Price Sensitivity to Supply Traded Under Alternative Mechanisms in the New England Fish Industry*

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ABSTRACT

The New England fishing industry from 1982-1992 demonstrates the effect of different trade mechanisms on price determination. Prices in Gloucester are more responsive to changes in supply landed in Boston than to supply landed in Gloucester itself. The underlying cause for this phenomenon lies in the different mechanisms used in the two ports -- an auction in Boston, long-term non-contractual relationships in Gloucester --, and the proximate cause in the use of the Boston price as an informal index for the negotiated price in Gloucester. This pricing convention makes auction supply more "high-powered" than supply traded under long-term, bilateral relationships.

Gloucester is a fishing port, about forty-five minutes northeast of Boston. In the 1980s and early 1990s, it landed more groundfish[1] than any other U.S. port. Most of the fresh groundfish landed in Gloucester is subsequently trucked to Boston for processing. Groundfish is also landed in Boston itself, though over that same period the groundfish volume landed there was but half that of Gloucester's, as competition from higher valued economic activity forced vessels and crews out of that once predominant fishing port. The vessels from these two ports fish in the same waters: groundfish are found most plentiful in the Georges Bank and other neighbouring offshore banks about a day's steam northeast of the two ports.

The ex-vessel price in Gloucester obeys the most basic law of supply and demand: an extra 100,000 pounds of cod landed in that port reduces the Gloucester price by one cent. But an equal amount of cod landed in Boston reduces the Gloucester price by three cents. The ex-vessel price in Boston behaves similarly. That extra 100,000 pounds, if landed in Gloucester, would reduce the Boston price by two cents; if landed in Boston, it would reduce the Boston price by six cents.

These numbers illustrate three basic facts common to prices of all groundfish species:

(i) The Gloucester price is more responsive to Boston landings than to changes in it own landings.

(ii) The Boston price is more responsive to its own landings than to Gloucester landings.

(iii) The Boston price is more responsive than the Gloucester price to landings in either port.

Taken together, these observations demonstrate the effect of alternative trade mechanisms

[1]The principal groundfish in New England are cod, haddock, redfish, hake, pollock, cusk and wolfish. Flounder is sometimes counted as groundfish as well, and I will mean groundfish to include flounder in this paper. Cod is by far the most important species in New England, and in Boston and Gloucester in particular.

on price formation.

The first observation is inconsistent with perfect competition. This is true whether or not one regards the two ports as belonging to one, structurally integrated market. If transportation costs exceed the difference in the ports' autarky prices, making trade across them unprofitable, then small changes in supply conditions in Boston should leave the price in Gloucester unchanged. Otherwise, when transportation costs are small enough for trade to take place across ports, increases in supply from either port should affect price equally.[2]

Why, then, is there a differential effect on price? I argue that the cause must lie in the different trade mechanisms that are used in the two ports. Boston has an auction. Gloucester does not. In Boston, all dealers gather together at the New England Fish Exchange building every weekday morning for about an hour to bid on that day's landings in simultaneous oral, ascending auctions for each boat's catch of each species. In contrast, buyers in Gloucester have long-term, non-contractual relationships with vessels that predetermine the allocation of fish among dealers. Evidently, the effect on price of supply traded under long term relationships falls far short of the price effect of supply traded through centralized exchanges.

Market participants' own description of the pricing procedure in Gloucester makes explicit Boston trades' domination of the market. The Gloucester price is said to be "set in Boston".[3] By that claim they mean that on a given day dealers and vessels in Gloucester quote a price equal to that morning's auction price less some varying amount. A dealer might quote "five cents off Boston board", for example. Trades consummated before the Boston price is established or made known may even be indexed to that price.

This pricing convention is an obvious response to the mode of trade in Gloucester. Locked in bilateral relationships, vessel and dealer must find some way to establish a

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[2]See Spiller and Huang (1986) for a discussion of the autarky and arbitrage regimes for two spatially separated markets. We don't usually think of perfect competition as providing functional form restrictions. But, in fact, it does. If demand is D(p), and the two sources of supply are S_1 and S_2, then equilibrium price in the second regime is $p = D^{-1}(S_1 + S_2) / f(S_1 + S_2)$; this is more restrictive than the general form $p = f(S_1, S_2)$.

[3]This appears to be a universally held opinion. It was stated to me by dealers and port agents, and is claimed by a number of more informed observers of the market, including Wilson (1980) and Peterson.

price, and pricing according to a publicly disseminated auction price is an obvious response. The benefit is the time saved on negotiating, and, its prelude, gathering information on market conditions. The consequence and social cost is the failure of the price in Gloucester to fully reflect variations in its own supply.

The second observation -- that the Boston price is more responsive to variations in its own supply than to Gloucester's -- is not of itself inconsistent with perfect competition. That model would interpret the differential sensitivity to the two sources of supply as evidence that the two ports are typically in an autarky regime. But industry descriptions clearly belie that conclusion. The two ports appear to be highly structurally integrated. (By the degree of "structural integration", I mean the extent by which a competitive equilibrium in this industry would be characterized by the arbitrage regime.) Only a very small part of the fish that is landed in Gloucester stays in Gloucester. Some is first processed there and then shipped elsewhere, though as time goes by less processing is done in Gloucester, and more in Boston. The rest is either transported to Boston (at a cost of about 3 cents a pound[4], or 5 percent of the average price of cod), for processing, consumption, and/or further distribution outside of Boston, or transported directly to end-users elsewhere. Of course, even in the later case it will face competition from Boston fish at the end-user stage. Georgiana, Dirlam and Townsend (1993) claim that "there is little doubt that most groundfish landed in Gloucester is trucked to Boston for processing", and FMP (1985, p. 3.45) concurs, noting that the small amount of fresh cod and haddock processed in Gloucester is destined for the local market.

Under these circumstances, one would expect Boston prices to be much more responsive to Gloucester supply. Demand at the auction is derivative. In determining it, dealers must conjecture their customers' demand, which will be decreasing in non-Boston supply. Boston dealers' own demand, then, will be decreasing in their estimates of Gloucester supply. The apparent high degree of structural integration of the two ports would suggest that the Boston price, and so Gloucester's as well, would be nearly as responsive to Gloucester landings as to its own. But this is not the case.

What aspects of the different trade mechanisms might be responsible for Boston

[4]This is according to a Gloucester processor. Georgiana and Hogan (1986) cite a 1979 figure of 5¢/pound for transportation from New Bedford to New York City.

dealers taking so little account of Gloucester landings? There are two possible answers. Incomplete observability of Gloucester landings at the auction is one. The catch of each boat landed in Boston is listed on a chalkboard in the auction room. What has been landed and what will be landed in Gloucester that day can only be known from word of mouth, from those who have unloaded or seen boats unloaded there, or overheard radio conversation. As it is reasonable to suppose that all of the catch at Boston is known, one infers that only about one-third of (the change in Gloucester) trades is observed. So trade mechanisms affect price responsiveness to supply through the observability of trades.

Alternatively, landings in Gloucester might be fully observable at the auction, yet irrelevant to traders there. That supply may not be available to the end-users that the Boston buyers trade with. As discussed in Section 1, there are substantial supply assurance understandings between dealers (those who purchase from vessels) and their clients further downstream. Those understandings may be so strong that in the short run of a single day, the supply of the two markets may be effectively unintegrated. On the other hand, end-users hold a portfolio of dealers, which may very well include dealers in both ports,[5] so that fish landed at different ports might co-mingle along the supply chain and may even end up lying side by side in a stall at New York City's Fulton Fish Market. If end-users switch between dealers on the margin, even with substantial supply assurance agreements, Gloucester landings will still matter to bidders in Boston.

The normative and policy implications of these two aspects are quite different. The non-observability of market-relevant trades decreases the efficiency of the product's allocation; gathering and disseminating information on those trades would improve the market allocation. In the second case, buyer and seller pairs' withdrawal from the market might impose a negative externality on the market, but it is that withdrawal that is the source of the problem and not the non-responsiveness of price.

Whichever of these two explanations is true, however, the non-responsiveness of the auction price to landings in a port so closely tied to it suggests a general principle: that prices in centralized exchanges fail to fully reflect variations in supply traded under bilateral relationships.

[5]One informant claimed that the typical wholesaler trades with twenty dealers. To my knowledge, no dealer operated in both ports during the period.

