# The Unexpected Impact of Information Sharing on US Pharmaceutical Supply Chains

Leroy B. Schwarz, Hui Zhao
Krannert School of Management, Purdue University, West Lafayette, Indiana 47907
{lschwarz@purdue.edu, zhaoh@purdue.edu}

This paper examines a change in business practices in the pharmaceutical manufacturer-to-distributor supply chain, a change that essentially forced pharmaceutical distributors to maintain lower inventories. This change provided pharmaceutical manufacturers with information about distributor customer demand and inventories that had previously been withheld from them. Supply chain theory and practice in other industries suggest that by improving decision making and implementation, companies can operate with substantially lower inventories. This happened in pharmaceutical distribution when a Securities and Exchange Commission investigation led manufacturers to force distributors to operate with less inventory. Theory and practice further suggest that manufacturers who are provided with relevant information that they did have previously would take advantage of this information to reduce their inventories. This evidently did *not* happen in pharmaceutical manufacturing. We contend that pharmaceutical manufacturers either do not know how to take advantage of such information or they do not care.

*Key words*: pharmaceutical industry; health care; supply chain management; inventory management; information sharing.

*History*: This paper has been refereed.

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Over the last 20 years, information sharing has revolutionized supply chain management. We now generally assume that information sharing in the supply chains for *any* product or service will bring about improved efficiency and effectiveness at all supply chain levels.

This paper examines the introduction of significant inventory reduction and information sharing into the supply chains for pharmaceutical products in the United States. This introduction was unusual because its catalyst came from *outside* the industry—a Securities and Exchange Commission (SEC) investigation into improper financial reporting by a manufacturer, Bristol Myers Squib (BMS). It is also unusual because pharmaceutical manufacturers initiated it to keep distributor inventories low. The impetus for the fee-for-service model came from the drug manufacturers, who are under pressure by the SEC and FDA to reduce the inventory in their channels (Becker 2004).

Note that manufacturers generally want to keep downstream inventories high to reduce their own inventory holding costs. Brand-name pharmaceutical manufacturers also have a reason for ensuring large downstream inventories: to provide high distributor service levels to maintain or gain market share. Although its effect on pharmaceutical distributors has been profound, evidence indicates that information sharing has had *no* impact on the inventory management practices of pharmaceutical manufacturers.

This paper should interest anyone interested in how *quickly* and *profoundly* a company's business model—in this case, that of the major pharmaceutical distributors—can change, and how its efficiency can increase if it is forced to carry significantly lower inventories. It should be an object lesson for anyone who believes that information sharing *will* bring about improvements in efficiency and effectiveness at all levels of the supply chain.

Information sharing has improved the performance of supply chain partners in many industries. Large computer manufacturers (e.g., IBM and Hewlett-Packard) routinely ask for sales data from their resellers to improve their own performance (Lee and Whang 2000). Manufacturers such as Campbell Soup Company and VF Corporation obtain sales information from retailers for production and distribution planning (Simchi-Levi et al. 2003). In this paper, we investigate the impact of information sharing in the pharmaceutical industry. The evidence we provide is based on (1) financial information from AmerisourceBergen, McKesson, and Cardinal Health—the "Big-3," (2) US Census Bureau (M3) data on US pharmaceutical and medicine manufacturing inventory dollars and shipment dollars, and (3) annual surveys conducted by the Healthcare Distributors Management Association (HDMA). We also conducted one- to two-hour interviews with approximately one dozen pharmaceutical supply chain executives.

## BACKGROUND

Relatively little has been published in the supply chain and operations management literature about health-care product supply chains, in general, or pharmaceutical supply chains, in particular. Burns et al. (2002) is the most frequently cited general reference. The Kaiser Family Foundation (2005) describes the organizations involved in the US retail supply chain and the key financial relationships among them. Schwarz (2010) describes the flows of products, dollars, and information in the supply chains for medical and surgical supplies, pharmaceuticals, and orthotic devices. Most other available resources are website postings from industry experts and consulting companies; these typically do not cite accessible databases. We offer the following background.

Although the development and manufacture of pharmaceuticals is typically complex, the physical distribution of pharmaceutical products is straightforward. Nearly 80 percent of prescription drug volume flows from manufacturers to distributors (often called wholesalers), and then either to providers (e.g., hospitals and clinics) or to retail pharmacies (Center for Healthcare Supply Chain Research 2007).

Pharmaceutical manufacturing is diverse in nature and international in scope. In the United States, the 10 largest pharmaceutical corporations accounted for almost 60 percent of sales in 2004 (The Kaiser Family Foundation 2005). Brand-name pharmaceutical manufacturers generally enjoy large profit margins; between 1995 and 2008 the top five manufacturers had an average aggregate profit margin of 18.5 percent.

Pharmaceutical distribution in the United States is highly concentrated. The Big-3 share about 90 percent of the market. Pharmaceutical distributors, unlike manufacturers, generally have small profit margins; during the same 1995–2008 period, these three distributors had an average aggregate profit margin of 1.2 percent. More interesting, however, is the *source* of distributor profits. According to Fein, "...approximately 85% of wholesaler gross-margin dollars come from the buy side" (Fein 2004, p. 21).

Indeed, unlike distributors of most other products who earn money on the "sell side," pharmaceutical distributors earn most of their gross margin from the *manufacturers* whose products they distribute. As we describe below, distributors earned this margin primarily through investment buying (i.e., forward buying) prior to 2002–2003; however, they have since earned this margin primarily through fee-for-service (FFS) (i.e., a fee in exchange for information reported to the manufacturer by the distributor, such as distributor days-on-hand inventory, daily

orders and shipments to the distributor's customers, and sometimes customer demand forecasts) agreements.

Distributors earn their margin on the buy side for many reasons; these include the buying power of large retail pharmaceutical chains, which dispense the majority of pharmaceuticals, and cost pressure on providers (e.g., hospitals) by third-party payers (e.g., Medicare, Medicaid, and insurance companies). This cost pressure encouraged the development of health-care group-purchasing organizations, which negotiate the prices that their (otherwise unaffiliated) provider members pay for pharmaceuticals and other supplies.

