start of each wave. In round 1 of the first wave, future market value was significantly related to current share demand for 23 out of 25 fund managers even after controlling for public information. In the second wave, all 25 of the largest fund managers apparently possessed information beyond the general public information in round 1. As expected, in every case the sign of the coefficient relating the eventual market price to the fund's allocation was positive.²⁷

As seen in Table 4, the extent of this private information dropped off substantially in later rounds.²⁸ By round 3 of each wave, only 20 percent or fewer of the fund managers possessed information beyond that reflected in public information including voucher prices, while the extent of this information (as indicated by the significance level of the coefficients) was

²⁷The design of the test does not allow us to make an easy inference regarding the actual value of this inside information. In other work Hanousek and Filer (1999b) we have compared the relative performance of professional investors (i.e. mutual fund managers) and individual investors (who we show above had no private information). The average market value per voucher point of shares bought in the first round by uninformed individual investors was about 75 per cent of that per point spent by investment funds in the first wave and 85 per cent of the value per point spent by funds in the second wave (when we argue that funds had less private information due to the fact that a substantial fraction of the shares available were also trading on the open market). By the fifth round the ratio of value obtained per point spent by individuals and to that of funds was 98 percent in the first wave and 108 per cent in the second wave, strongly suggesting that funds no longer possessed superior information. Overall, these results suggest that private information (including idiosyncratic processing ability) increased the value of funds' eventual portfolio by between 15 and 25 percent.

²⁸In fact, the way our test was constructed is biased against the finding of no private information since we hold public information constant at what was available at the start of each wave of the voucher process. Presumably since this process took at least a year for each wave, new public information would arrive continually during this period and be known to (and used by) bidders even though it was unknowable for the purposes of our econometric estimation.

substantially smaller. In rounds beyond the third, voucher prices apparently reflected all information about firm value and future market price no longer had any relationship to the demands of fund managers once public information had been taken into account.²⁹

Although a positive and significant coefficient on eventual market price in determining bids by a fund operator indicates that the management company possessed private information, there is not a monotonic relationship between the size of the coefficient and the extent of this information. There is, however, such a relationship between the extent of private information and $\rho_{B,MP}$, the partial correlation between bids and market price, holding constant other variables in Eq. (3). Thus, in comparing the extent of private information across rounds or the types of firms that possessed the most such information, we will focus on the partial correlation coefficients.

The declining importance of private information across rounds is easily seen in Figs. 2.1 through 2.6, which show the 95 percent confidence intervals for the partial correlation coefficients between the share of available points allocated to firms and eventual market prices for each of the 25 largest fund groups in three rounds for each wave.³⁰ The conclusion that information possessed by management firms at the start of the process was incorporated into prices by the later rounds is reinforced by the fact that in neither wave was there a significant correlation between the firms with the highest partial correlation coefficients (most inside

²⁹The only apparent exception is in round 6 of the the second wave. Prices in this wave may have been severely distorted by the desire of the authorities to ensure that all shares were sold (a factor less important in the first wave when unsold shares could be carried over to the second wave). In addition, random chance might be expected to generate one apparently significant coefficient at the 5 percent level and 2 at the 10 percent level in 25 replications of an analysis even if there were no true relationship.

³⁰Because the largest groups changed between waves there is no correspondence between the identifying numbers in the two figures. In addition, coefficients are not reported for some fund managers in some rounds if these managers did not bid in those rounds, conserving their points for later rounds.

information) in the first round of bidding and those with the highest coefficients in the latter rounds.

Although the estimates indicate that almost every bidder possessed private information about firms in round 1 of each wave, the pattern of partial correlation coefficients across bidders is also revealing. In the first wave the top five fund managers in terms of their apparent ability to predict future share prices conditional on public information (the only managers where the partial correlation coefficient was greater than 0.20) were sixth, eighth and eleventh, fourteenth and twenty-fifth largest fund groups. The average partial correlation coefficient for these four managers was 0.224 as opposed to 0.124 for the remaining 20 managers. The identity of these fund managers provides further insight into the role of private information. They were managed by the one of the largest daughter branches of the former communist monobank, the Agricultural Bank (Agrobanka), the national insurance company (Česká pojišťovna) whose institutional clients included almost every firm involved in voucher privatization, another most prestigious private Czech bank, Živnostenká banka³¹ and the most significant foreign bank operating in the country at the time (Austria's Creditanstalt) as well as one private management company. Thus, private information appears to have been most available to true insiders in the Czech corporate structure. Nevertheless, after approximately two price adjustments, the voucher prices incorporated all the information available even to these insiders and, conditional on voucher prices, their point allocations were no longer significantly related to future market prices.³²

³¹Founded in the 19th century as a bank primarily serving the aristocracy, Živnostenká holds a special place among Czech banks. A leading bank during the interwar years of the First Republic, it remained nominally independent of the monobank during communism, serving mainly foreigners in Prague and Czechs abroad.

