Antidumping and Production-line Exit: The Case of the U.S. Steel Industry

Bruce A. Blonigen*
University of Oregon and National Bureau of Economic Research

Benjamin Liebman†
Saint Joseph University

Wesley W. Wilson‡
University of Oregon

* bruceb@uoregon.edu, Department of Economics, University of Oregon, Eugene Oregon, 97403. Tele: (541) 346-4680, fax (541) 346-1243.

† Corresponding author. bliebman@sju.edu, Department of Economics, Saint Joseph's University, Philadelphia, PA 19131. Tele: (610)-660-1553, fax (610) 660-3379.

‡ wwilson@uoregon.edu. Department of Economics, University of Oregon, Eugene, Oregon, 97403. Tele: (541) 346-4680, fax (541) 346-1243.

Abstract: We present and examine a novel data set that contains production line information inside U.S. steel plants. We exploit this highly disaggregated data to perform the first study of entry and exit behavior at the level of the production line within individual plants. Our empirical analysis reveals a number of interesting results. First, smaller production lines are more likely to shut down, as are lines that are owned by larger firms. Younger production lines and lines that have undergone modernization are more likely to survive. Our results indicate that lines that are operated by integrated producers are more likely to exit. We find no evidence, however, that antidumping decreases the likelihood of exit, despite the steel industry's frequent use of antidumping protection.

KEY WORDS: Antidumping, Trade Protection, Exit

JEL CODES: L11, L12, L13, F12

1. INTRODUCTION

The steel industry has been the largest recipient of U.S. antidumping (AD) and countervailing duty (CVD) protection for decades, typically accounting for at least one-third of all orders.[1] The industry has argued that trade relief is necessary for its continued viability, and has received multiple forms of trade relief over the last 40 years.[2] A primary justification for this ongoing protection is that foreign companies receive subsidies from their governments, causing them to overcapitalize and dump their excess production on the U.S. market, thus placing U.S. firms are at a competitive disadvantage in their own domestic market.[3]

In this paper, we present a novel data set on steel plants and use it to examine the role of AD and CVD protection, as well as a variety of industry and plant characteristics, in the shutdown of production lines inside U.S. steel factories during the period 1978-2007. We also examine the role of foreign ownership in the widespread shutting down of steel lines since the late 1970s.

---

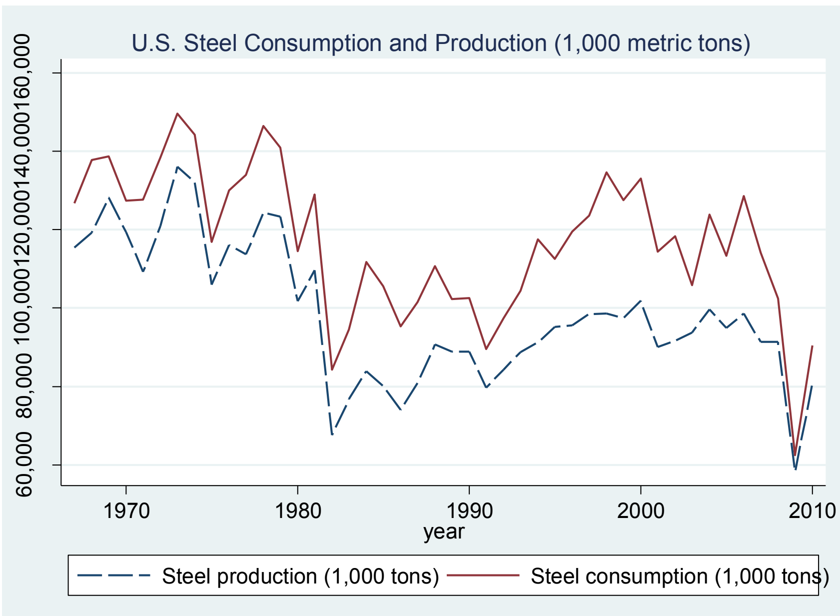
[1] USITC statistics from July 2012 report that steel mill products accounted for about 39 percent of all current AD/CVD orders in place. Data from Bruce Blonigen (http://pages.uoregon.edu/bruceb/adpage.html) indicate that from1980-1995, steel petitions comprised about 40 percent of the total caseload, while data from World Bank's Global Antidumping and Countervailing Databases (developed initially by Chad Bown) show that from 1996-2010 steel petitions were 48 percent of the total caseload.

[2] Other forms of protection include price supports (1978-1982), quotas against Europe and Japan (1969-1974, 1982-1984), comprehensive quotas (1984-1992), and safeguards (2002-2003).

[3] See Blonigen and Wilson (2010) for an empirical analysis of this issue. Their results fail to find evidence to support this argument.

Despite the intermittent problems of the industry over the last several decades, the consumption of steel in the U.S. primarily increased from the mid-1980s until the 2008 recession (albeit more slowly than the overall economy). In general, cyclical fluctuations in both domestic production and imports have been regular features of the U.S. industry (see figure 1), although production has never returned to its 1973-1974 peak.