**The Rise of Investment Buying**

Given little or no opportunity to earn gross margin from the sell side of their business, pharmaceutical distributors looked for ways to earn money on the buy side, and the pharmaceutical manufacturers provided a way for them to do so: steady price increases. During the 1990s, manufacturers' annual price increases for prescription drugs averaged 1 percent above inflation (see Figure 1a). For the period 2002–2008, manufacturers' annual price increases for the most widely used brand-name drugs averaged 4 percent above inflation, ranging from 5.3 to 8.7 percent, while inflation ranged from 1.6 to 3.8 percent (see Figure 1b). These steady and relatively predictable increases provided the opportunity for distributors to capture gross margin on the buy side (i.e., investment buying).

Insert Figure 1a about here.

Insert Figure 1b about here.

Under investment buying, distributors purchase large quantities of pharmaceuticals *in anticipation* of a manufacturer's price increase. Then, when the price increases, distributors are

able to sell to their price-conscious buyers at a very small mark-up—sometimes at a discount with respect to the new higher price—and still earn a positive margin.

> ... the rule of thumb at the time was that a 1% price increase paid for 1-month's supply. (Trade Account Manager, Major Pharmaceutical Manufacturer)

Investment buying became such a significant source of gross margin that according to a manager at one of the Big-3 distributors, "The Big-3 all had teams of employees using mathematical models to forecast price increases."

Investment buying also provided pharmaceutical manufacturers with the opportunity to manage sales by pushing product down to distributors (i.e., channel stuffing), which virtually guaranteed manufacturers that they would never lose sales because of distributors running out of their products.

There were, of course, disadvantages to both parties. For distributors, investment buying involved financial risk (i.e., gambling on a price increase). Some of these bets were wrong. The excess inventories that resulted were typically sold to the pharmaceuticals secondary market. This market, which was originally used by high-volume distributors to sell to low-volume distributors for sale to low-volume providers, evolved to become a source of supply to high-volume distributors. Although this opportunity to reduce overstocks was desirable to legitimate businesses, it also provided an opportunity for counterfeit drugs to enter the legitimate US pharmaceutical supply chain—and they did. But, this is another story.

For manufacturers, investment buying meant reduced margins on the products sold to distributors at the lower rather than the higher price. That is, the manufacturers transferred to their distributors margin that *they* would have otherwise earned themselves. Investment buying

also created significant volatility in distributor ordering. Presumably, this volatility required manufacturers to carry larger safety stocks than would be required in the absence of investment buying.

Yet, the major disadvantage of investment buying, from the perspective of supply chain coordination, was that it led to an environment of *no* information sharing, and sometimes *mis*information sharing, between the manufacturers and the distributors. According to a manager in one of the top US-based pharmaceutical distributors,

> It was a game of cat-and-mouse: the distributors didn't want the manufacturers to know what they were selling and what they were holding, so that they could order whatever they wanted. The manufacturers, well, they wanted to manage their sales, but they didn't want to give away the farm.

Hence, instead of sharing information, distributors went out of their way to *not* share inventory, customer ordering, or shipping information with manufacturers.

Despite the disadvantages of investment buying, the catalyst for its end came from *outside* the industry—the SEC. In 2001, the SEC announced an investigation of BMS. BMS was

> ...alleged to have had its wholesalers purchase excess inventory in 2000 and 2001 in order to meet sales and earnings projections...subsequent investigations forced BMS to restate its financial records from 1999 through 2002 and officially announce an end to forward (investment) buying by wholesalers in March, 2003.... (Fein 2005, p. 6).

It is important to note that channel stuffing is not, per se, illegal. Nor was BMS ever found guilty of anything in this investigation. The company reached a settlement with the SEC; it agreed to restate its financial reports and pay $300 million in fines and payments to investors. BMS entered into a final settlement with the SEC in August 2004, which was reported to "limit future sales to wholesalers based on demand or amounts that do not exceed approximately one month of inventory on hand" (Fein 2005, p. 6).

Although public attention was focused on BMS, most major pharmaceutical manufacturers participated in investment buying, and some were under scrutiny. Drug manufacturers are

> under "a lot of pressure to reduce their amount of inventory in the channel" by the Securities and Exchange Commission and the Food and Drug Administration, said Larry Marsh, managing director of Lehman Brothers. "This is an indirect response to greater regulatory scrutiny over the drug industry, which came about when there was the recognition that channel-stuffing (stockpiling drug inventory) had become a fairly persistent practice, " Marsh said. (Becker 2004, p. 9)

**The Rise of Fee-for-Service and Inventory Management Agreements**

With the SEC investigation of BMS in the background, the pharmaceutical supply chain began to replace investment buying with an FFS model with inventory management agreements (IMAs).

Under an FFS/IMA model, pharmaceutical distributors receive fees directly from pharmaceutical manufacturers for the distribution services that the distributors provide. The

details of these agreements are proprietary; however, according to insiders, FFS/IMAs have two parts: the first is an IMA (i.e., a schedule of incentives for the distributor to maintain *low* inventories). The *lower* the distributor's inventory, the *larger* the distributor's discount on products purchased, provided that the distributor meets specific (high) service level targets. (Our interview notes indicate that the manufacturers' desire for lower distributor inventories was motivated by a desire to show that they were *not* channel stuffing. It also provided another source of revenue and margin to the distributors in lieu of investment buying.) The second part involves FFS agreements.

Although determining exactly when FFS/IMAs started is difficult, we believe they began in 2002–2003; according to Fein (2005, p. 1): "Industry estimates indicate that up to 70 percent of distribution volume was covered by IMAs by the end of 2004." According to a vice president of marketing at McKesson, 95 percent of McKesson's manufacturers were under IMAs by the end of 2004.

Note that although distributors continue to receive most of their gross margin from the buy side, they now receive that margin directly from the manufacturers (as discounts or fees) for their services. Indeed, under IMAs, distributors are rewarded for maintaining *lower inventories.* Last, but most relevant to one of our major findings: since 2002–2003, IMAs have provided manufacturers with information about distributor inventories and their downstream customer orders—information that manufacturers did not receive in the days of investment buying, and which *should be* very useful to them in managing their inventories.

Next, we present the findings from our study of the impact of the FFS/IMAs on the pharmaceutical distributors and manufacturers.

## THE IMPACT OF INVENTORY MANAGEMENT AGREEMENTS ON PHARMACEUTICAL DISTRIBUTORS

IMAs have had a profound effect on pharmaceutical distributors; the effect appears to have taken place in two steps. In the first step, distributors were required to dramatically reduce their inventories, and they did so (see Figure 2, which is an extension of Exhibit 2 in Fein 2005).