The third observation, that Gloucester is less responsive to both sources of supply than Boston is, will receive less attention in what follows. Revenue smoothing, as part of a long term relationship, is a likely explanation. The variance in the value of the landed cod in Gloucester would be 14 percent greater[6], were Gloucester vessels to land the same quantity but be paid the Boston price instead of the Gloucester price. Obviously, it would be greater still if there were to be a supply response to the more variable price. Vessel owners, who face typical monthly mortgage payments between $6,000 to $8,000 (NEMFC) and as high as $10,000 (Collins, 1994), would benefit from this revenue smoothing if they face borrowing constraints.

The interesting question may not be why the Gloucester price is relatively unresponsive to market conditions, but why it reacts to them *at all*. After all, since trades in Gloucester takes place within the confines of long-term relationship, one should not have to rely on current prices to clear the market. The answer, of course, is that loyalty to the relationship is unenforceable. Because the rules that govern the relationship between vessel and dealer are not enforceable in court, the actual terms of trade will reflect opportunities outside of the relationship, whether through renegotiation or because the rules are structured beforehand so as to ensure voluntary compliance. Prices within a relationship will thus inevitably reflect market conditions.[7]

The rest of the paper provides a fuller description of the industry, and then both lays out and defends the evidence summarized above. Section 1 describes the New England fishing industry and the trade mechanisms used in the two ports. Section 2 provides the methodology and statistical evidence, not only f or code, but for the other major groundfish species landed in New England ports as well. Section 3 provides a fuller discussion of pricing in Gloucester. Section 4 considers competing statistical and economic interpretations for our results: differences in the coverage ratio of the landings, the relative timing of sales in Gloucester and Boston, and collusion in Gloucester. In considering (and rejecting) the latter two interpretations, the behaviour of prices in a third port, that of Portland, Maine, will prove useful. It will be shown that the Portland price is

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[6]The 14 percent increase is true both for the standard deviation calculated over the entire sample period, and once corrected for monthly means.

[7] See Klein (1993), and Baker, Gibbons and Murphy, 2001.

more responsive to changes in Boston landings than to changes in Gloucester landings. Section 4 concentrates on pricing in Gloucester. Section 5 concludes the paper.

1. The New England Fishing Industry

About a thousand boats landed fresh fish in New England during the period of this study. They sold that fish by various means (auctions in New Bedford and Boston, MA, and since 1986, Portland, ME; consignment in Point Judith, RI; bilateral trades in Gloucester, MA) to "dealers", who are the first buyers, who may either process (i.e., fillet) it themselves, sell it to processors or other wholesalers, or ship it whole to end-users (restaurants, stores and institutional buyers), whether directly or through Fulton Fish Market[8], which is the wholesale market in New York City. On a daily basis, this industry is little affected by the frozen fish industry, both because the technology for producing frozen fish blocks (which involves huge, almost exclusively foreign factory ships which freeze fish at sea) differs so much from that for fresh fillets, and because a perceived quality difference generates a substantial premium for fresh over frozen, thus making the freezing of freshly landed fish rarely profitable (Gerogiana and Dirlam, 1982, and Gerogiana, Dirlam and Townsend, 1993).

Whatever trade mechanism is in place at the ex-vessel level, it must solve a difficult allocation problem daily. First, both the amount and the species composition of supply varies dramatically from day to day. For example, the standard deviation of daily changes in the quantity of cod landed in Gloucester approximately equals the mean daily quantity landed. Second, the allocation of fish among the dealers must be done rather quickly. Fish spoils -- it is no accident that Marshall chose this good to illustrate his "market day" -- and dealers need time to contact buyers further down the distribution chain to see what demand there is. Third, end-users typically exhibit very inelastic short run demand; both restaurants and supermarkets must set price, whether in menus or advertisements, before demand is realized. This generates the classic supply assurance need between end-users and dealers,[9] who inherit the inelastic demands of their clients.

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[8]See Graddy, 1995, for a description of the Fulton Fish market.

[9] The following is one dealer's description of his allocation of his product among his clients:

During the period of this study, Boston and Gloucester embodied two different approaches to solving the allocation problem at the ex-vessel stage. In Boston, all dealers gather together at the New England Fish Exchange building every weekday morning at 7:00 a.m. to bid on that day's landings in simultaneous oral, ascending auctions for each boat's catch of each species. The quantity brought to market is made known to all participants before bidding begins. There is a price for the entire catch of "market cod" of the *Jules et Jim*, another price for the pollock catch of the same boat, and a third price for "market cod" of the *Dante Alligheri*. At any point in the process, a buyer can bid by raising the price on any species and boat pair. The bidding is typically concluded in an hour's time. The average price, by species and cull, is subsequently disseminated over the radio. Thirty-three boats landed in Boston in 1991 (NEFMC, 1993). In the early 1980s (the early part of our sample), thirty to forty firms purchased at the auction; by 1993-4, just after the sample period, the number of firms had fallen to about eighteen.

In contrast, buyers in Gloucester had long-term, non-contractual relationships with vessels. These bilateral relationships lasted about a year during the same period, and were apparently somewhat weaker in the later than in the earlier part of the period. They involved not only a commitment to trade with one's regular partner, but also the dealer's provision of certain inputs, such as fuel and ice, to the vessel. Traders were dispersed along the waterfront, and prices determined by independent bargaining dispersed in time

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"One client likes large cod and market cod, another likes market cod and cod scrod, another client likes a little bit of pollock, and it doesn't matter what kind of cod. So it all depends on what we have, and we have to decide with what we have, who we would target first, and we would call them first, and give them the first shot, and then if that doesn't fly, then we call somebody else, and then if we really have to, but we really haven't had to, because we do have a pretty good clientele, we break it up somehow, and maybe have to go to two different places. But worst comes to worse, if no one could agree to take it all, we could get rid of it all in one place in [a major city], ... , and he wouldn't be too happy to hear about all the other customers. Well, he knows, but if you don't rub their nose in it, it's not a problem. (Personal conversation, 1992.)

This description of the market, and the dealer's function in it, is reminiscent of Carlton (1991), which views firms as allocating their product among their buyers, according to their knowledge of their buyers' demands.

over the course of the morning. There was no organized announcement of landings. Two hundred and four boats landed in Gloucester in 1991, though only half landed groundfish. In the early part of the 1980s, there were perhaps twelve buyers. Ten years later, there were about six or seven buyers, the rest having left Gloucester or the industry.

What are the relative advantages of these two trading mechanisms? The principle disadvantage of a long-term relationship is the arbitrariness it imparts to the allocation of fish to dealer. Vessels' fishing efforts will presumably be directed to their dealers' preferred portfolios, but given the inherent randomness of the vessel's catch and transitory shifts in the demand of the dealer's clients, any given day's match of catch to dealer is likely to be far from efficient. The consequence of a worse allocation at this stage is either greater inefficiency at the end-user stage, or costly actions by dealers to improve efficiency further upstream. The latter requires either a greater array of clients for each dealer (who overlap across dealers) or trades among dealers themselves (Wilson, 1980).

There may be several advantages to long term relationships. Wilson (1980) has argued that such relationships in ex-vessel trades thwart opportunistic behavior by dealers whose information about demand and supply conditions elsewhere is superior to sellers'. But that reason seems more appropriate to the small ports of Maine that may boast only a single dealer than to a large port like Gloucester. Bilateral trade does economize on middlemen, of which the auction is one; but the dealer in Gloucester is typically a middleman himself, and not a processor, as only a fraction of fish landed in Gloucester is, in fact, processed there. Another possible advantage to long-term relationships is that vessels can inform their dealers of the size and composition of their landings earlier, and thus provide dealers with more time in which to allocate their product among their clients.[10] I suspect that this lead time is the most important benefit of the long-term relationship. Thus a system of long-term relationships reduces the dealer's direct allocation costs at the expense of a less efficient allocation among dealers themselves.[11]

[10]This argument is reminiscent of Arrow (1975), where firms purchase suppliers to gain early information on upstream supply conditions, and thus improve investment decisions.