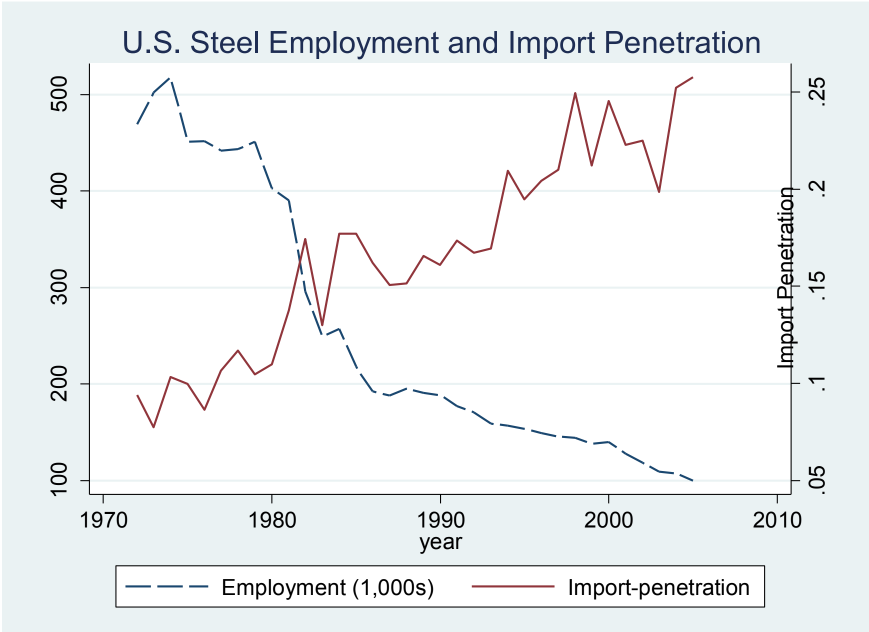
Figure 1 – U.S. Steel Consumption and Production (1967-2010)



Data source: International Iron and Steel Institute

During this time, there have been literally hundreds of antidumping and countervailing duty investigations on various steel products as well. The industry has had mixed success proving that unfair trade has been the source of its woes, including a drastic decline in employment, despite the clear upward trend in import penetration (see figure 2).

Figure 2 – Steel Employment and Import Penetration (1974-2005)



Source: NBER-CES Manufacturing Industry Database, Becker and Gray (2009) Iron and Steel Mills (sic 3312).

Alongside the laying off of hundreds of thousands of workers, the industry also closed scores of production lines within numerous steel plants over this period.

In this paper, we investigate the determinants of these shutdowns, but do so at a level of disaggregation that has not been examined before in this context – production lines within a plant. Many steel plants have multiple production lines, which allow plants the flexibility to shut down (and start) production lines without any change in the overall operating status of the plant. Thus, studies of plant exit may mask the within-plant reorganizations that may occur from changes in policy and economic conditions. This may be particularly true with respect to AD and CVD actions, which often involve quite specific products. This allows us to examine whether AD/CVD protection alters the relative probability of product-line exits and, thus, affects resource allocations within plants.

Given these rich data, we are able to control for plant and firm heterogeneity in capacities, products, and type of firm (integrated versus minimill producers). We also observe the startup year of the individual production line within each plant, as well as major modernization efforts and the role of foreign and domestic investment in the form of joint ventures. Finally, we observe all of the plants that are operated by all of the firms that operated in the U.S. for the set of steel products in our study, which provide a particularly useful opportunity to examine how antidumping policy affects the exit of steel production lines.

Consistent with Lieberman (1990) and Deily (1991), our results provide strong evidence that smaller production lines (measured in terms of tons per year) are more likely to exit. However, we also find that lines that are owned by larger firms are more likely to shut down. Moreover, our results reveal significant differences across product lines and types of plants e.g., integrated versus minimills as well as vintage of plants. However, unlike previous findings in the literature, we fail to find any significant link between foreign ownership and exit.[4] Finally, we find no evidence that the steel industry's aggressive pursuit of antidumping protection has decreased that likelihood of production-line exit.

2. PRIOR LITERATURE

There is an established literature that focuses on the exit of firms from markets. Standard neo-classical theory suggests that exit typically occurs in high-cost firms because of smaller scale in the presence of scale economies. More recently, strategic exit

[4] See, e.g., Bernard and Sjöholm (2003) and Beveren (2007).

models have been developed, beginning largely with theoretical papers by Ghemawat and Nalebuff (1985; 1990), Whinston, (1988) and others. The typical focus of these studies is on the exit decision of firms in the light of a declining market. In Ghemawat and Nalebuff (1986), the decision is first framed as an all or nothing capacity decision in which a single-plant large firm plays an exit game with a single-plant small firm. In this case, it is demonstrated that there is a strategic liability of firm size and the large firm is the first to exit. Later, they demonstrate that when firms can adjust capacity, the large firm moves first and will adjust capacity to mimic the smaller firm.

Fudenberg and Tirole (1986) examine a model where firms enter knowing their own costs, but not that of their rivals. The longer its rivals survive, the more pessimistic a firm will get in its estimate of its rivals' costs and will therefore be more likely to exit. Whinston (1988) extends Ghemawat and Nalebuff (1985) to multiplant operations and finds that size does not give clear predictions of exit order. Instead, size, rate of market decline, and outside factors will negate any clear predictions.