³²It should be noted that some decline in significance levels could be expected as a result of the decline in the number of firms on offer as some firms were fully sold and closed out in each round. At the maximum this might explain a four or five per cent decline in the reported significance levels, not the substantial decline seen in the data.

In the second wave the disparity across fund managers in the extent of private information diminished.³³ There were only four fund managers with partial correlation coefficients between their bids and eventual market prices in excess of 0.2. The average coefficient among these four firms was 0.236 as opposed to 0.155 for the other 20 largest managers. There was, however, a high degree of consistency among the managers with the greatest access to private information. Both Živnostenská banka and Česká pojišťovna were among this group as was Creditanstalt. The second best performer from the first wave, Agrobanka, was not among the largest 25 managers in the second wave. It was replaced among the leading performers by another daughter of the former monobank, the commercial bank (Komerční banka), the largest bank in Central Europe.

We need to consider the possibility of reverse causality in Eq. (3). If certain bidders were able to create value (and hence higher market prices), rather than merely to recognize mispriced firms (Katz and Owen, 1997), high demand by these managers for shares in particular firms, if translated into a greater ownership stake in those firms, could produce an eventual higher stock market price for these shares. It is unlikely, however, that the results presented above are due to such causality. This conclusion is based on two factors. First, the extent of the reduction in the apparent influence of private knowledge across rounds is substantially greater than the change in managers' *successful* bids. Indeed, investment funds purchased more shares in the second round than the first round in each wave³⁴ yet the apparent influence of private information was

³³In part this may be because there was already an easily observable market price for the stocks included in the second wave that were also a part of the first wave.

³⁴IPFs bid almost all their available points in every round in both waves. Because of excess demand, however, they were not always successful in having these bids accepted. In the first wave, 38 per cent of IPF points were actually spent in Round 1, 41 percent in Round 2, 12 percent in Round 3, and 4 per cent in each of Rounds 4 and 5. Thirty-eight percent of shares demanded were purchased in Round 1. The comparable figures for later rounds were 54, 17 37 and 88 percent. Patterns were similar in the second wave, with 20, 42, 15, 15, 7 and 2 per cent of IPF points being spent in Rounds 1 through 6, while the fraction of shares demanded actually purchased was 20, 18, 17, 54, 80 and 84 in the successive rounds.

much less in the second than the first round, as seen in Table 4. This is inconsistent with an interpretation that the effect of greater bidding for shares in a given company on its eventual price comes from the fact that greater bids translated into greater successful bids, with the eventual owner able to create value by restructuring.

Even more importantly, reestimation of equation (3) restricted to the sample of firms where excess demand means that shares were *not sold* in that round and firm ownership effects could not, therefore, have increased value generates identical results. The fact that the relationship between bids and eventual prices is invariant to whether these bids were successful or not strongly suggests that the effect is due to private information about eventual value rather than the ability of winning bidders to create such value.

4. Conclusion

Voucher privatization in the Czech Republic provided a natural experiment of the ability of prices adjusted using a simple rule based on excess supply and demand to fully reflect both public and private information. The price adjustment rule between successive rounds is known and was based largely on the extent of excess demand. Bidders had a substantial financial incentive to perform well, and many could be presumed to have had private information.

Only for the smallest firms was there any evidence that public data contained information beyond that reflected in the prices established in the voucher process. For the larger firms comprising the bulk of assets involved in the scheme, prices rapidly incorporated all the information available in public data. Even more strikingly, although there was substantial private information about which firms were most valuable at the start of the process, this information

was also rapidly incorporated into prices. After approximately two price adjustments based on excess demand, even the most informed insiders no longer possessed private information about firms' future value beyond what could be inferred from the voucher prices of the shares in these firms.