Insert Figure 2 about here.

Note that in 2001, when investment buying was still largely in place, inventories increased more than sales. In each year since 2001 (except 2007), inventories increased less than sales, and in 2005 and 2009 they decreased (see Figure 3). Note that between 2001 and 2004, turnover increased from 7.4 to 9.5 percent.

Insert Figure 3 about here.

Common sense (and the theory of efficient markets) suggests that to accomplish a significant reduction in inventory in the 2001–2004 interval, distributors *must* have improved their business processes. Schwarz (1998) codifies these notions using the information/control/buffer (ICB) portfolio paradigm. Under the ICB portfolio paradigm, every management system consists of four elements (information, decision making, implementation, and buffering). Each element has quality characteristics. All else being equal, the better the information, decision making, and implementation (e.g., the more accurate the forecast, the faster the implementation), the smaller the buffers (e.g., inventory) required to manage at any fixed level of customer service. Correspondingly, if inventories are forced to be lower, then information, decision making, and/or implementation must become better. According to a vice president of marketing at McKesson, "McKesson adopted SAP starting in 2002. This system including tracking inventory at the SKU level." During this same period, AmerisourceBergen adopted internal

systems to provide incentives for improving order-selection efficiency. Many distributors also installed new information technology systems to improve their inventory management.

These improved business processes—and, perhaps, a refocusing of management attention away from gambling on manufacturer price increases and toward their own internal operations—brought about step two: even further reductions in inventory and increased efficiency. Look at Figure 3 again, focusing on the 2004–2009 interval, after the industry had widely adopted IMAs: inventory turnover increased from 9.5 to 13.5 percent! (Regression analysis on the 2001–2009 data estimates the turnover increase to be 0.82/year, significant at 5 percent level.) Figure 4 displays increasing distributor average fill rates and decreasing distributor out-of-stocks over the same time interval.

Insert Figure 4 about here.

Figure 5 displays the impact of IMAs on the distributors in a different way.

Insert Figure 5 about here.

It displays the changes in total inventory at the Big-3 distributors over three time intervals. On the left, note (shaded area) that distributor inventory increased $1,386 million between 2001 and 2004. Assuming the same inventory turnover in 2004 as in 2001, inventory *should* have increased $6,901 million. This is a savings of $5,515 million. Similarly, between 2004 and 2009 distributor inventory increased $485 million. Assuming the same inventory turnover in 2009 as in 2001, inventory *should have* increased $11,342 million, a savings of $10,857 million. Hence, the distributors' inventory saving between 2001 and 2009 was $16,371 million.

## THE LACK OF IMPACT OF INFORMATION SHARING ON PHARMACEUTICAL MANUFACTURERS

Next, we examine the impact of information sharing on pharmaceutical manufacturers. A great deal of literature is available to demonstrate the value of downstream information to upstream suppliers. In particular, this literature shows that with more information about the downstream inventory replenishment-policy parameters and/or information of their sales or on hand inventory, manufacturers can improve production planning, reduce their stock levels, and reduce total costs. For example, Gavirneni et al. (1999) show that compared with a traditional model in which downstream orders are the only information available to a capacity-constrained manufacturer, when informed of the downstream replenishment policy and its parameters, the manufacturer can modify its production and inventory policy to obtain significant savings. Further, when provided with downstream on hand inventory information, the manufacturer can further reduce its stock level and achieve more savings. Lee et al. (2000), Cachon and Fisher (2000), and Aviv and Federgruen (1998) report similar results. For a comprehensive literature review on value of information sharing, see Chen (2003).

Based on the above, supply chain theory suggests two effects of information sharing on the manufacturer: the first addresses the short run (i.e., 2001–2004), before manufacturers were able to take advantage of the information provided to them under IMAs; the second addresses the long run (i.e., 2004–2009), when manufacturers were able to do so.

In the short run, several influences must have been at work. First, manufacturers might have chosen to increase their own inventories based on concern that reduced distributor inventories might otherwise lead to lost sales. The increase might not have been deliberate. That is, if investment buying had caused too much inventory to accumulate downstream, this temporary increase in manufacturer inventory could simply have been the temporary result of too much supply and not enough demand. However, given the volatility of distributor ordering under

investment buying, theory would predict that manufacturers should be able to reduce their safety stocks under FFS/IMAs, because distributor orders should be smaller, more frequent, and hence more predictable (see, for example, Federgruen and Zipkin (1986a, b) and Gavirneni et al. (1999)). In summary, theory suggests that manufacturer inventories should either increase or decrease in the short run, the net effect depending on the magnitude of these opposing influences. In the long run, once manufacturers have been able to take advantage of the information provided to them in their production and distribution planning, Milgrom and Roberts (1988) would predict reduced inventory and increased turnover. The reduced volatility of distributor orders should further reduce inventories and increase turnover.

Figure 6 displays a plot of aggregate inventory turnover at US pharmaceutical manufacturers between 2001 and 2009.

Insert Figure 6 about here.

It does display a decrease in turnover (i.e., an increase in manufacturer inventories) in 2004 (7.8 percent) compared to 2002 and 2003 (8.1 and 8.3 percent, respectively). More important, the overall trend shows a *decrease* in turnover (regression analysis estimates the turnover decrease to be 0.11/year, statistically significant at 5 percent level), that is, an increase in manufacturer inventories.

This decrease in turnover at the manufacturers has several possible causes, such as an increase in product variety or increased manufacturer concern about inventory allocation. However, the same or similar causes did not yield a decrease in turnover at the distributors. Hence, the evidence suggests that manufacturers have not taken advantage of the information being provided to them under IMAs to lower their inventories (based on improved forecasting, better production planning, etc.). Indeed, those inventories have increased!

Figure 7 provides an alternative perspective.

Insert Figure 7 about here.

Between 2001 and 2004 total manufacturer inventory increased $3,529 million. Assuming the same inventory turnover in 2004 as in 2001, inventory should have increased only $3,362 million, a *loss* of $167 million. Similarly, starting in 2004, manufacturer inventory increased to $2,306 million by 2009. Assuming the same inventory turnover in 2004 and 2009 as in 2001, inventory should have increased only $1,773 million, a *loss* of $533 million. Finally, assuming the same inventory turnover in 2009 as in 2001, inventory should have increased only $5,135 million instead of $5,835 million, a *loss* of $700 million.