Empirically, there is a large and growing literature on the determinants of firm and plant exits. Lieberman (1990) may be the first to test the predictions of Ghemawat and Nalebuff (1985), framing the decision to exit in terms of a "shakeout" of small firms (costs are higher due to scale or learning) versus a stakeout wherein large firms have the strategic disadvantage of firm size, and then exit first. The results indicate that the small plants are more likely to close. The study also finds that as firms' capacity shares increase, the likelihood of exit also increases.

More recent empirical research examining plant survival and exit behavior (including Chen (2002), Buehler (2004), Dunne *et al.* (2005), Sabuhoror *et al.* (2006), Bernard and Jensen (2007), and Feinberg (2010)), focuses on other factors that affect exit. Chen (2002) presents a duration model of U.S. petroleum refining plants from 1981-1986. He finds that size and technology effects enhance survival duration. Survival duration is also enhanced by the number of plants held, but vertical integration may reduce survivability, while younger refineries have lower rates of survival. Buehler (2004) finds that a tightening of Swiss antitrust legislation had asymmetric effects on firm exit probabilities: Firms that were not involved in exporting were more likely to exit with a tightening, while firms that were involved in exporting were unaffected by the policy change. They used these results to posit a positive relationship between the intensity of product market competition and the likelihood of exit.

Dunne *et al.* (2005) hold that producers that enter a market have different prior production experiences from one another. They quantify the nature of experience and find that these differences affect the decision to exit markets. They find that exit patterns differ according to prior experience. In particular, experienced plants that enter to diversify their product mix are the most likely to exit, followed by *de novo* entrants and then new plants that are owned by experienced firms. They conclude that the characteristics of the plant at time *t* are not sufficient to explain the decision to exit a market, but the initial conditions and the experience at time of entry are central. Bernard and Jensen (2007) examine firm structure, multinationals, and manufacturing plant deaths. They find that plants that belong to multi-plant firms and those that are owned by multinationals are less likely to exit, but that after controlling for plant and industry attributes, multi-unit and multinationals are more likely to close. Feinberg (2010) studies exit behavior among small firms in manufacturing, wholesale, and retail in response to currency shocks. His results indicate that while manufacturers and wholesalers are negatively affected by a strong currency, retailers appear to be little affected by currency shocks.

While Bernard and Jensen (2007) focused on the relationship between domestic multinational enterprises (MNEs) and exit, several recent papers have looked at the impact of ownership by foreign MNEs and exit behavior. Gorg and Strobl (2003) study survival rates in Irish manufacturing plants and find that foreign ownership increases the probability of exit, which support the theory that foreign MNE are more "footloose" than are domestic firms. Bernard and Sjöholm (2003) also find that, after controlling for the larger plant size and higher productivity of foreign-owned facilities, foreign ownership increases the likelihood of exit in the of Indonesian manufacturing sector. Beveren (2007) produces similar results for both foreign and domestic MNEs in her study of exit behavior of Belgian manufacturing firms. Inui *et al*. (2010), however, find that after controlling for plant characteristics, MNEs are not like more likely to close plants, and thus rejects the "footloose" hypothesis. Feinberg and Hartigan (2007) also find no evidence that multinationals are more likely to shut down plants. Finally, Bandick (2010) and Bandick and Gorg (2010) use highly detailed Swedish manufacturing data to show that while foreign MNEs are more likely to shut down plants than are domestic firms, the likelihood of survival increases for plants that are owned by foreign MNEs that are also exporters.

There have been a number of studies that examine exit in the context of the steel industry. These include Deily (1988a, 1988b), Baden-Fuller (1989) and Deily (1991). Deily (1988a) points to the chronic overcapacity of the industry and the role of exit barriers to restrict exit. Deily (1988b) tests and finds support for the hypothesis that firms adjust to a declining state by disinvesting first and then closing their high cost plants. Her empirical analysis, which used data on 43 steel plants from 1960-1981, found that firms disinvested from plants that were least likely to remain profitable, and more generally that the industry was highly competitive due to strong competition from minimills and imports along with stagnate domestic demand. Baden-Fuller (1989) examined exit in a declining market by examining steel castings. In this paper, there is "only a little support for the strategic view of exit." While plant profitability is an influence on exit there are other explanations. Firm characteristics such as diversification and operations in other markets increase the likelihood of closure. Finally, Deily (1991) also shows that plant characteristics that determine expected revenues and costs explain much of exit, but that firm and plant size may have some effect as well. More specifically, she finds that small plants were more likely to be closed, while plants owned by larger firms were more likely survive. This latter effect diminished with firm size, and actually had the opposite effect at the largest firm size.