These results strongly support the ability of prices adjusting in response to excess demand or supply to rapidly reflect all available information, confirming in a real world situation the inferences drawn from limited laboratory investigations of one of the fundamental precepts of economics. It would appear that simple market mechanisms are so powerful that they are able to accurately reflect information even in the most unfavorable situations. If excess demand signals can establish appropriate prices in Czech voucher privatization where a large number of assets with no prior history had to be simultaneously valued by an administrative process in an economy with no experience in free markets or investment analysis, they must be a powerful tool indeed.

Acknowledgments

This research was supported by the National Science Foundation of the United States (grant number SPR-9712336), the PHARE/ACE Research Program of the European Union (grant number P95-2063-R) and the National Council for Soviet and East European Research (grant number 811-15). The authors thank Orley Ashenfelter, Richard Zeckhauser, Barbara Forbes, anonymous referees at the European Economic Review and seminar participants at CERGE-EI, Columbia University, Hunter College, the University of Linz, and the University of Michigan for comments and suggestions.

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Table 1
Chronology of voucher privatization

	First Wave	Second Wave
Purchase and Registration of Voucher Books	11/1/91 - 2/15/92	10/1/93 - 12/8/93
Assignment of Vouchers to Funds (If Desired)	3/1/92 - 4/26/92	12/15/93 - 3/9/94
Announcement of Participating Companies	5/13/92	3/4/94
Round 1	5/18/92 - 6/08/92	4/11/94 - 4/25/94
Round 2	7/7/92 - 7/28/92	5/23/94 - 6/6/94
Round 3	8/26/92 - 9/15/92	7/4/94 - 7/18/94
Round 4	10/14/92 - 10/27/92	8/15/94 - 8/29/94
Round 5	11/23/92 - 12/4/92	9/26/94 - 10/10/94
Round 6	N.A.	11/7/94 - 12/3/94
Distribution of Shares	5/93 & 6/93	2/95

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Table 3a
Impact of public information on market price

	Adjusted R ² Without Public Information (Equation (1))	Adjusted R ² With Public Information (Equation (2))	F-Test of Added Explanatory Power (Significance Level)
First Wave			
Round 1	0	0.236	15.21 (.000)
Round 2	0.503	0.535	4.18 (.000)
Round 3	0.578	0.602	4.00 (.000)
Round 4	0.574	0.6	4.32 (.000)
Round 5	0.565	0.59	3.97 (.000)
Second Wave			
Round 1	0	0.123	5.05 (.000)
Round 2	0.442	0.476	4.31 (.000)
Round 3	0.508	0.547	4.68 (.000)
Round 4	0.515	0.558	4.29 (.000)
Round 5	0.521	0.561	3.79 (.000)
Round 6	0.535	0.578	3.78 (.000)

Table 3b

Impact of public information on market price by size of assets in voucher privatization

	Firms with Greatest Value in Voucher Privatization			Firms with Medium Value in Voucher Privatization			Remaining Firms		
	Adj R ² w/o Pub Info.	Adj R ² with Pub Info.	F-Test (sig)	Adj R ² w/o Pub Info.	Adj R ² with Pub Info.	F-Test (sig)	Adj R ² w/o Pub Info.	Adj R ² with Pub Info.	F-Test (sig)
First Wave	n=97 76% of market capitalization 88% of trading volume			n=191 16% of market capitalization 12% of trading volume			n=665 8% of market capitalization 1% of trading volume		
Round 1	○	○△○○○	△△△ ▽ △△△○○○△	○	○△△▽	△△△ ○△△○ △△○○○○△	○	○△△○○	△△△ ▽○○○ △△○○○○△
Round 2	○△△▽△	○△△△▽	○△△○ △ △△△○○○	○△△△△	○△△○○△	△△△ △△△ △△○○○○△	○△△○○○	○△△○○△	△△△ △△△ △△○○○○△
Round 3	○△△○○○	○△△○○○	○△△○○○ △ △△△○○○△	○△△○○○	○△△○○△	△△△ △△△ △△○○○○△	○△△○○○	○△△○○○	△△△ △△△ △△○○○○△
Round 4	○△△△△	○△△△○○	○△△○○○ △ △△△○○○△	○△△○○○	○△△○○○	△△△ △△△ △△○○○○△	○△△○○○	○△△○○○	△△△ △△△ △△○○○○△
Round 5	○△△○○○	○△△○○○	△△△△ △△ △△△○○○△	○△△○○○	○△△△△△	△△△△ △△ △△△○○○△	○△△○○○	○△△○○○	△△△△ △△ △△△○○○△
Second Wave	△ ○△ △△△△△ △△△△△△△△△ △△△△△ △△△△△			△ ○△ △△△△△ △△△△△△△△△ △△△△△ △△△△△			△ ○△ △△△△△ △△△△△△△△△ △△△△△ △△△△△		
Round 1	○	○△△△	△△△ △△ △△△○○○△	○	○△△△	△△△ △△ △△△○○○△	○	○△△○○○	△△△ △△ △△△○○○△