Figure 8 provides a supply chain view, by combining Figures 5 and 7.

Insert Figure 8 about here.

Supply chain inventory (manufacturer plus distributor) inventory increased $4,915 million between 2001 and 2004. Based on inventory turnovers in 2001, this increase should have been $10,263 million, a saving of $5,348 million. Finally, based on 2001 inventory turnovers, between 2001 and 2009, the pharmaceutical supply chain enjoyed an inventory reduction of $15,671 million, or $15.7 billion, $16.4 billion in savings at the distributors and a $700 million increase at the manufacturers.

Hence, the evidence shows that manufacturers failed to take advantage of the information provided to them by the distributors to improve their production planning and reduce their inventories. Based on our interviews, the data provided to manufacturers under IMA/FFS agreements are not requested or provided to functions such as production planning, inventory management, or logistics.

Are manufacturers using this information for *other* purposes? Based on our interviews, the answer is "yes." First, sales and marketing uses it, on an aggregate basis, to forecast quarterly sales for financial forecasting. According to the supply chain director of a major pharmaceutical manufacturer:

> We are using IMA information to forecast day-by-day orders from the distributors, and using this information to prepare financial forecasts (e.g., monthly and quarterly sales and income), to provide better explanation to analysts regarding our financial statements.

Manufacturers are reported to also use IMA-provided information about specific large-provider and retail accounts for sales and promotional purposes. An executive of one provider chain reported the manufacturers are offering *providers* the opportunity to do investment buying! Nonetheless, the question remains: *If* manufacturers are *not* using the information about downstream orders and inventories to manage their own inventories better, then *why not?*

Pharmaceutical manufacturing often involves long cycle times, large fixed-lot sizes, and "delays" for quality assurance. Consequently, according to one consultant we interviewed, it is not unusual for forecasts to be blocked out 12–18 months in advance, and for production schedules to be frozen 6 months in advance. Another consultant suggested that some manufacturers understand the potential of supply chain management to reduce inventories and improve profits, but that they do not know how to take advantage of this information.

The *production* supply chain for pharmaceuticals is relatively complex, making it more difficult to use information. However, another explanation, more blunt, yet probably more accurate, is that most manufacturers do not think of supply chain management as a priority and

probably have not paid much attention to it. An internal supply chain consultant for a well-known brand-name manufacturer offered the opinion that "our inventories just aren't that large."

Although some manufacturers do operate with smaller inventories than others, in 2009 the top-five pharmaceutical manufacturers (Pfizer, Merck, Johnson&Johnson, AstraZeneca, and BMS) reported an aggregate inventory investment of $28.8 billion, or 17.2 percent of current assets and 49.0 percent of earnings before interest and taxes (EBIT). Looked at another way, using an inventory-holding cost rate of 20 percent, these manufacturers incurred aggregate inventory-holding costs of $5.8 billion, or 9.8 percent of EBIT.

Given the rise in importance of supply chain management in other industries and the uncertain future profitability of pharmaceutical manufacturing, this leads to the question: Why do pharmaceutical manufacturers not pay more attention to supply chain management? One expert offered the opinion that, from a public relations perspective, pharmaceutical manufacturers do not want to be seen as limiting supply to increase prices. But, given better information, other industries have demonstrated the ability to lower inventories and maintain or improve supply.

Finally, is it possible that pharmaceutical manufacturers *are* paying attention to supply chain management, but that it just has not (yet) had an impact? One consultant mentioned that some manufacturers are starting to look at the potential of supply chain management in terms of information sharing.

In summary, although there are several possible reasons for the increase in manufacturer inventories, we believe that pharmaceutical manufacturers may be forgoing the opportunity to improve their production planning and reduce their inventories—potentially substantial reductions—either because they are ignorant of the opportunity or because they just do not care.

Given the tremendous pressure on pharmaceutical manufacturers to improve their long-term profitability, perhaps it is time for them to add supply chain management to marketing and product development as a competitive priority.

## OPPORTUNITIES FOR SUPPLY CHAIN RESEARCHERS

Although our results find fault with the priorities and/or abilities of pharmaceutical manufacturers, there is plenty of fault to go around. In particular, supply chain researchers have largely ignored the supply chains for health-care products. Or, like the authors a few years ago, they assumed that health-care product supply chains are similar to those of consumer or industrial products. These supply chains are quite unusual, as Schwarz (2010) describes, both in terms of the organizations involved (e.g., group-purchasing organizations) and the business processes (e.g., investment buying).

Pharmaceutical supply chains, in particular, are quite complex on both the input (manufacturing) and the output (distribution) sides. To illustrate: each step of the manufacturing process is typically complex, with very long setup times (e.g., weeks) and subject to rigorous quality control. Different steps in the production process are often performed in different countries, based partly on familiar notions of plant loading, but also because of sensitivity to tax and financial considerations. One consultant that we interviewed suggested that, in view of this complexity, manufacturer inventories are simply the result of a *feasible* plan, that is, inventories or inventory-related costs are not in the planner's objective function. Many opportunities for learning and research on the input and manufacturing side of pharmaceutical supply chains are available.

Many opportunities for learning and supply chain research on the distribution and logistics side of pharmaceutical supply chains also exist (The Association for Healthcare Resource & Materials Management 2010). At the macro level, there are questions to be answered in terms of supply chain design. For example, (1) should a pharmaceutical manufacturer use the existing wholesaler intermediary or distribute direct to providers (e.g., hospitals) as some medical-device manufacturers do? Recently, there have been questions about the value added by the distributors in the pharmaceutical supply chain. Corresponding to these questions, in 2004, the Healthcare Distribution Management Association (HDMA) commissioned a study to assess the pharmaceutical distributors' role (Center for Healthcare Supply Chains 2007). Additional analysis is needed in this area as the industry evolves and new opportunities develop; for example, Martino et al. (2010) recently explored the direct-to-pharmacy model. (2) Should a manufacturer manage its own inventory and logistics, as most do today, or outsource it to a third-party logistics provider (3PL), as Pfizer recently did to United Parcel Service? Some providers (e.g., RO*i*) have started to manage their own distribution instead of using external pharmaceutical distributors and are looking at expanding their business by building large provider networks that will use their distribution and supply chain competence.