[11]Lead time will in some cases be no more than an hour or two, because to protect their private information on the location of the fish (which Wilson (1990) has described) vessels will sometimes wait until they are near to shore to contact the dealer and inform

The advantage to the auction mechanism is, of course, the better allocation of fish among the dealers. Its disadvantage is the need to agglomerate trades in time and space. The latter is not obviated by electronic trading, given that buyers need to inspect the fish quality (if not before, as in display auctions, then right after the trade, as in Boston). These agglomerations are mitigated by scale economies, such as specialized unloaders.

However much these explanations might illuminate the relative advantages of long-term relationships over centralized trade, none explain why the auction is in Boston and not Gloucester. If we are to attribute the impotency of Gloucester landings to the differing trade mechanisms, we must be sure that there is no factor that makes Boston suitable for an auction, and Gloucester not, and which is also responsible for the relative inability of Gloucester landings to move prices. Understanding why the auction is in Boston and not in Gloucester should help us in that.[12]

One would have expected the opposite. Fish auctions are found only in major ports, for the obvious reason that the fixed costs involved in establishing a formal, centralized marketplace require a large volume of trade. Boston is, indeed, a major port, but Gloucester is a larger one. As Table 1 shows, Gloucester has landed more groundfish than Boston since the early 1970s, and more of all species combined since World War II. During the sample period, it landed between six to nine times as much fish as Boston did, and at least fifty percent more groundfish than is traded at the auction. (The auction trades almost nothing other than groundfish.)

The answer lies in the combined effects of history and sunk investments in infrastructure. Trading exchanges have a network good aspect to them, leading to multiple equilibria,[13] and so providing an opening for history to determine the outcome. Empirically, Carlton (1984) has shown very clearly, the role of inertia on the continuance of organized trading places. So it is noteworthy that Gloucester was not always larger than Boston. In 1908, the year in which the Boston auction was established (White, 1954; German, 1982, page 4), groundfish landings in Boston slightly exceeded

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him of the catch (personal conversation with dealer, 1992).

[12] It is also possible that the equilibrium system of mechanisms is for there to be an auction in one port, and bilateral trading in another, but with an arbitrary assignment of port to mechanism.

[13] See, for example, Economidies and Siow and Pagano (1989a, 1989b).

Gloucester landings.[14] The history of the ensuing years is instructive. Over the next 25 years, Gloucester declined while Boston prospered, the latter arguably because of the auction, or more specifically, the million dollar state financed pier that was constructed in 1914 to serve the auction. Gloucester recovered somewhat in the early 1930s with the development of the market for redfish, which were located somewhat closer to it. Still, on the eve of World War II, Boston was landing four times as much groundfish as Gloucester. With the war, however, came competing demands on the Boston port. Boston landings in 1942 were only two-thirds, and in 1943, only half, of 1941 levels.

In 1944, Gloucester surpassed Boston. Significantly, that same year saw the establishment in Gloucester of a 'selling room' - an auction – by the Atlantic Seamen's Union. Although one informant of mine claimed that the auction closed within a year, it was obviously still operating when White wrote his dissertation in the early 1950s. It apparently closed soon after, as Doeringer, Terkla and Moss (1986) claim that the auction operated in the late 1940s and early 1950s.

The reason for the demise of the Gloucester auction is unclear.[15]. The two month strike by the union in 1953 may have played a role. Another factor might have been the lack of any supporting investment in infrastructure. Yet a third factor might have been the ease of defection from the exchanges. With port land relatively cheap in Gloucester, it would have been easy to have re-established the dealer-vessel bilateral relationship, a much more difficult proposition in Boston, especially after the war. Ironically, the same force that robbed Boston of its volume of landings may have also supported the auction

[14]The 1908 data are county level data. The country description suggests that whereas there were several other smaller ports in Essex county, where Gloucester is located, Suffolk county only had Boston, which indicates that the difference in groundfish landings at the two ports was somewhat greater than the numbers indicate. The numbers for the remaining years are all calculated at the port level.

[15]However, Doeringer, Terkla and Moss (198?) claim that the union operated a "selling room" in Gloucester in the late 1940s and early 1950s. In 1941, the Atlantic Fishermen's Union had established an auction in New Bedford, and, until the summer of 1994, that port has not been without an auction since (though control of it has changed hands twice). In the early 1990s, there was talk of establishing an auction in Gloucester, but no auction was established. Aside from the usual difficulties of establishing centralized trading places, the effort faced the closures of vast fishing areas mandated by federal management policy, in response to the depletion of the New England groundfish stocks, the consequences of which are evident from the landings figures in Table 5.

equilibrium there. Thus the presence of the auction in Boston and not Gloucester would appear to be the result of a number of historical events unrelated to other aspects of price determination. Indeed, that Boston is the smaller port makes the results of this paper all the more striking; this is an example of the tail wagging the dog.

2. The Evidence

For most industries, determining whether a supply shift in one market segment has a greater effect on price than would an equivalent supply shift in another segment would be a difficult task. But the fishing industry boasts daily and vigorous supply shocks, which allow us to check the hypothesis in a very simple way: does the price in Gloucester respond more to a one pound increase in Boston landings than Gloucester landings?

Formulating the hypothesis that way suggests estimating the following simple regression

(1) $$p_t = a_0 + a_B B_t + a_G G_t + \varepsilon_t$$

where p_t denotes the price in Gloucester, and B_t and G_t denote the quantities landed in each of the two ports.[16] Under the null hypothesis of perfect competition, equation (1) has the interpretation of an inverse excess demand curve. The error term, ε_t, represents deviations in inverse excess demand, and includes both variations in demand by end-users, such as restaurants and supermarkets, own-species supply elsewhere, such as landings in other New England ports and fresh imports from Canada, as well as landings of other species and variations of supply in competing non-fish food products.

My interest is in the relative responsiveness of prices to the daily shocks to supply in each port, i.e., a_G / a_B. Ordinary least squares estimation of equation (1) would confound that pricing responsiveness with the supply responsiveness of the Gloucester

[16]What is landed at a port and what is traded there ex-vessel can differ now that trucking from the vessel itself has become more common in the industry. However, a very small fraction of landings are immediately trucked to or out of Gloucester, and none in or out of Boston, without being sold first.

and Boston groundfish vessels, who, over time, may enter or exit the industry, or shift across species, in response to any of the omitted excess demand factors listed above. Should the supply response to these omitted factors be the same in each port and so impart the same bias to the coefficient on Gloucester supply as to that on Boston supply, the result would be to bias the ratio of the coefficients to one. The test for the null hypothesis of equal responsiveness would remain valid, but it would be low power, and of course the ratio of interest would be unrecoverable. Furthermore, the induced response need not be equal. On the one hand, with the mean Gloucester supply larger than Boston's, we would expect the level response also to be greater. On the other hand, as the Boston labour market is many times larger than that of Gloucester, we might expect entry and exit in the Boston port to be greater. With these two effects, irrespective of which dominates, even the test of the null hypothesis would be invalid.

My solution to this endogeneity problem takes advantage of the nature of production and the timing of price determination in the industry. Almost all the volume landed at the two ports comes from "trip" boats that go out to sea for five to ten days (Georgiana, Dirlam and Wang, 1991) and require a day's return from the fishing grounds to the port. Only once the vessel is in port is the price determined, rather by auction or bilateral negotiation. Consequently, while supply can respond to higher prices within a period as short as a week or two, it can not do so on the same day as the price shock. Thus by controlling for the predictable component of excess demand, and so isolating the unpredictable innovation in demand, the parameters in equation (1) can be consistently estimated.

Formally, I model the serial correlation of the error term as a first order autocorrelation process, and add the following conditions to equation (1)

(2a) $$\varepsilon_t = \alpha\varepsilon_{t-1} + u_t$$

(2b) $$p\lim Q_s u_t = 0, \quad Q = B, G, \quad s \le t$$

which, as suggested by Durbin (Harvey, 1991, p.194), allow (1) to be rewritten as

(3) $p_t = a_0 + \alpha p_{t-1} + a_B \Delta_\alpha B_t + a_G \Delta_\alpha G_t + u_t$

where $\Delta_\alpha = 1 - \alpha L$ is the quasi-difference operator. The parameters α, a_B and a_G may be estimated by nonlinear least squares applied to equation (3).