Finally, we are aware of only two prior papers that study the relationship between antidumping and exit, which is a primary focus of our study. Feinberg and Hartigan (2007) investigate the inter-temporal link between the announcement of AD determinations and plant exit decisions by petitioning firms. Their empirical results fail to find evidence that these announcements impact the timing of exit, regardless of whether there is an affirmative or negative determination. In contrast, Pierce (2007) studies US manufacturing plant behavior in response to AD protection over the 1992-2002 period and finds that duties allow firms to continue production of protected products. While Pierce's study is closest to ours, there are a couple important differences: First, he examines the impact on all manufacturing industries. We instead focus on the steel industry because of the individual production line data that are available for this industry, which even the Census data used by Pierce does not have.[5] Second, our data sample spans a much longer time period (1978-2007) than Pierce's study.

3. EMPIRICAL FRAMEWORK AND DATA

We follow past exit studies in assuming that exit occurs when a unit is no longer profitable. Assume that the long-run profitability of a production line is a function of its attributes at a given point in time (*t)*,

$$\pi_{ijkt} = x_{ijkt}\beta + \varepsilon_{ijkt},$$

where *i* indexes firms, *j* indexes plants, *k* indexes production lines, *x* is a matrix of explanatory variables, and ε is an error term. These long-run profits are not observed, but when they fall below zero, we will observe that the firm exits the activity. Given this, the probability of exit can be expressed as:

$$\Pr(Exit)_{ijkt} = \Pr(x_{ijkt}\beta + \varepsilon_{ijkt} < 0). \qquad \textbf{(1)}$$

As is standard, we estimate this model using a binary exit variable as our dependent variable and assume the error term is of the form such that we can estimate the parameters (β) using a logit model via maximum likelihood estimation.

[5] The closest that the Census data come is in having some economic output (e.g., revenues) by product code for a plant. But this is different from our data, which contain capacity by production line, as the Census data may aggregate multiple production lines that are producing the same product in a plant.

Before describing our explanatory variables, we first describe our data on production line operations and exit, which cover the operation of steel production lines that are inside individual U.S. steel plants from 1978-2007. More specifically, we have constructed a panel dataset that tracks specific production lines that operate within individual U.S. plants of all steel firms producing five key carbon steel products: hot rolled sheet, cold rolled sheet, galvanized sheet, plate, and wire rod.

The primary source of these data is the trade journal, *Metal Producing and Processing*, which periodically surveyed steel firms that operate in the U.S. during 1978-2000. Specific survey years are 1978, 1982, 1987, 1989, 1991, 1996, 1998, and 1999. We used the *Directory of Iron and Steel Plants* published by the Association for Iron and Steel Technology (AIST) to update the data for plants that were operating in 2007. We also did some Internet searches and contacted individual plants and companies to fill in missing information or to generally verify our data.[6] In total, there are 284 production lines in our sample that produce at least one of these five products that operated during at least one year of our data period (Table 1). These production lines comprised 44 hot rolled sheet lines, 98 cold rolled sheet lines, 87 galvanized lines, 28 plate lines, and 27 wire rod lines.

[6] In some cases, data were verified and/or taken from a variety of secondary sources. These include: Christopher Hall's 1997 volume, *Steel Phoenix – the Fall and Rise of the U.S. Steel Industry*; the University of Pittsburgh's Center for Industry Studies 'Steel Plant Database, The U.S. International Trade Commission's 2005 report, "Steel: Evaluation of the Effectiveness of Import Relief"; William T. Hogan's 1994 volume, *Steel in the United States: Restructuring to Compete*, and Purchasing Magazine's 1999 report, "North America Galvanized Steel Capacity."

Table 1. Production Lines in Sample

Product	Frequency	Percent
Hot Rolled	44	15.5
Cold Rolled	98	34.5
Galvanized	87	30.5
Plate	28	10
Wire Rod	27	9.5
Total	284	100

Table 2 contains the frequency of lines in production through time by product. First note that overall there were 215 lines in operation in 1978. This fell through 1991 and then increased in 1998 and 1999 to 185 lines. However, in 2007, the number of lines had fallen significantly to 160. Also note that in 1978, the number of cold rolled sheet lines was 82, but by 2007, the number had fallen to only 46, representing a net reduction in cold-rolled lines of 44%. Indeed, for all products except galvanized, the number of production lines in 2007 is lower than the number in 1978. For example, hot-rolled, wire rod, and plate experienced net declines of 8, 10, and 18 lines, respectively, which represented net reductions of 23 percent, 48 percent, and 67 percent. In contrast, the number of galvanized lines rose by 17, or 34%, a trend that is consistent with the shift by automobile and other downstream consumers away from cold rolled sheet towards galvanized sheet.

Table 2. Operating Production Lines by Year and Type

Year	Hot Rolled	Cold Rolled	Galvanized	Plate	Wire Rods	Total
1978	35	82	50	27	21	215
1982	32	70	46	24	20	192
1987	29	61	51	16	18	175
1989	28	58	50	16	17	169
1991	29	55	52	15	17	168
1996	28	49	63	13	13	168
1998	30	50	77	14	14	185
1999	30	49	79	13	14	185
2007	27	46	67	9	11	160

The focal point of the empirical model is to explain exit across different production lines across different trade regimes: AD and CVD. Table 3 provides a summary of exits over time. Our observation years indicate only that a particular line has exited, although the precise year of exit cannot be quantified. That is, we only know that exit occurred sometime between our observation periods, not the exact date of exit. Over the entire time period, there were a total of 114 exits. These included 21 from 1979-1982, 24 from 1983-1987, 23 from 1992-1996, and 24 from 2000-2007.