In terms of the existing supply chain, how can pharmaceutical manufacturers take advantage of the information already available to them? In addition to the literature already cited, Lee et al. (2000), Aviv and Federgruen (1998), and Aviv (2001, 2007) provide some prescriptions. However, none of the above incorporates the unique characteristics of the pharmaceutical supply chain. Price increases are one such characteristic of brand-name drugs. As Lee et al. (1997) show, price uncertainty is one cause of the bullwhip effect (that orders to the supplier tend to have larger variances than sales to the buyer, i.e., demand distortion, and the

distortion propagates upstream in an amplified form, i.e., variance amplification). Although the FFS/IMA business model has discouraged investment buying, distributors still take advantage of price increases within the boundaries of IMA contracts. Therefore, incorporating the impact of price increases is an important aspect when developing models for pharmaceutical decision making. Another interesting problem involves the design of FFS/IMA contracts. Specifically, how would (or should) the contract parameters affect the manufacturer's production and inventory decisions and the distributor's profits? Hence, how should these contract parameters be set? More importantly, how should these parameters be set such that all players are better off under FFS than under the investment buying model? Zhao et al. (2010) provide answers to these questions. Finally, how *might* IMAs and FFS contracts be structured to possibly coordinate the supply chain? Are there other business models that can better coordinate the incentives in the pharmaceutical supply chain?

## CONCLUSION

This paper documented the impact and potential of information sharing on US pharmaceutical supply chains. We also provided an overview of current business practices in the pharmaceutical supply chain, and identified opportunities for researchers.

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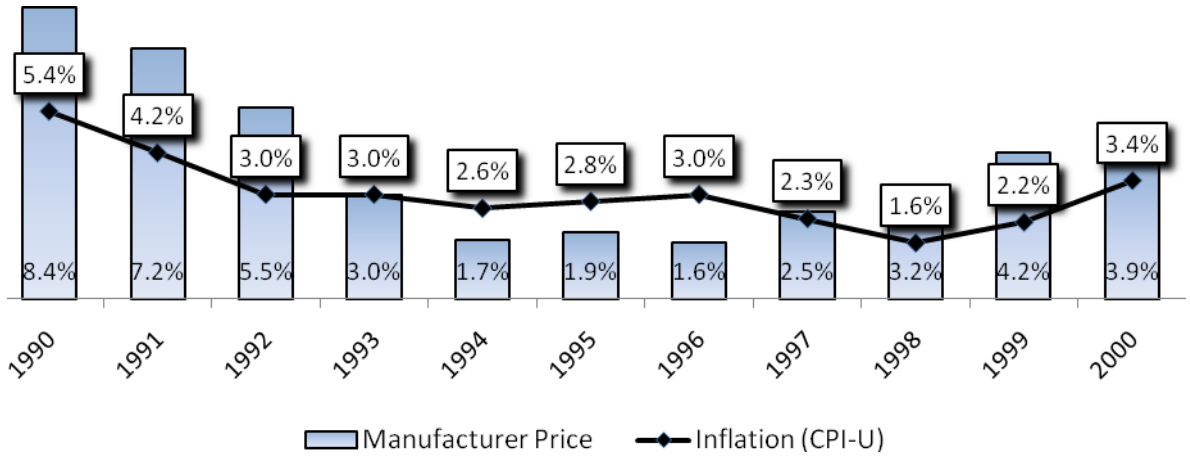


**Figure 1a: The graph shows manufacturer price increases for existing prescription drugs (1990–2000).**

**Source. The Kaiser Family Foundation (2001).**

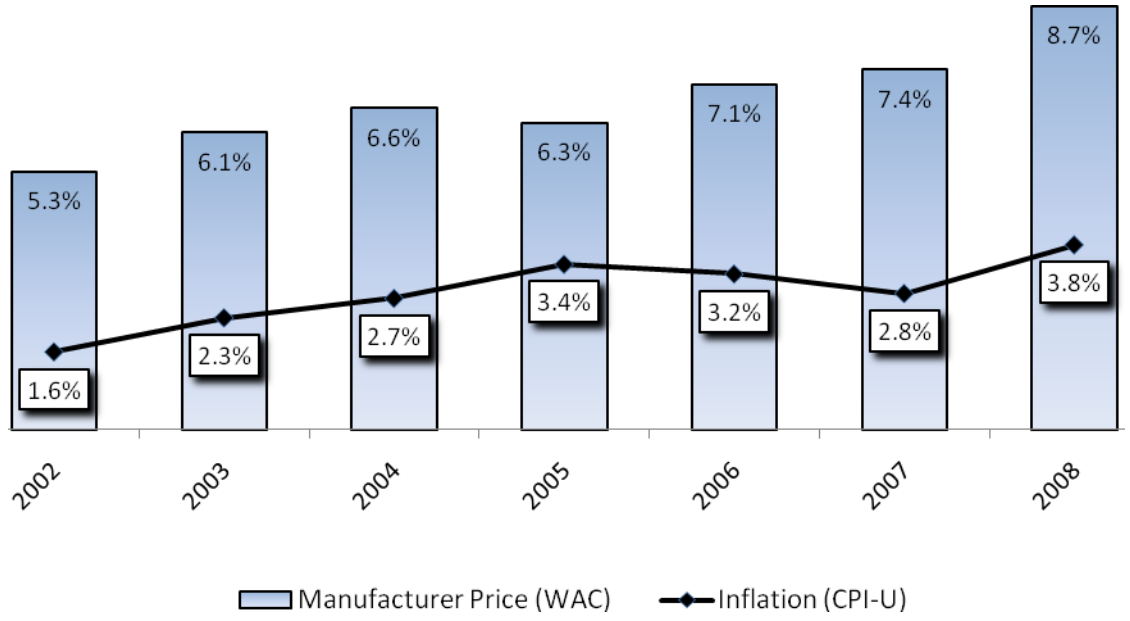


**Figure 1b: The graph shows average annual percentage change in manufacturer prices for widely used brand name prescription drugs (2002–2008).**