This approach, of course, assumes that the fishermen cannot anticipate the innovation u_t. That seems reasonable to me, as any information on excess demand is likely to be known by the dealers on shore and so reflected in prior days prices (i.e., $\varepsilon_s, s < t$). Even if they could anticipate it, they would have to be able to do so several days beforehand for the information to be useful. First, given the day required to return home, a one day lead would be of no use. Second, there is little opportunity to profitably time the return to port the fish - leaving early sacrifices quantity, while leaving later risks spoilage and wastes the crew's time. Fishing is not that flexible. As Binkley (2002, p. 46) writes, "Deep sea fishing is actually hunting at sea. There is no guarantee that fish will be available at any particular time, or that they will remain available in any particular area. Therefore, once a crew finds fish and begins to catch them, they most continue to harvest and process the catch until there are no more fish." Or capacity is reached.

In practice, this quasi-differencing approach requires large day to day, and cross port, variation in supply. Such variation clearly exists, due to weather conditions (although because the vessels fish in the same areas, most of that will be common across ports), as well as the randomness of the total volume and species composition of individual boats' catch, and the timing of trips, including shipping mishaps that force boats to return to shore with a less than full catch.

In principle, there may be a second endogeneity problem. If the Gloucester price is abnormally high (say, because demand of Gloucester buyers is abnormally high), it may induce boats that would normally land in Boston to land in Gloucester instead. The effect of such behavior on OLS estimates of equation (1) will be to increase the coefficient on the own-port (decrease its absolute value) relative to coefficients on quantity landed in other ports.

This bias is likely to be quite small, for the opportunity for vessels to shift between the two ports in the short run is quite limited. Landing at a port other than one's own requires either that the crew be deprived of shore leave, or that both fuel and time be expended in traveling to the home port; traveling by sea is much more difficult than traveling by land. Fishermen's time on shore between trips in the busy season is already quite short, compressed and thus very stressful, as several anthropological studies of fishermen's families have described.[17]

For Gloucester based boats, landing elsewhere has the additional disadvantage of potentially jeopardizing the long-term relationship with the dealer. As for, Boston boats landing in Gloucester, they do not have the benefit of a long-term relationship to protect them from the dealer's opportunistic behavior once the fish is unloaded. Also, until 1993, which is *after* our sample period, there was no public docking area in that port. Permanently switching ports is especially costly; it requires either a new crew, or that the existing crew relocates. As many of the crews are kinship based, the former would be especially difficult to do. But shifting among ports does occur, both in the short and long term, and so this endogeneity problem needs to be addressed.

All data are derived from the National Marine Fisheries Service's (NMFS) Landings File, 1982-1992. NMFS attempts to conduct a complete census of U.S. fish landings. The attempted census uses buyer reports, and is more successful in some ports than others. (The implications of the differential coverage rate in Gloucester and Boston are examined in Section 4 and the appendix.) This program was voluntary over the sample period. No quotas were in force for any of these species during the period. The Landings File is the compilation of weigh-out slips filled out by each buyer of fish from a vessel. For quantities, I use the total volume landed in each of the two ports. For price, I use the (unweighted) mean price of that port's landings, where price is the ratio of value to volume, deflated by the monthly CPI. I consider nine species: cod, cusk, yellowtail flounder, American flounder, haddock, hake, redfish, pollock, and wolfish. These species were chosen because, as Table 2 shows, Boston lands very little of any other species. I include all days on which there are positive quantities of the chosen species and cull landed on that day and the previous day in each of the two ports. Because the Boston auction was usually closed on weekends during this period, most of the days in the

[17] Examples include and Brinkley's (2002) study of fishermen families in Atlantic Canada, especially page 53.

sample fall between Tuesday and Friday.

Table 3 shows the summary statistics. Cod sells, on average, for 60 cents a pound (in 1982-84 dollars), and in revenue terms is the dominant species. Twenty-one thousands pounds a day are landed, on average (when any are landed), with about two-thirds of that landed in Gloucester. Of groundfish, only Pollock has a greater volume (at about 28,000 pounds), but at half the price. At 72 cents and one dollar, Yellowtail and Large American flounder are more expensive, but much less of each is landed. All the other major groundfish species sell for less than cod, at prices that range between thirty-one to thirty-eight cents.

Table 4 presents ordinary least squares estimates of equation (1). There is no systematic pattern to the coefficients here. For some species, the coefficients on the landings in the two ports are quite close, as for cod in Gloucester, and Pollock and Wolfish in both ports. For others, Cod in Boston, and Cusk, Large American Flounder and Haddock in both ports, Boston landings have a greater effect than Gloucester landings on the price. For the remaining species, it is Gloucester landings that have the greater effect. In all cases, the Durbin-Watson statistic is very large, indicating a very high degree of autocorrelation of the error term and/or misspecification.

Table 5 presents non-linear least squares estimates of equation (3). Without exception, and for both the Gloucester price and the Boston price, the coefficient on the quasi-change in Boston quantity is significantly more negative than the coefficient on the quasi-change in Gloucester quantity. For four of the nine species -- Yellowtail Flounder, Unclassified Redfish, Drawn Pollock, and Wolfish -- one cannot even reject the hypothesis that Gloucester quantity has no effect on either Gloucester or Boston price. When yearly dummies are included, the F-statistic for joint exclusion is highly insignificant, with p-values of at least 65 percent. The estimates in Table 5 exhibit the three basic facts with which this paper began.

The large positive serial correlation in the demand error is not surprising. First, the high frequency of the data of itself suggests a large positive serial correlation. Second, opportunities to inventory the fish for a day or two exist at all stages of the industry, including the processor, wholesaler and end-user stage. That implies some degree of demand substitutability between any two days. Third, the error will reflect supply at other ports, both in New England and elsewhere, which, especially because of seasonal effects, is serially correlated.

To make sure that our findings do not result from functional misspecification, I consider an alternative specification in which the inverse demand curve is linear in the log of quantity:

(4) $$p_t = a_0 + \alpha p_{t-1} + a_B \Delta_\alpha \ln[B_t + \beta G_t] + u_t$$

β measures the impact of Gloucester landings relative to Boston landings.

Table 6 presents nonlinear least squares of equation (4). With the exception of one species, β is always estimated to be positive but less than one. The coefficient on the log of quantity is, again with one exception, always negative and typically twice as large when the Boston price is the dependant variable than when the Gloucester price is. The abnormal results are for Yellowtail Flounder and seem to be due to local non-identification. The estimated value of β is much less constant across the species than the ratio of coefficients presented in the previous table. Nonetheless, the three basic findings with which this paper began are clearly robust to the choice between the linear and the linear-log inverse demand curves.

Table 7 examines two additional extensions to the empirical analysis for the most important species, cod. The first two columns repeats the estimates for that species from Table 5. The following two columns add the lagged one day landings to the inverse demand curve, so that, taking into account first order autocorrelation in the error term, it presents the regression of price on lagged price and the quasi-differenced landings for the day of sale and the preceding day. I restrict the sample to observations with positive landings on not only that day and the previous but on the day before as well. The same basic pattern of greater relative sensitivity to Boston than to Glocuester landings in both ports, and overall greater sensitivity in Boston that in Gloucester is evident not only in the concurrent day landing coefficients but also in the coefficients on the lagged landings. The magnitude of the lagged effects is about a third to half that of the concurrent effects.

Table 7 also shows the effect of landings in these two ports on price in a third port. How price in some third port responds to landings in Boston and Gloucester can help discriminate among the various interpretations of our three basic findings. How we evaluate the price response will, of course, depend on the pricing mechanism in the third port. New Bedford, MA and Portland, ME are the two other large New England Ports. Unfortunately, in neither of them has a single price mechanism been used to the exclusion of all others over our sample period. New Bedford has had an auction since 1941, but not all transactions in New Bedford are conducted through the auction. I have no data on the share of auction transactions during the sample period, but in 1994, the auction's share of all landings was only one-third and in September 1994, the auction closed down temporarily. Portland's auction was established only in 1986, and though it struggled through its first few years, by 1994 it commanded a volume equal to all of Portland landings. Only about half of Portland landings actually traded at the auction, however, with the rest of the volume at the auction being trucked in from other Maine ports or Canada. Non-auction transactions in both ports operate in a similar manner to Gloucester.

Of the two, Portland is the more useful. Portland is much more distant from the two other ports than the two are from each other, and, being north of Gloucester, is somewhat closer to that port than to Boston. It is thus reasonable to suppose that the degree of structural integration between that port and either of the other two is essentially the same. Also, the Portland auction data has been made available to me.