Table 3. Production Line Exits by Year

Years of Exit	Production Lines Operating at the End of the Relevant Time Period	Exits During the Time Period
1979-1982	192	21
1983-1987	175	24
1988-1989	169	6
1990-1991	168	7
1992-1996	168	23
1997-1998	185	7
1998-1999	185	2
2000-2007	160	24

We now turn to describing our explanatory variables that influence the long-run profitability of a production line, many of which follow past studies of exit. We begin with attributes of the plant (or production line) that we observe. First, we include the logged age of a production line since startup (*Age of Production Line*) and hypothesize that it has a positive coefficient, as older production lines presumably become less efficient over time and are, therefore, more likely to shut down. However, firms have the ability to modernize the equipment in an existing production line and we have information on when each line experiences such modernization. We include a variable, *Modernize*, which is a dummy value that is equal to '1' if the production line has recently been modernized. We hypothesize a positive coefficient on this variable since modernized lines are more likely to be efficient and, thus, less likely to be shut down.

We next include two variables to account for the effect of capacity on exit, which neo-classical and strategic models of exit suggest is an important determinant of exit. Neo-classical models suggest that the greater capacity (here, of a production line) makes exit less likely because of efficiencies that stem from economies of scale. In contrast, Ghemawat and Nalebuff's (1985) strategic game theoretic model suggests that greater capacity, especially in the context of a declining market where capacity must be cut to maintain profitability, accelerates the onset of losses and makes exit more likely. As a result we include the variable, *Production Line Capacity*, and the sign of its coefficient will be informative in identifying the relative explanatory strength of these competing theories.

We also include the entire capacity of the firm other than its capacity in this particular production line, which we label *Firm Capacity Other Than Production Line*.

Whinston (1988) finds that plants that are operated by firms with large amounts of capacity in other plants might be more likely to be shutdown while the firm continues to operate its other facilities. Bernard and Jensen (2007) also find evidence of this effect after they control for other plant-specific characteristics. If such effects extend beyond the plant level to the production line level, then larger capacity at these more aggregate dimensions at the firm level would make exit of a particular production line more likely, and suggests an expected positive coefficient. Capacity of each production line is recorded in tons per year, as is firm capacity, and both of our capacity measures are logged to account for substantial skewness.

We next include a measure of foreign ownership, *Production Line Foreign Owned*, which denotes whether a product-line is controlled by a foreign firm or not.[7] Foreign ownership has been shown to be correlated with increased profits and efficiency, as well as overall firm survival. However, Bernard and Sjöholm (2003), Bernard *et al*. (2007), Beveren (2007), and Bandick (2010) all find that foreign-owned plants are more likely to shut down, after controlling for plant-specific characteristics. The intuition is that foreign firms, as multinational firms, have more flexibility to shift production across locations. Interestingly, our dataset contains instances in which a single production line is foreign-owned, while other parts of a facility are U.S.-owned. Thus, foreign ownership is truly something that varies at the production line level.

[7] We define foreign ownership as having at least ten percent of the US firm owned by non-US investors (generally non-US steel firms), although in most cases, foreign ownership is greater than 30 percent. Also, in some cases, foreign investment takes place only for particular plant within a firm, or even for a particular product at a particular plant. Information for this variable came primarily from Hall (1997).

The next set of variables relate to production technology. There are three types of firms in the data: Integrated steel firms, minimills, and steel processors. The primary difference between these three types of firms is the way in which they produce the raw steel that is ultimately processed into five steel products in our data. Integrated firms produce steel by first combining iron ore and coking coal in blast furnaces, while mini-mills produce steel from recycled scrap that is melted in electric arc furnaces. The raw steel that emerges from integrated furnaces is sometimes processed into downstream products on-site, and other times shipped to processing facilities nearby. Raw steel produced at minimills is almost always processed into downstream steel products on-site.[8] Finally, steel processing firms are distinct from integrated and minimill producers in not producing their own raw steel, but instead buy steel that has already been processed to varying degrees, which they then refine into downstream steel products.

Minimills are traditionally smaller than integrated plants and can idle facilities far more cheaply than can integrated firms during periods of slack demand. Thus, minimills generally face much lower fixed costs than do integrated firms. Steel processors are entirely unburdened with the capital costs that are involved in raw steel production. As a result, we may expect these types of plants to be more flexible in their exit decisions,

[8] The minimum efficient scale of an integrated steel firm is generally much larger than that of a minimill, and minimills often carry cost advantages over integrated firms even when the latter are producing at efficient scales of operation. Through the years, the integrated producers held that the steel that they produced was "purer" than that of minimills and hence they could compete through quality differences. Recent technological innovations, however, have allowed minimills to encroach upon downstream markets (such as automobiles) that traditionally required integrated steel products.

making them more likely to respond to changing economic conditions. They also benefit when the upstream steel products (their primary inputs) are cheap and/or are unfettered by tariffs or AD duties. These three types of firms differ from each other not only because of the capital that they employ, but also because of their labor policies. Integrated firms tend to be unionized, whereas minimill and steel processing firms tend to have non-unionized workforces with more incentive-based compensation.