**Source: AARP Public Policy Institute (2009).**

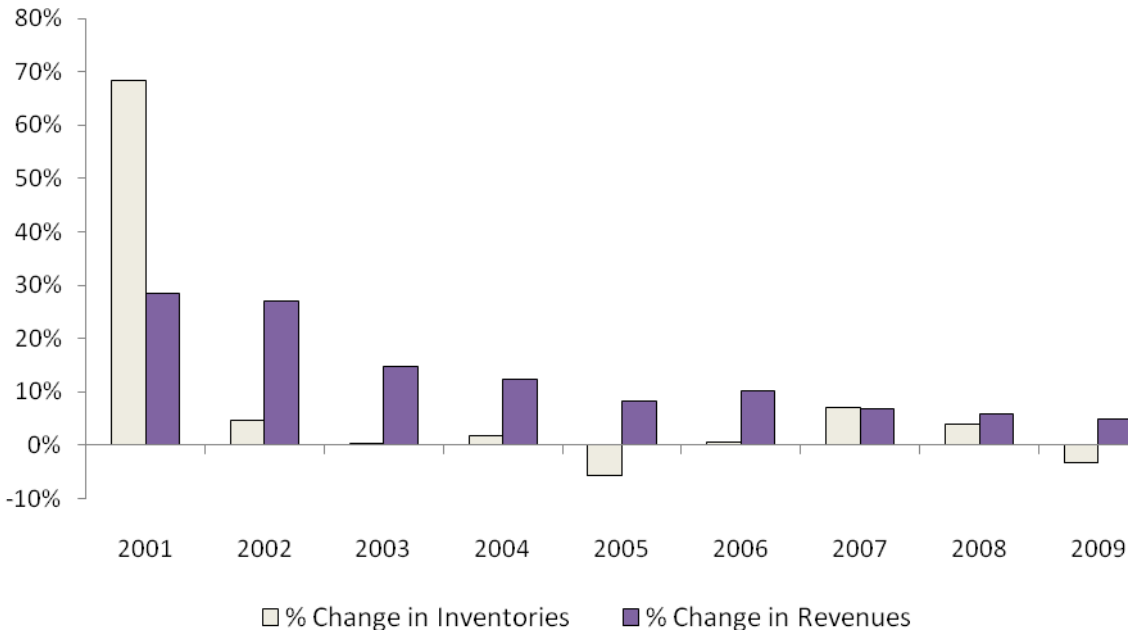


**Figure 2: The graph shows annual % changes in revenues and inventories at the Big-3 distributors (2001–2009). These data are based on December filings of AmerisourceBergen, McKesson, and Cardinal Health, which we calculated from Compustat inventories (INVTQ) and sales (SALEQ) variables.**

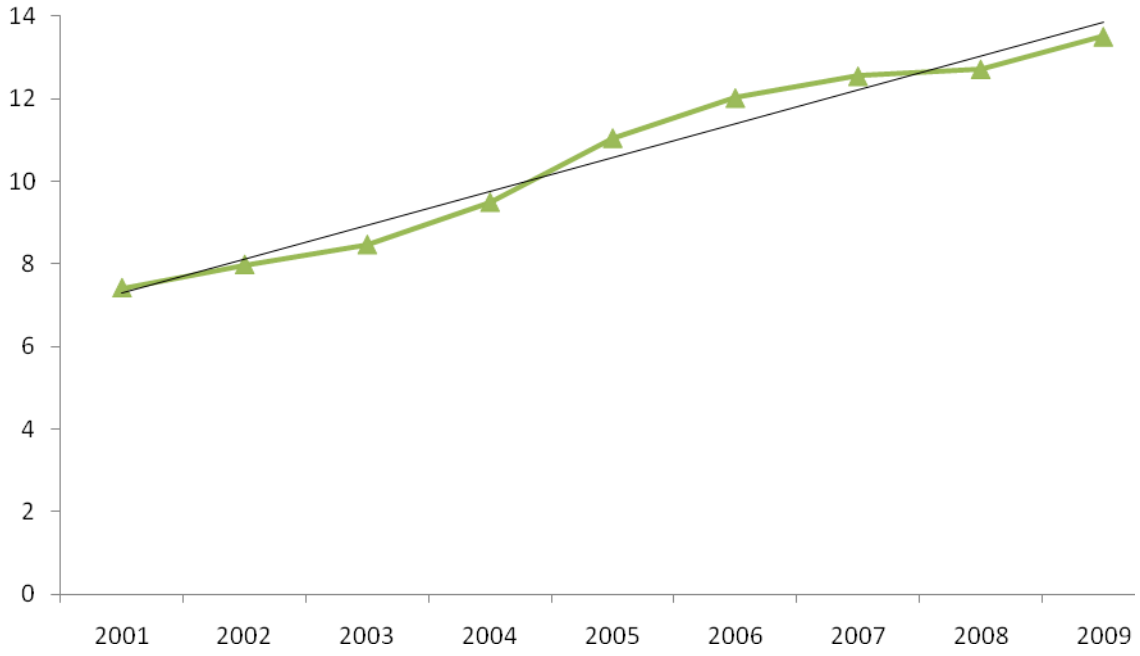


**Figure 3: The graph illustrates inventory turnover at the Big-3 distributors (2001–2009). These data are based on quarterly filings of AmerisourceBergen, McKesson, and Cardinal Health, which we calculated from Compustat INVTQ and SALEQ** variables**. (Note that we calculated aggregate inventory turnover by dividing combined revenue by combined average inventory in the calendar year.)**