Table 7 documents the behavior of the Portland price. Column (5) shows the regression of the Portland price on its one day lag, and the quasi-differenced landings in all three ports. Strikingly, Portland is, like the other ports, three times as sensitive to Boston landings as to landings in Gloucester. It is interesting to separate out the auction from the non-auction trades in Portland. To this end, column (7) is restricted to the June 1986-1992 period, when the auction operated, and uses the average price at the Portland auction.[18] At this point, the decrease in the number of observations and the thinness of the Portland auction in its early years takes its toll on the standard errors, but the general pattern remains the same both on and off auction: Boston supply has a greater impact on

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[18]The NMFS' data (described in Section 2) does not discriminate between auction and nonauction trades. Columns (5) and (6) use average prices derived from the NMFS data. Column (7) uses average prices from the Portland auction's own records. In all columns, the definition of the Portland supply is the NMFS' figures on the catch landed at Portland.

price than does Gloucester supply.

4. Pricing in Gloucester

Because the two ports do not operate in isolation, the behavior of prices in any one port depends not only on the mechanism of trade there but on the mechanism operating in the other port as well. Fortunately, our task is considerably eased by the mechanism type in Boston, as we can reasonably approximate the auction price mechanism by the competitive mechanism. This is not to deny the presence of strategic opportunities to misrepresent one's true value at auctions; however, Rustichini, Satterthwaite and Williams (1994) and Cripps and Swinkels (2006) have shown that such opportunities are very small at double auctions (of which the simultaneous auction in Boston must be a close cousin) with only a few participants.

About the nature of bargaining in Gloucester, we know much less. The testimony of market participants is that the Gloucester price is "set in Boston". In practice, this convention takes the form of quoting the price as a discount off the known, or perhaps not yet known, Boston price. However, the mere existence of this convention does not reveal how much freedom remains in the setting of the Gloucester price. In principle, pricing with reference to the Boston price need not constrain the Gloucester price at all, as the discount might vary freely, leaving the pricing convention essentially meaningless. However, that for all species the relative effects on price of Gloucester and Boston supply does not differ much by port suggests that the Gloucester price is, indeed, mimicking the Boston price, though also smoothing it.

Although transactions in Gloucester are part of long-term relationships, their prices nonetheless reflect current market conditions, if not in Gloucester than at least in Boston. The reason why long-term partners, who, after all, have removed themselves from the market, might, nevertheless, choose to tie their prices to it is familiar from the literature on specific investments and implicit or legally unenforceable contracts. Because the rules that govern the relationship between vessel and dealer are not enforceable in court, the actual terms of trade will reflect opportunities outside of the relationship, whether through renegotiation or because the rules are structured beforehand so as to ensure voluntary compliance. It might seem that, if there is any significant value in the relationship, the prospect of an improvement in one trip's revenue or outlays would be insufficient to tempt either side to trade outside of it. But given the high autocorrelation in market prices, which is inherent in the seasonality of excess demand, any discrepancy between a stable price within the relationship and the market price is likely to persist for several trips. For example, were prices held constant throughout the year near the yearly market average, then sellers might find it advantageous to dissolve the relationship near the beginning of the spring; buyers would face a similar incentive in the fall. Prices within a relationship will thus inevitably reflect market conditions. Indexing prices to a spot market to begin with is an obvious way to formalize this within an existing agreement.[19]

Viewing Gloucester prices in this way suggests a possible explanation for the last of our three findings from Tables 5, 6 and 7: that the Gloucester price is less sensitive to supply shocks from either port than is the auction price. Non-cooperative bargaining theory predicts that a negotiated price will reflect either a surplus sharing rule (the Nash bargaining solution), or the outside option of one of the bargainers. The surplus sharing rule would predict prices that are less responsive within than without bilateral relationships, if an increase in the market price increases the surplus by an amount no greater than one. That condition is satisfied if we interpret the threat point in the Nash solution as the value of abandoning the partner for a single trip's transaction only[20] and then assume some positive probability that the vessel will fail to find a substitute partner for that period.[21]

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[19]The best known example is the indexation of long-term coal contracts to the spot market (Joskow, 198?). Spot transactions in the coal market typically are for a month's worth of delivery; the average duration in Joskow's sample of long-term contracts is thirteen years. Since a vessel is typically out at sea for anywhere between ten days to two weeks, and long-term relationships currently last about a year (though were perhaps somewhat longer in the 1980s), the value of a spot transaction as a proportion of the value of all transactions in the relationship is about three times as great in the ex-vessel market as in the coal market.

[20]See MacLeod and Malcomson (199?) for a model in which trade is simultaneous with the bargaining game, and the threat point represents non-trade with the partner. It is natural to interpret the outside option as the value of a permanent dissolution of the relationship.

[21]Let p define the market price, p+k and p+k' the return to the dealer of a sale to his client when the catch originates from his regular partner and from some other vessel,

Of course, the true alternative is to trade elsewhere in Gloucester, not Boston. But to gather information on supply and demand available in decentralized markets requires one to canvass other market participants; that activity is time-consuming. Quoting prices from another port conserves on that cost tremendously, at the cost of the use of an inappropriate representation of the outside opportunity. That cost will be small when the degree of structural integration of the two ports is great. Also, as long as others in Gloucester are "pricing by Boston", Boston *will* represent the outside option.

Other Explanations

There are three other possible interpretations of the differential measured effect on Gloucester price of contemporaneous supply: the variable coverage ratio of Gloucester landings, the relative timing of landings in the two ports, and dealer collusion in Gloucester. I consider each in turn.

Unrecorded Landings in Gloucester

Variability in the coverage ratio in Gloucester is an obvious explanation for the apparent impotency of Gloucester trades in moving price in either port. All Boston trades occur through the auction, and, consequently, are recorded in the NMFS file. In contrast, the port agents in Gloucester estimate that they miss between 5 to 15 percent of any given day's landings, and about 10 percent on average. This variation in the coverage ratio generates a nonlinear errors-in-variable bias.

As the appendix shows, the probability limit of the NLS estimator of a_G in (3) is approximately equal to $a_G(\lambda/\mu)$ where μ is the mean coverage rate, and λ is the (rescaled) signal to total variance ratio, so that λ/μ is the regression of the change in

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respectively, and $\alpha^B(\alpha^S)$ the probability that another vessel (dealer) from which to buy (to sell) can be found. Ex-vessel transactions with parties outside of the relationship are at price p. Then the surplus is $p+k-\alpha^B(p+k'-p)-\alpha^S p = p(1-\alpha^S)+(k-\alpha^B)k'$. Alternatively, one might assume that the vessel can always find a partner, but with delay that causes quality deterioration, with a corresponding proportional decrease in price.

total Gloucester landings on measured Gloucester landings.[22] The bias from the missing landings cuts both ways. On the one hand, because measured landings are a fraction of total landings, there will be a tendency for a_G to be biased away from zero in order to adjust for scale. On the other hand, daily variations in the extent of coverage will bias a_G towards zero, and to the extent that daily changes in the two ports are positively correlated, a_B away from zero, in the manner of the classical errors-in-variables problem. As it turns out, the scale effect dominates the errors-in-variable effects. The algebra is relegated to the appendix, but the reasoning is simple. The variance of the change in the coverage ratio is too small to explain the results. The variance of the level of the coverage ratio is bounded by the lesser of the square of the distance from the minimum or maximum to the mean, which, if the port agents are to be believed, is $(.95 - .9)^2 = (.85 - .9)^2 = .0025$, so that the variance of the change is at most twice that, assuming that the autocorrelation in the coverage ratio is nonnegative. This implies that $\lambda \approx 1$.

The assumption that the coverage ratio is independent of total landings is reasonable if we think of the probability that a boat's catch fails to be recorded on any given day as essentially random (because the weigh-out slip is lost, for instance). It is less reasonable to the extent that the unrecorded landings represent a set of boats that are rarely covered (such as boats that predominately deal in cash, or sell to very small dealers). However, the Appendix shows that, here, too, the resulting bias leads to an underestimate of the true differential.