Finally, we measure the presence of AD and CVD trade protection as the sum of AD and countervailing ad valorem duty rates that are present in the first year of the observed interval.[9] A potential concern is that AD and CVD protection measure will be endogenous with exit, since firms that are in danger of shutting down lines are more likely to receive protection. This problem is alleviated to a significant degree in our model because of how we measure exit. Since we only observe whether a production line has exited by the subsequent observation period, there is always at least some lag between the application of AD/CVD duties and the observations of exit.[10] After our initial results, we explore other ways to examine the potential impact of AD/CVD duties within our sample, as discussed more below.

[9] Antidumping and countervailing duties are product specific, and vary across our five different products (hot-rolled sheet, cold-rolled sheet, galvanized sheet, plate, and wire rod.)

[10] Feinberg and Hartigan (2007) study the inter-temporal link between AD investigations and plant closure. Their study, which includes US petitioners of dumping protection during the period 2003-2005, finds little evidence of any link between recent case outcomes and the timing of exit, regardless of whether the case outcome was an affirmative or negative determination.

Table 4. Means and Differences of Selected Variables by Exit Status.

Variable	**Exit**	**Non-Exit**	**Overall**
Production Line Capacity (tons)	572,717	878,500	854,250 *
Firm Capacity Other Than Production Line (tons, 000)	14,300	11,900	12,100*
Age (years since startup)	38.6	27.8	28.7*
Modernize (=1 if production line was modernized)	0.07	0.35	0.25*
Integrated Steel	0.854	0.75	0.77*
Minimill	0.11	0.15	0.14*
Processor	0.02	0.10	0.08*
Production Line Foreign Owned	0.11	0.21	0.18*
AD/CVD duty	0.152	0.126	0.132*

Note: A * indicates statistically important differences in the variable across exit status at the 5% level.

Table 4 contains a summary of these variables by exit status. Cursory examination of Table 4 suggests that there are statistically important differences in the line capacity, firm production line capacity, age, and production technology exit status. Firms that exit have smaller line capacities and greater product capacities in the firm. They also tend to be older and non-modernized. Each of these is as predicted by theory. In addition, the table reveals that there are a higher proportion of exits by integrated firms and a lower proportion by processers and minimills (these are all identified by dummy variables). Moreover, exiting lines are less likely to have experienced investment by a foreign firm than non-exiting firms. Finally, lines that shut down received higher AD/CVD protection than lines that survived.

4. RESULTS

Table 5 provides results from estimating the impact of various determinants on the likelihood of a steel production line exit using a logit specification.[11] Column (1) of

[11] We also use survival analysis to check the robustness of our logit results. The results are qualitatively very similar, regardless of whether we use a survival or an exit model.

Table 5 presents our base model, which includes production line vintage, modernization, production line capacity, firm-level capacity (minus the capacity of the line) and foreign ownership as explanatory variables. We include a control for the duration between observation years, since some observation periods have longer gaps than others ("Duration" ranges from 1-8 years).

In the following columns in Table 5, we add a number of additional variables sequentially to our base model. In column (2), we add our main trade protection measure (*AD/CVD duty*), as well as a control for years in which cumulative voluntary export restraints (VERs) were in place (1985-1991), since they replaced AD/CVD action during this period. In column (3), we add dummy variables for the technology type of firm (minimill steel serves as the base type). Columns (4) and (5) add year- and firm-fixed effects, respectively, to control for macro shocks and unobserved time-invariant firm capabilities, respectively.[12]

To control for product market attributes, we add product dummy variables in column (6) – where "wire rod" is the excluded group. Finally, in column (7), we isolate the impact of antidumping and countervailing duty protection after 1992 by including a term that interacts our *AD/CVD Duty* variable with a dummy variable for years after 1992. This allows us to see whether there are differences over time in the effect of AD/CVD duties on exit.

[12] The inclusion of firm-specific dummy variables causes the sample size to decrease from 1415 to 1164. The is because some firms have no variation over time in the exit rate of their production lines, i.e. they never exit or they all exit during the same period. For such firms, the inclusion of the firm dummy variables serves as a perfect predictor for exit and is therefore dropped from the regression.

Plant and Firm Characteristics

Across all of the specifications, we include the log of the capacity of the production line as well as the log of total firm capacity (minus the capacity of the line) for all the products in the sample. In addition, to capture differences between new and old lines (an index for technology), we include the log of the number of years since the line's initial startup. We also control for whether the production line has undergone recent modernization.[13]

In all of the relevant specifications, production line capacity is negative and statistically important. This provides strong evidence that smaller lines are more likely to exit than are larger lines and is consistent with economies of scale at the level of the production line.[14] Moreover, the age of the line is positive and highly significant in all specifications, while the modernization variable is negative and highly significant in all specifications. These results support the notion that a critical component of the steel industry's downsizing involved the removal of smaller, inefficient lines. Total firm capacity is positive and significant once we control for firm-specific effects

[13] Production lines that underwent modernization were, on average, modernized 11.5 years prior to the observation year. The standard deviation of this lag is 10.2 years. We experiment with different definitions of "recent" modernization, including any modernization in the previous10 years, previous 20 years, etc., and the results are basically unaffected by these differences.