Table 4
 Number of significant coefficients on demand by 25 largest mutual fund managers

	Number of Coefficients Significant at 1%	Number of Coefficients Significant at 5%*	Number of Coefficients Significant at 10%*
First Wave			
Round 1	21	22	23
Round 2	3	4	6
Round 3	1	3	4
Round 4	0	0	1
Round 5	0	0	0
Second Wave			
Round 1	25	25	25
Round 2	2	7	13
Round 3	0	2	5
Round 4	0	0	0
Round 5	0	0	0
Round 6	0	1	2

* Cumulative - includes those significant at a stricter confidence level.

Confidence intervals for the partial correlation coefficients between the (future) price on the secondary market and investor's bid in the voucher scheme.

Fig. 2.1 First Wave, Round 1

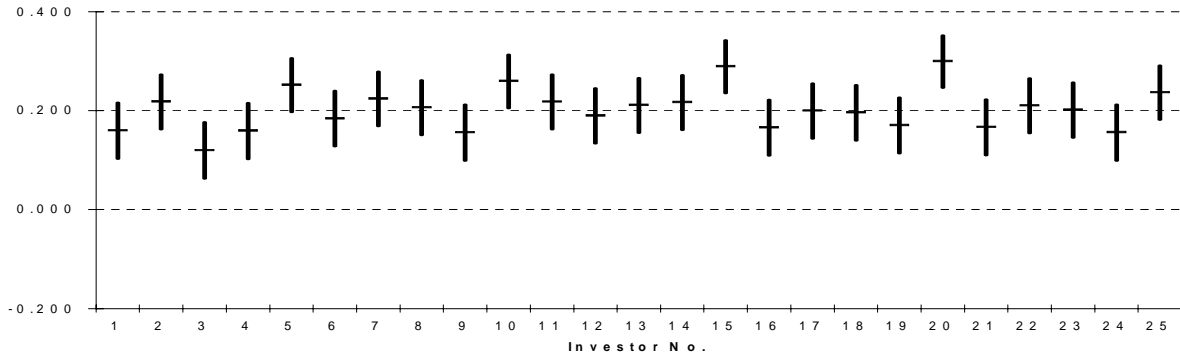


Fig. 2.2 First Wave, Round 3

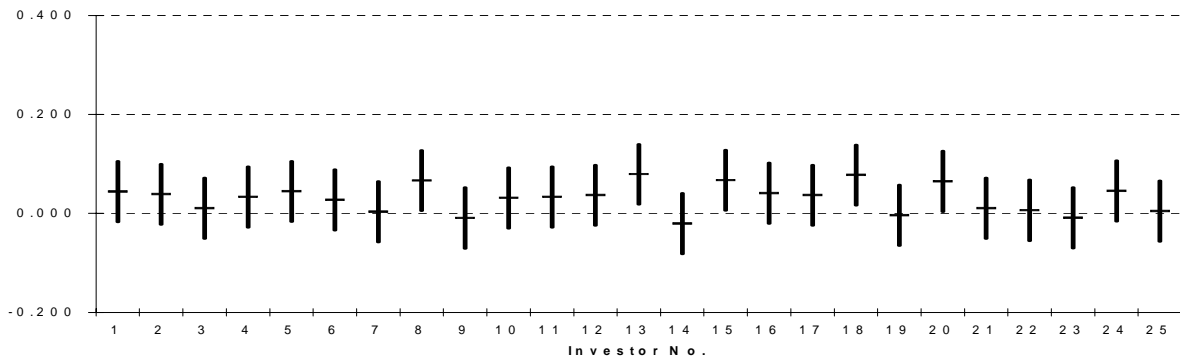
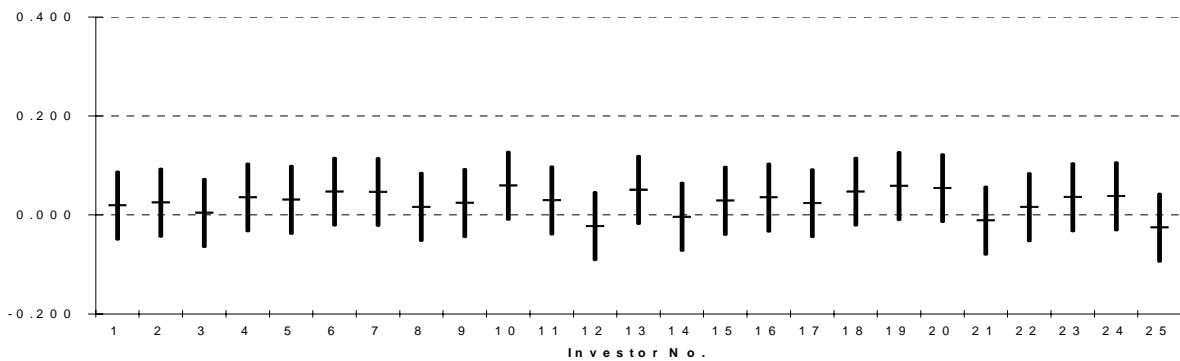