Timing of Trades

The next competing explanation relies on Boston's supply arriving earlier and in a narrower time span than Gloucester's. Recall that the Boston auction begins at 7:00am and ends an hour later. It would be reasonable to suppose, then, that the price of the last trade of the day in Gloucester incorporates more information about the total quantity landed there that day than does the first trade's price; both incorporate the whole of Boston's supply, since that is known relatively early on in the day. If so, then as the

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[22] The appendix shows that the correlation between daily changes in landings in Gloucester and Boston is sufficiently small that the correction for the presence of the Boston landings as a regressor is negligible.

Gloucester price is the mean of all Gloucester prices throughout the day[23], Gloucester supply will be seen to affect Gloucester price less than Boston supply does.

Though the relative timing argument can explain the first observation, it fails to explain various other empirical regularities in the data. If timing is the sole explanation, than Gloucester prices should incorporate much more of Gloucester trades than Boston does, implying the ratio a_G / a_B should be larger in Gloucester than in Boston. To see this, let m be the fraction of Gloucester landings that occur before the auction, and assume the two ports are always in the arbitrage regime. If prices incorporate only the supply that has been landed already that day, then the average supply incorporated in the Gloucester price will be $\int_0^{mG} x dx + [\int_{mG}^{G} x dx + (1-m)B] = (1/2)G + (1-m)B$, while that incorporated in the Boston price will be $B + mG$. Under this scenario, the ratio a_G / a_B will be $\frac{1/2}{1-m}$ and m in Gloucester and Boston, respectively, so that the supply responsiveness ratio of the Gloucester price would be at least twice that of Boston's.[24]

The lagged effects estimated in Table 7 are also inconsistent with the timing explanation. Since by date t all of B_{t-1} and G_{t-1} will have been landed and traded, the relative timing argument predicts that the two coefficients equal each other, if the two markets are structurally integrated, or if not, a_{G1} should exceed a_{B1} in the Gloucester price equation in magnitude. The opposite, however, is true.

Finally, and most convincingly, the behaviour of the Portland price is inconsistent with the timing explanation. As the Portland auction takes place rather late in the day, at one in the afternoon, when most if not all of the Gloucester vessels would have landed and sold their fish, the timing explanation would predict that its price should be as responsive to Gloucester as to Boston supply. Yet the differential effect is clearly evident in the Portland price.

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[23] Unfortunately, the time of a given vessel's landing in Gloucester is unknown.

[24] The difference would be even greater if the markets were not wholly integrated.

Collusion

The third explanation relies on collusion.[25] Perhaps, the dealers in Gloucester are more effective colluders in their trades with vessels than their counterparts in Boston. Indeed, the relative concentration of buyers and sellers in the two ports suggest that Gloucester dealers would find collusion easier. Of course, the number of dealers is, in part, a consequence of the trading institutions themselves. One doesn't need a pier to be a dealer in Boston.[26]

By itself, collusion cannot explain the empirical results. A perfectly collusive equilibrium would not entail a price that is more responsive to own supply than to Boston supply. However, Gloucester's dealers might find the Boston price to be a convenient focal point. Under this interpretation, the pricing convention serves not to solve the bilateral monopoly problem, but to aid dealer collusion. Collusion in an environment in which supply shifts so dramatically from day to day and supply assurance is so crucial, as is the case in the fishing industry, is not an easy task. A successful collusive price, one that would ensure maximal profits such that no firm would find it individually advantageous to cheat on the agreement, would have to be continually recalibrated as supply and demand conditions change. How much easier to rely on an agreement to price according to the publicly announced price from Boston! There would be a loss to using the Boston price (or some simple adaptation of it), rather than the optimal collusive price, but so long as the two markets are sufficiently integrated and bidding at the auction reflects supply and demand conditions, that loss will be small.

A variation on the collusive story is secret price hikes. According to this view, dealers do not report to the NMFS the true price they offer their suppliers, for fear of being caught cheating on the collusive agreement by other dealers. The error in (3), u_t, will represent, in part, deviations of the true from reported price. If the incentive to cheat on the agreement is highest when supply in Gloucester is lowest, then u_t will be positively correlated with Gloucester supply, and so will impart an upward bias to the

[25]Although accusations of price-fixing in purchasing have been leveled against Gloucester dealers, they have never been proven. An indictment against dealers in New Bedford, MA, was handed down in the mid-1990s (Commercial Fisheries News).

[26] Also, by an antitrust decree from 1919, the auction in Boston is open to all.

estimated value of a_G.

There are some problems peculiar to the `secret price cutting' version. To begin with, the NMFS does not publicly announce the individual transaction prices. This version of the collusive story also has the unfortunate implication that the relative supply effect in the Boston equation (which is understood to reflect the degree of structural integration) is equal to the relative supply effect in the Gloucester equation (which is understood to reflect the correlation between price cuts and Gloucester supply).

Both versions of the collusive explanation ultimately fail to explain the small effect of Gloucester supply on prices in Boston and Portland. In order to explain the Boston price equation, the collusive story, of either version, must assume that the two markets are far from fully integrated. Such an assumption faces a number of difficulties. First, it is inconsistent with what is known about these markets, as presented in Section 1. Second, as we see from Table 7, the Portland price assigns the same relative weight to Gloucester as does Gloucester.

It needs emphasizing that nothing here precludes the possibility that dealers in Gloucester may, in fact, collude, only that collusion cannot explain the empirical regularities I have presented here.

5. Conclusion

Fish is not the only good whose transactions are governed by both a centralized exchange and long-term, bilateral relationships. It is merely a convenient good to study, given the nature of its supply shocks. As the studies in Hayenga (1979) point out, many agricultural products, such as sugar[27], cheese, butter, eggs, and meats, have a similar trading structure. There, too, the long-term partners trade at a price pegged, formally or informally, to the exchange's price. Indeed, in many cases, the imbalance between the volume on and off the exchange is much more extreme than described here. Less than one percent of cheese produced in the United States is sold at the National Cheese Exchange, yet the price there governs trades between producers and their buyers.

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[27]American Sugar Refining Corporation's three year contract with the Hawaiian Growers' Association stipulated that price would be transacted at the daily raw sugar price in New York City.

Sometimes there are no trades at this and other exchanges, and a committee sets the price instead, which the off market trades follow.

For other products, decentralized spot markets take the place of the exchange. In such cases, long-term partners use an average of the spot prices that government or commercial reporting agencies have gathered and disseminated the spot prices. Markets for many fuels, such as coal in the United States, which Joskow (1990) has described, operate in this fashion. Such is the situation for many agricultural products, after technological changes led to the demise of the wholesale exchanges at city terminals (Hayenga, 1979). Here, too, the situation can be quite extreme, to the extent that all transactions are pegged to the disseminated average price.

The central lesson of this paper is that the mechanism of trade matters for the responsiveness of price to supply. It is also reasonable to conclude that the mechanism of trade will matter for the responsiveness of price to demand, as well. Thus when evaluating the effect of an increase in, or the volatility of, supply or demand, it is essential to know where that demand or supply will be expressed. For example, an increase in demand for American currency if exchanged between corporations and individuals, without bank or market intermediation, will not move the dollar as much as an equivalent increase in demand that is effected at one of the currency exchanges. Likewise, with the emergence of eBay, we should expect that variations in supply or demand for those goods that were previously traded in many isolated bilateral transactions or small stores would effect much greater price changes than before.

This is not an issue that has received any attention in the theoretical or empirical literature. There has been a tremendous amount of work on the implications for the terms of trade and the allocation of goods of the choice of trading mechanisms, particularly auctions, and, more recently, some corresponding empirical work (although most empirical work uses the theory simply to infer bidders' values). There is also a smaller theoretical literature on the equilibrium choice of trading mechanisms. It is rare, however, for different trading mechanisms to co-exist in equilibrium in such models.[28] When they do, the consequences for the effects of demand or supply shocks are not examined.

[28] See Kranton (1996), Gehrig (1996) and Rust and Hall (2003) .

Left unresolved here is which of two aspects of the trading mechanism is responsible for the differential effect on price. Is the source of the lower responsiveness of price to supply shocks within the long-term relationships a lesser observability of those trades or that those buyer and seller pairs have removed themselves from the market, making their demand and supply irrelevant? It will be necessary to repeat the empirical exercise of this paper in industries where the off-exchange transactions are between short-term buyer and seller pairs in order to answer that question.