[14] As a robustness check, we also perform disaggregated tests across our sample's five different products, and find that the production line capacity variable generates a particularly large coefficient compared to the estimated coefficients for the other four products.

(specifications 5-7), indicating that larger firms were more likely to shut down production lines during our sample period.[15]

Table 5. Logit Estimation of the Determinants of Exits by Steel Production Lines

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	exit	exit	exit	exit	exit	exit	exit
Age of Production Line	1.323***	1.312***	1.341***	1.386***	1.555***	0.901***	0.905***
	(0.220)	(0.225)	(0.227)	(0.239)	(0.314)	(0.306)	(0.306)
Modernization dummy variable	-0.873***	-0.813***	-0.825***	-0.846***	-0.929***	-0.986***	-0.986***
	(0.254)	(0.256)	(0.257)	(0.260)	(0.309)	(0.334)	(0.334)
Production Line Capacity	-0.289***	-0.332***	-0.330***	-0.337***	-0.269*	-1.172***	-1.169***
	(0.108)	(0.107)	(0.108)	(0.113)	(0.151)	(0.217)	(0.218)
Firm Capacity Other	0.0122	0.0151	0.0276	0.0419	2.108**	2.346**	2.332**
Than Production Line	(0.0248)	(0.0261)	(0.0335)	(0.0350)	(0.882)	(0.946)	(0.947)
Production Line Foreign Owned	0.242	0.373	0.301	0.343	0.307	0.775	0.767
	(0.274)	(0.286)	(0.299)	(0.305)	(0.494)	(0.528)	(0.527)
Duration	0.323***	0.431***	0.433***	0.462***	0.573***	0.718***	0.536
	(0.0475)	(0.0674)	(0.0675)	(0.146)	(0.179)	(0.212)	(0.603)
(AD/CVD Duty)		-2.337**	-2.417***	-2.445**	-1.820	0.00970	
		(0.926)	(0.932)	(1.237)	(1.471)	(1.843)	
VER dummy variable		0.188	0.183	1.072**	1.443**	0.402	0.397
		(0.246)	(0.246)	(0.459)	(0.639)	(0.912)	(0.900)
Integrated Firm dummy variable			-0.207	0.0246	2.136	3.441**	3.480**
			(0.422)	(0.450)	(1.456)	(1.366)	(1.367)
Steel Processor dummy variable			0.232	0.511	1.285	1.873	1.893
			(0.560)	(0.586)	(1.368)	(1.412)	(1.414)
Galvanized Sheet dummy variable						-3.478***	-3.517***
						(0.852)	(0.863)
Hot-Rolled Sheet dummy variable						0.880	0.881
						(0.894)	(0.872)
Cold-Rolled Sheet dummy variable						-0.974	-0.955
						(0.809)	(0.776)
Plate dummy variable						0.000180	-0.0354
						(0.831)	(0.840)
AD/CVD Duty After 1992							0.550
							(1.762)
Constant	-4.454***	-1.901	-1.959	-2.889	-32.24**	-24.55*	-23.67
	(1.646)	(1.958)	(1.970)	(2.204)	(13.48)	(14.26)	(14.48)
N	1415	1415	1415	1415	1164	1164	1164
Year-specific effects	No	No	No	Yes	Yes	Yes	Yes
Firm-specific effects	No	No	No	No	Yes	Yes	Yes
Product-specific effects	No	No	No	No	No	Yes	Yes
Log likelihood	-329.441	-318.319	-322.874	-315.113	-263.451	-240.891	-243.429
Psuedo R^2	0.1478	0.1655	0.1648	0.1849	0.2531	0.3170	0.3098
LR chi2	114.30	126.30	127.44	142.96	178.52	223.64	218.56
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Wire Rod is the base dummy for products, and minimill steel is the base dummy for type of technology.

[15] We also test for the impact of the total capacity of the plant that contains the production line, and find that this variable is not statistically significant.

This result is possibly consistent with Ghemawat and Nalebuff (1985), who find that larger firms were more likely to exit, though firms in their model do not have multiple plants or production lines. This result is certainly consistent with Bernard and Jensen (2007) and Inui *et al.* (2010), who find that exit is more likely to occur for multi-plant firms.[16] Finally, it is consistent with Feinberg and Hartigan (2007), who find that larger firms are more likely to shut down plants.

The expectation of the effect of foreign ownership on exit is ambiguous, given prior literature, and we do not find evidence that foreign ownership affects the likelihood of survival. As noted in Audretsch and Mahmod (1995), firms that innovate tend to be survivors, which suggests that foreign ownership should have a negative sign because they are typically larger, more innovative firms. On the other hand, managers of foreign firms may feel less constrained in shutting down lines in markets that are not located in their home country, as the "footloose" hypothesis of multinationals suggests. Indeed several papers, including Bernard and Sjöholm (2003) find that, after controlling for plant and firm characteristics, multinationals are more likely to shut down plants, but our estimates fails to find evidence that is consistent with this.[17] However, Feinberg and

[16] We also try specifying the model with a variable that measures the number of *other* plants that are operated by the firm instead of our firm capacity variable, which captures the firm's other (alternate) capacity. This variable is statistically significant and produces almost identical results as the firm capacity variable.