Fig. 2.3 First Wave, Round 5



Confidence intervals for the partial correlation coefficients between the (future) price on the secondary market and investor's bid in the voucher scheme.

Fig. 2.4 Second Wave, Round 1

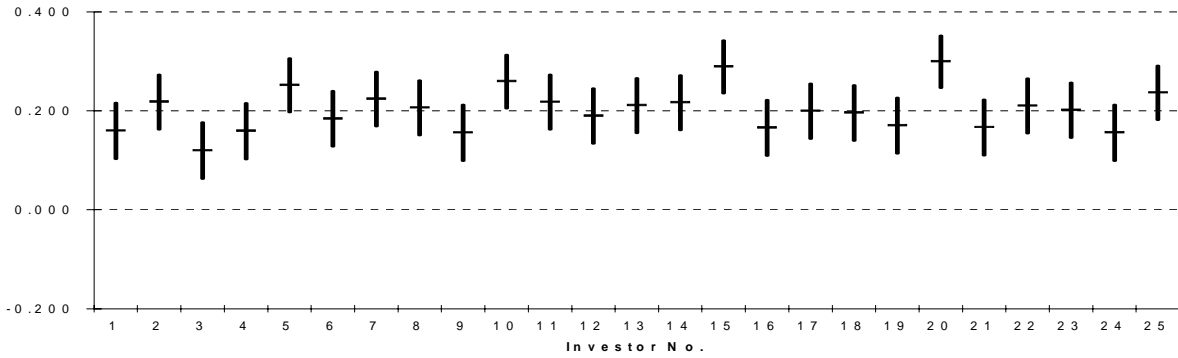


Fig. 2.5 Second Wave, Round 3

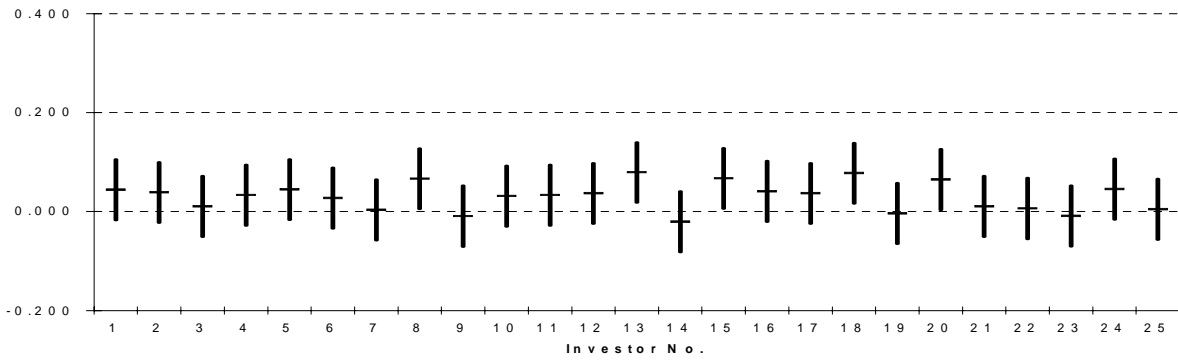


Fig. 2.6 Second Wave, Round 5