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Appendix: Unrecorded Landings in Gloucester

I. Independent Coverage Ratio

Let δ denote the coverage ratio, G the recorded landings in Gloucester, and G^* total landings in Gloucester, so that $G=\delta G^*$. Assume that δ is distributed independently of both G^* and lagged values of itself, and has mean μ and variance v, and that α=1.

We will have need of the following identities:

(A.1) $$E\delta\Delta\delta = v$$

(A.2) $$E\Delta\delta\Delta\delta = 2v$$

(A.3) $$E\Delta G^*\Delta G^* = 2EG^*\Delta G^*$$

as well as the approximation

(A.4) $$\Delta G \approx \delta\Delta G^* + G^*\Delta\delta$$

The probability limit of the NLS estimator of a_G is

$$\{\sigma_{\Delta p\Delta G}\sigma_{\Delta B}^2 - \sigma_{\Delta p\Delta B}\sigma_{\Delta B\Delta G}\} / \{\sigma_{\Delta G}^2\sigma_{\Delta B}^2 - \sigma_{BG}^2\}$$

$$= a_G\{\sigma_{\Delta G^*\Delta G}\sigma_{\Delta B}^2 - \sigma_{\Delta G^*\Delta B}\sigma_{\Delta B\Delta G}\} / \{\sigma_{\Delta G}^2\sigma_{\Delta B}^2 - \sigma_{BG}^2\}$$

$$\approx a_G([\sigma_{\Delta G\Delta G^*} / \sigma_{\Delta G}{}^2] - (\rho^2/\mu)])/(1-\rho^2) \quad = a_G\mu^{-1}(\lambda - \rho^2)/(1-\rho^2)$$

where ρ is the correlation between measured daily changes in landings in the two port, and $\lambda \equiv \mu\sigma_{\Delta G\Delta G^*}/\sigma_{\Delta G}{}^2$. The approximation follows from $\sigma_{\Delta G^*\Delta B} \approx \mu^{-1}\sigma_{\Delta G\Delta B}$, from (A.4).

Note that were δ constant, λ would equal one. To calculate λ, first note that

$$\sigma_{\Delta G \Delta G*} \; . \; Cov(\delta \Delta G^* + G^* \Delta\delta, \Delta G^*) = \mu \, \sigma_{\Delta G* \Delta G*} + E\Delta\delta\sigma_{G* \Delta G*}$$

$$= \mu \, \sigma_{\Delta G* \Delta G*}$$

$$\sigma_{\Delta G}^2 \approx Cov(\delta\Delta G^* + G^*\Delta\delta, \delta\Delta G^* + G^*\Delta\delta)$$

$$= (\mu^2 + v)\, \sigma_{\Delta G* \Delta G*} + 2vEG^{*2} + 2Cov(\delta\Delta G^*, \Delta\delta G^*)$$

$$= (\mu^2 + v)\, \sigma_{\Delta G* \Delta G*} + 2vEG^{*2} + 2vG^*\sigma_{\Delta G* \Delta G*}/2$$

$$= (\mu^2 + 2v)\, \sigma_{\Delta G* \Delta G*} + 2\,(v/\mu^2)\, EG^2$$

Thus

$$\sigma_{\Delta G* \Delta G*} \approx \{ \sigma_{\Delta G}^2 - 2v\mu^{-2}EG^2 \} \,/\, (\mu^2 + 2v), \text{ and so}$$

$$\lambda = \mu^2 \; \sigma_{\Delta G* \Delta G*}/\sigma_{\Delta G}^2 = \mu^2 \{ 1 - 2v\mu^{-2}(EG^2/\sigma_{\Delta G}^2) \} \,/\, \{ (\mu^2 + 2v) \}$$

$$\approx 1 - 2v\mu^{-2}(EG^2\sigma_{\Delta G}{}^2)$$

In turn, $(EG^2/\sigma_{\Delta G}^2) = \{1 + (E(G)/\sigma_G)^2\}/\{1 - \text{autocorrelation of } G\}$. As Table A.1 shows, this ranges between 1.8 and 4.8 (for cod); thus $\lambda \approx 1$. The ρ^2 terms can be ignored because, as row 4 of Table 4 shows, the correlation in measured daily changes in the two ports is very small. In fact, it never exceeds .11. Since by the port agents testimony, $\mu \approx .9$, the scale effect dominates and a_G is slightly biased away from zero. Although a_B is also biased away from zero, that bias is also small. Thus we conclude that the true differential effect on price of quantities landed in the two ports is at least as great as we have measured it to be.

II. Dependant Coverage Ratio

Let ξ represent the change in unrecorded Gloucester landings. Then

$$\text{plim } a_{G,OLS} = a_G + a_G\{ [\sigma_{\xi\Delta G}/\sigma_{\Delta G}^2] - [\sigma_{\xi\Delta B}\sigma_{\Delta B\Delta G}/\sigma_{\Delta G}^2\sigma_{\Delta B}^2] \} / \{1 - \rho^2\}$$

$$. \ a_G\{ 1 + [\sigma_{\xi\Delta G}/\sigma_{\Delta G}^2] - [\sigma_{\xi\Delta B}\sigma_{\Delta B\Delta G}/\sigma_{\Delta G}^2\sigma_{\Delta B}^2] \}$$

where ρ is the correlation coefficient between ΔG and ΔB. Likewise,

$$\text{plim } a_{B,OLS} \ . \ a_B + a_G\{ [\sigma_{\xi\Delta B}/\sigma_{\Delta B}^2] - [\sigma_{\xi\Delta G}\sigma_{\Delta B\Delta G}/\sigma_{\Delta G}^2\sigma_{\Delta B}^2] \}$$

It is reasonable to suppose that $\sigma_{\xi\Delta B} = (1 - \delta)\sigma_{\Delta B\Delta G}$, where δ is now considered to be constant and about .9. Define ψ so that $\sigma_{\xi\Delta G} / \psi\sigma_{\Delta G}^2$; we should expect that $0 < \psi < 1 - \delta$, but that the two parameters are of the same magnitude. Then

$$\text{plim } a_{G,OLS} - a_G \approx a_G\{ \psi - (1 - \delta)\rho^2 \} \approx a_G\psi < 0$$

$$\text{plim } a_{B,OLS} - a_B \approx a_G\{1 - \delta - \psi\}\sigma_{\Delta B\Delta G}/\sigma_{\Delta B}^2 \approx 0$$

noting, from Table 4, that $\sigma_{\Delta B\Delta G}$ is typically an order of magnitude less than $\sigma_{\Delta B}^2$.

Table 1: Total Quantity Landed (in thousands of pounds)

	All Species		Major Groundfish Species	
Year	Boston	Gloucester	Boston	Gloucester
1908	76 030	106 007	65 139	60 582
1939	295 353	75 766	276 843	67 443
1944	151 762	188 661	129 951	145 129
1959	113 257	228 722	109 272	81 930
1964	124 020	140 445	105 000	63 924
1969	57 675	80 250	43 452	34 156
1974	31 485	133 845	23 363	31 466
1979	34 320	166 545	26 792	31 466
1984	17 925	168 915	16 643	64 184
1989	15 105	94 275	14 218	20 763
1992	12 480	96 885	12 033	19 294

Table 2

Mean Yearly Quantity Landed, 1982-1992

	Boston	Gloucester	Boston's Share
Cod	6 678	16 300	.29
Cusk	443	1 061	.30
Y. Flounder	227	964	.19
Ame. Flounder	1 010	3 983	.20
Haddock	1 912	5 089	.27
Hake	1 112	3 454	.24
Redfish	1 294	1 853	.41
Pollock	4 358	10 500	.29
Wolffish	221	472	.32