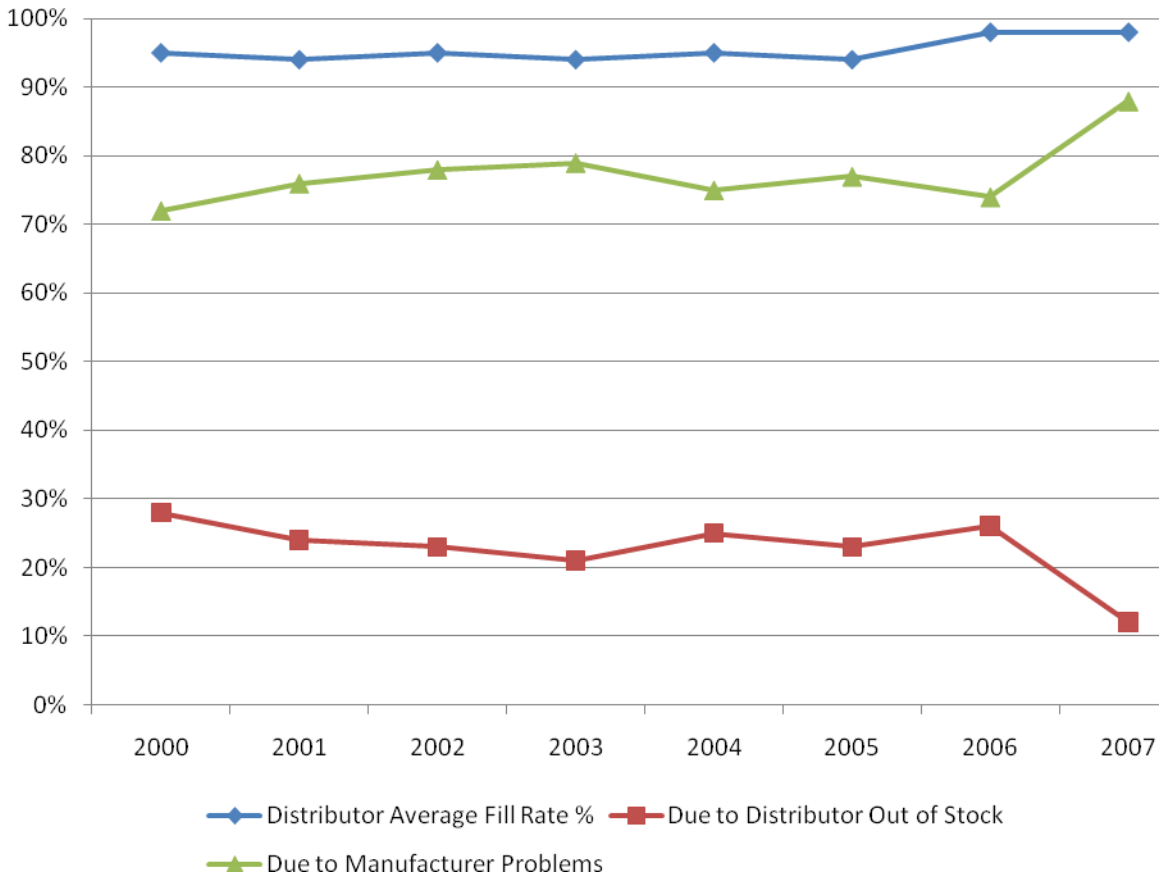


**Figure 4: The graphs illustrates distributor fill rate and reasons for inability to ship.**

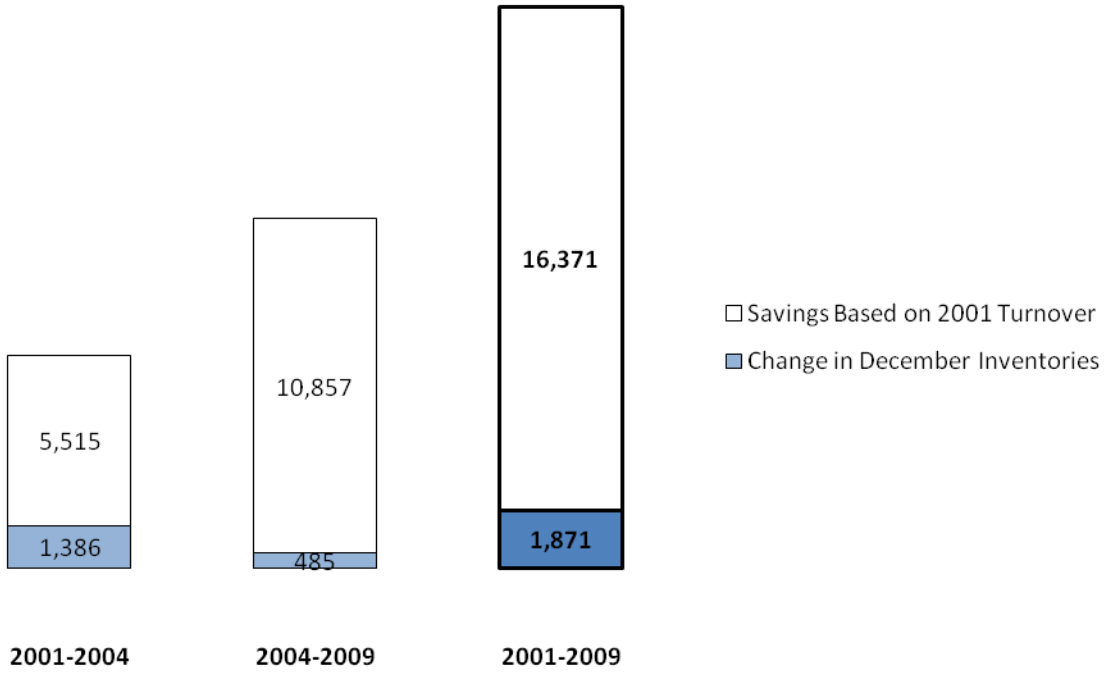


**Figure 5: The graph shows inventory changes and savings at the Big-3 distributors (in $1,000). The data are based on quarterly filings of AmerisourceBergen, McKesson, and Cardinal Health. We calculated these values based on Compustat INVTQ and SALEQ variables.**