Table 3: Summary Statistics

Species	Price in Gloucester	Change in Gloucester Price	Price in Boston	Change in Boston Price	Volume Landed in Gloucester	Change in Gloucester Volume	Volume Landed in Boston	Change in Boston Volume
	(dollars per pound)				(pounds)			
Cod: mean	0.60	-0.00	0.68	-0.00	14088	-1709	7466	-575
s.d.	0.19	0.07	0.23	0.11	17662	18888	8967	11097
Cusk: mean	0.37	-0.01	0.44	-0.01	3607	-248	2061	-72
s.d.	0.16	0.08	0.21	0.17	4763	5975	2219	2725
Yellowtail	0.72	-0.01	0.82	-0.00	2435	-519	1534	-52
Flounder	0.25	0.12	0.30	0.17	3677	4843	1897	2581
Large American	1.00	-0.01	1.11	-0.01	7049	-715	2767	-160
Flounder	0.32	0.11	0.38	0.15	12123	14176	2603	3263
Whole Hake	0.38	0.00	0.49	-0.00	3057	-136	4912	-214
	0.25	0.15	0.30	0.12	4638	5207	5076	6250
Unclassified	0.31	0.00	0.49	-0.01	6915	-726	6437	-214
Redfish	0.11	0.08	0.19	0.12	10891	13141	9235	11634
Drawn	0.35	-0.00	0.43	-0.01	18436	-1364	10322	-784
Pollock	0.16	0.09	0.19	0.09	32498	33766	15117	19412
Wolfish	0.34	-0.01	0.40	-0.01	1658	-190	1016	-71
	0.16	0.08	0.19	0.08	2144	2316	1316	1770

Table 4: Ordinary Least Squares

	811 Large Cod	960 Cusk	1231 Yellow-tail Flounder	1241 Large Ame. Flounder	1470 Large Haddock	1530 Whole Hake	2400 Unclass. Redfish	2691 Drawn Pollock	5120 Wolf-fish
Landings:	Dependant Variable: Gloucester Price								
Boston	-1.7	-12.4	-.14	-18.7	-9.5	-1.6	-.4	-1.0	-22.7
	(.17)	(1.9)	(4.5)	(1.9)	(.79)	(1.8)	(.3)	(.2)	(3.1)
Gloucester	-1.5	-9.0	-13.6	-12.9	-4.9	-9.3	-2.4	-1.4	-26.4
	(.09)	(1.0)	(2.4)	(0.6)	(.32)	(.9)	(.3)	(.1)	(2.0)
D.W.	.46	.54	.53	.65	.73	.74	.79	.56	.62
	Dependant Variable: Boston Price								
Boston	-2.23	-19.3	-.85	-24.5	-12.5	-4.6	-3.2	-1.7	-29.4
	(.20)	(2.7)	(5.5)	(2.2)	(1.0)	(2.1)	(.6)	(.2)	(3.6)
Gloucester	-1.70	-11.0	-17.4	-15.4	-5.3	-11.5	-5.4	-1.6	-31.0
	(.11)	(1.3)	(3.0)	(.71)	(.45)	(1.0)	(.5)	(.1)	(2.4)
D.W.	.60	.86	.62	.68	.73	.54	.69	.48	.36
Number of Obs.	1606	1338	632	1438	1409	649	1108	1210	1304

Landings are in millions of pounds. Prices are dollars per pounds.

Table 5: Nonlinear Least Squares: Quasi Differencing

	811 Large Cod	960 Cusk	1231 Yellow-tail Flounder	1241 Large Ame. Flounder	1470 Large Haddock	1530 Whole Hake	2400 Unclass. Redfish	2691 Drawn Pollock	5120 Wolf fish
	Dependant Variable: Gloucester Price								
Boston	-.31	-5.35	-1.8	-2.97	-2.42	-1.80	-.64	-.37	-4.28
	(.06)	(.84)	(1.7)	(.65)	(.34)	(1.04)	(.22)	(.10)	(1.46)
Gloucester	-.10	-.81	1.4	-.55	-.41	-.61	.21	-.11	-.50
	(.03)	(.42)	(1.1)	(.26)	(.17)	(.54)	(.20)	(.07)	(1.10)
α	.93	.88	.88	.94	.90	.83	.72	.86	.83
	(.01)	(.01)	(.02)	(.01)	(.01)	(.02)	(.02)	(.02)	(.01)
	Dependant Variable: Boston Price								
Boston	-.62	-12.4	-4.30	-6.19	-4.52	-5.14	-2.61	-.92	-7.71
	(.09)	(1.97)	(2.28)	(.84)	(.46)	(.76)	(.33)	(.10)	(1.40)
Gloucester	-.18	-2.41	-.025	-.95	-.88	-.98	-.38	-.25	-1.39
	(.05)	(.97)	(1.41)	(.33)	(.23)	(.40)	(.30)	(.07)	(1.06)
A	.89	.64	.87	.93	.86	.91	.80	.87	.88
	(.01)	(.02)	(.02)	(.01)	(.01)	(.02)	(.02)	(.01)	(.01)
No. of Obs.	1606	1338	632	1438	1409	649	1108	1210	1304

Table 6: **Non Linear Least Squares: Logarithmic Inverse Demand Curve**

	811 Large Cod	960 Cusk	1231 Yellowtail Flounder	1241 Large Ame. Flounder	1470 Large Haddock	1530 Whole Hake	2400 Unclass. Redfish	2691 Drawn Pollock	5120 Wolfish
	Dependant Variable: Gloucester Price								
$\ln(Q_B+\beta Q_G)$	-.017	-.016	.005	-.020	-.040	-.015	-.007	-.014	-.006
	(.002)	(.002)	(.005)	(.004)	(.004)	(.007)	(.002)	(.003)	(.003)
β	.57	.14	2.55	.22	.14	.51	.22	.50	.14
	(.19)	(.07)	(9.80)	(.14)	(.05)	(.71)	(.28)	(.27)	(.24)
α	.93	.88	.88	.94	.90	.82	.71	.86	.83
	(.01)	(.01)	(.02)	(.01)	(.01)	(.02)	(.02)	(.02)	(.01)
	Dependant Variable: Boston Price								
$\ln(Q_B+\beta Q_G)$	-.034	-.043	.004	-.043	-.085	-.038	-.038	-.033	-.003
	(.003)	(.005)	(.006)	(.005)	(.006)	(.005)	(.003)	(.002)	(.002)
β	.21	.27	24.65	.43	.22	.11	.33	.30	.19
	(.06)	(.10)	(361.2)	(.14)	(.05)	(.05)	(.10)	(.07)	(.13)
α	.88	.63	.87	.92	.85	.91	.80	.86	.88
	(.01)	(.02)	(.02)	(.01)	(.01)	(.02)	(.02)	(.01)	(.01)

Q_B and Q_G are, respectively, quantities landed at Boston and Gloucester, in millions of pounds. Price is in dollars per pound.

Table 7: The Price of Cod: Nonlinear Least Squares (Quasi Differencing)

	Dependant Variable: Price in					
	Glouc.	Boston	Glouc.	Boston	Portland (All)	Portland (Auction)
$\Delta_\alpha B_t$	-.31	-.62	-.39	-.75	-.16	-.24
	(.06)	(.09)	(.08)	(.13)	(.10)	(.15)
$\Delta_\alpha G_t$	-.10	-.18	-.14	-.28	-.05	.01
	(.03)	(.05)	(.05)	(.08)	(.06)	(.10)
$\Delta_\alpha B_{t-1}$			-.13	-.31		
			(.07)	(.11)		
$\Delta_\alpha G_{t-1}$			-.08	-.18		
			(.04)	(.07)		
$\Delta_\alpha Port_t$					-.14	.13
					(.12)	(.16)
$Price_{t-1}$	.93	.89	.96	.90	.90	.86
	(.01)	(.01)	(.01)	(.02)	(.01)	(.02)
Number of Obs.	1606	1606	1034	1034	1034	300

B_t, G_t and $Port_t$ are daily quantities landed in Boston, Gloucester and Portland, respectively, in millions of pounds. Price is mean price in the port, denominated in dollars per pound. $Price_{t-1}$ is the previous day's price. The sample for columns (1) and (2) include days for which there were landings in both Boston and Gloucester on that and the previous day. Columns (3)-(5) require landings in those two ports and Portland on that day the previous two days.

Table 8

Covariances and Correlations

	811 Large Cod	960 Cusk	1231 Yellow-tail Flounder	1241 Large Ame. Flounder	1470 Large Haddock	1530 Whole Hake	2400 Unclass. Redfish	2691 Drawn Pollock	5120 Wolffish
Var(ΔB)	1000	7.3	8.7	23	180	41	140	720	2.9
Var(ΔG)	2800	30	23	150	710	150	180	1700	5.2
Cov(ΔB,ΔG)	60	.21	.45	5.2	39	-.96	21	120	.018
Corr(ΔB,ΔG)	.036	.015	.032	.088	.110	-.012	.135	.107	.005

Units are millions of pounds