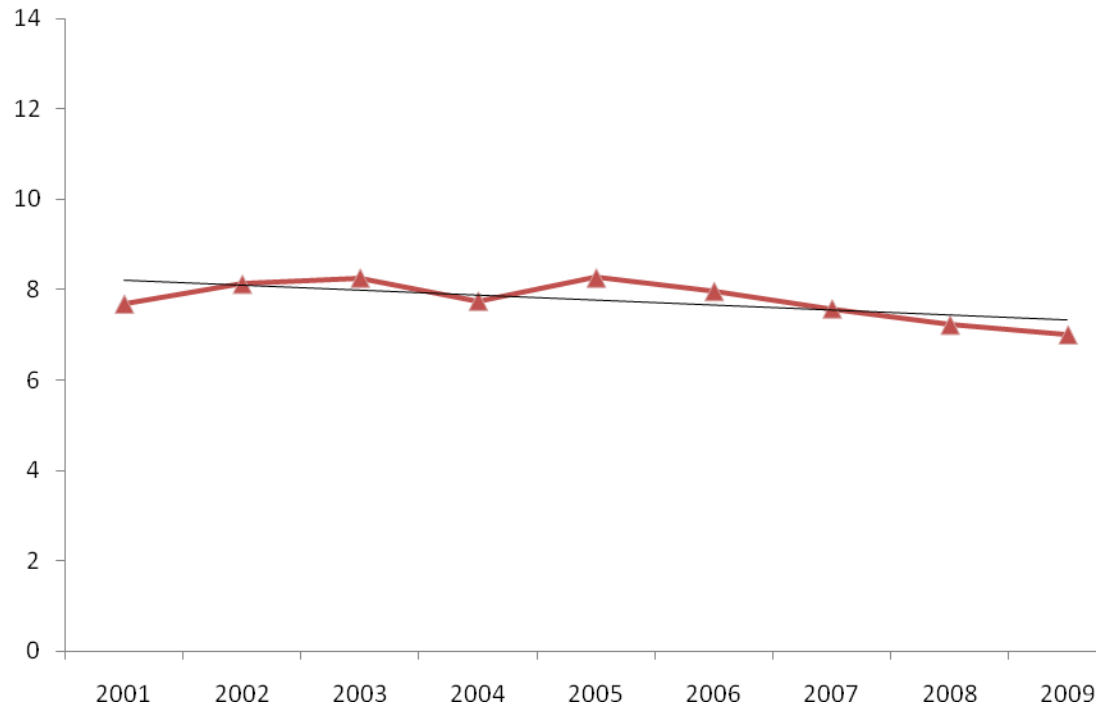


**Figure 6: The graph shows manufacturer inventory turnover from 2001 to 2009. (Note that we calculated aggregate manufacturer inventory turnover by dividing the total shipment value in any calendar year by the average inventory throughout the same year. We collected data from the US Census Bureau Manufacturers' Shipments, Inventories, and Orders reports (A25BVS: shipment values, A25BTI: total inventory).**

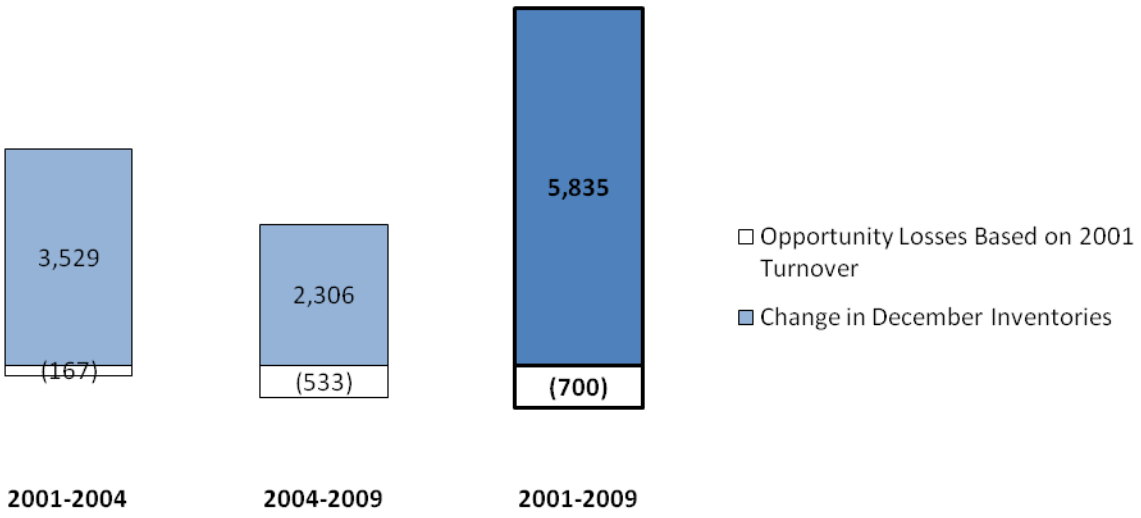


**Figure 7: The graphs show inventory changes and opportunity losses at manufacturers (in $1,000). We collected data from US Census Bureau Manufacturers' Shipments, Inventories, and Orders reports.**

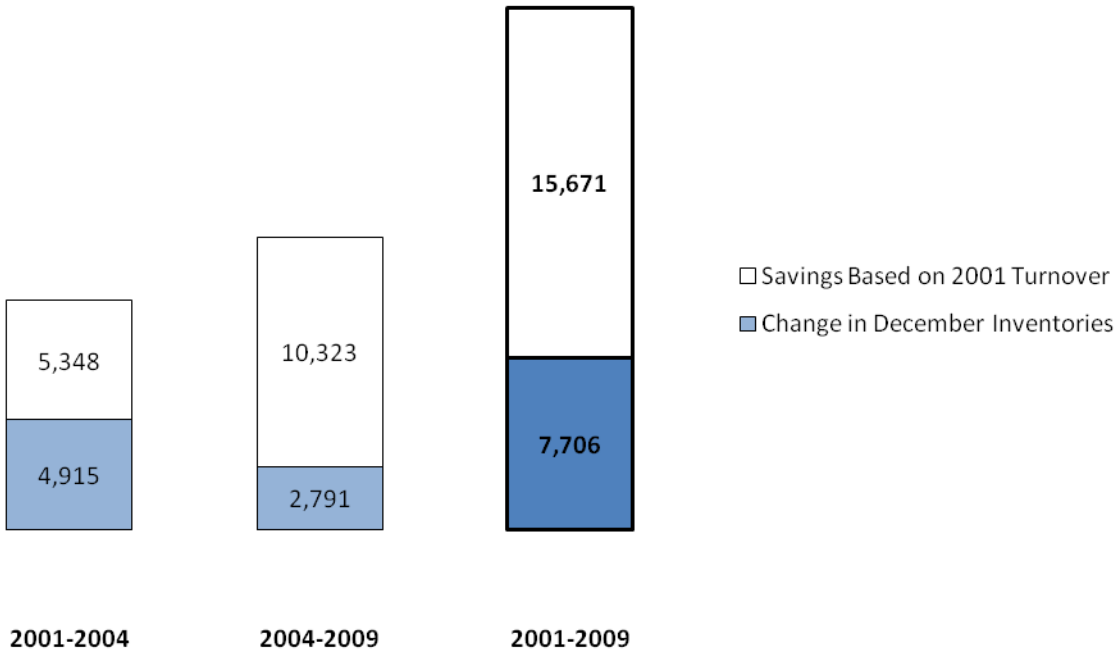


**Figure 8: The graphs show supply chain inventory changes and savings (in $1,000). We collected data from SEC quarterly filings of AmerisourceBergen, McKesson, and Cardinal Health and US Census Bureau Manufacturers' Shipments, Inventories and Orders reports.**

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This paper includes anonymous sources. For verification purposes, the Editor-in-Chief has received a list of these sources.