[17] The exception to this result is found when disaggregate the data across our sample's five products, and find that the "foreign-owned production line" coefficient is negative and significant for wire rod. This suggests that while foreign ownership has had no overall effect on production line exit, it may have prevented exit for wire rod lines.

Hartigan (2007) also find no evidence that multinational firms are more likely to shut down plants.[18]

Technology Dummy Variables

The specifications in columns 3-7 of Table 5 contain dummy variables to capture differences between integrated steel firms, minimills, and processors. Once we control for product-specific effects (columns 6-7), we find strong evidence that integrated firms were more likely to shut down, relative to minimills. This finding is somewhat expected, because of the lower labor and fixed costs that are enjoyed by minimills compared to integrated firms. Steel processors do not appear more likely to shut down production lines compared to minimills.

AD/CVD Variables

We now turn to our trade protection variables. The negative and significant AD-CVD coefficient in several of our specifications (columns 3-5) suggests that these forms of protection decrease the likelihood of exit. However, once we control for firm-specific and product-specific effects, we find no evidence that AD and CVD protection affects production line exit. In fact, the inclusion of product dummy variables causes the AD/CVD variable to become positive, although not statistically significant. We note that the galvanized steel sheet dummy variable is negative and highly significant in models 6-7, which suggests that galvanized lines were less likely to shut down (relative

[18] Feinberg and Hartigan (2007) note that they include a multinational dummy variable in results not reported in the paper and find that this variable is not statistically significant.

to wire rod, our base product dummy variable). This result is consistent with the growth in galvanized consumption that stemmed from an increased preference by auto producers and other downstream manufacturers for galvanized steel due to its corrosion-resistant properties

In model 7, we isolate the impact of AD and CVD protection after 1992, since prior to that period, voluntary export restrain (VER) protection was more heavily-used and often eliminated AD/CVD duties as part of the VER arrangement. The AD/CVD variable, and its interaction with a dummy variable for the period after 1992, are both insignificant. Furthermore, in results not shown, we try interacting AD and CVD rates with our integrated dummy variable, since integrated firms have been the most aggressive in pursuing protection. Finally, we control for whether the owner of the production line was a petitioner in an antidumping case within the last five or ten years. This includes controlling for whether the production line's firm participated in an AD/CVD case that resulted in an affirmative ruling (leading to duties), a negative ruling, or a terminated case. None of these measures results in a statistically significant coefficient on the AD/CVD variable.[19] [20]

---

[19] This result is consistent with Feinberg and Hartigan (2007), who find that the timing of AD determinations had no discernible impact of plant closures of petitioning firms, regardless of whether the case resulted in a negative or positive determination.

[20] As an additional robustness test, we remove our final observation period (2000-2007), which contains a spell of safeguard protection (2002-2003) that might interact with our antidumping variable. Even after removing this period, however, the AD/CVD variable continues to be insignificant. Finally, we separate the dataset by technology type and re-estimate the model for each type (integrated, minimills, and processors). Integrated firms have by the far the largest number of production lines, and are the only type

Table 6 contains the marginal effects for the statistically significant variables from column 6 estimates in Table 5, which is our preferred specification. In all of the cases, the reference points for the calculations are at the overall sample means. The effects of the discrete variables are simply the differences in the exit probabilities with and without the dummy variables, while the effects of the continuous variables are presented in terms of elasticities. Furthermore, in the last column of Table 6, we calculate a 'hypothetical effect' of the probability of exit that gives the marginal effect for a one standard deviation change of the continuous variables. The hypothetical effect for our dummy variables is simply equal to its marginal effect.

---

for which the logit model converges when we include company-specific dummy variables in the specification. Results are quite similar to the results from the overall dataset, including lack of significance of the AD/CVD variable. The minimill subset converges once company dummy variables are excluded, and produces similar results to the full dataset, with the exception that the AD/CVD variable is negative and significant at the 5% level. A similar test for integrated firms, in which company dummy variables are removed, fails to produce a statistically significant AD/CVD variable. Thus, it is tempting to suggest that perhaps antidumping protection reduces the likelihood of production line exit for minimills, but not by integrated firms. However, without the inclusion of company-specific effects, we are hesitant to assert this interpretation.

Table 6. Marginal Effects

Variable	Marginal Effect	Z- statistic	Mean of X	Hypothetical Effect
*Age of Production Line**	0.0144	2.34	3.23	0.0123
Modernize Dummy Variable	-0.0144	-2.22	0.369	-0.0144
*Production Line Capacity**	-0.0187	-2.57	13.22	-0.0199
*Firm Capacity Other Than Production Line**	0.0375	4.03	15.39	0.1876
Integrated Dummy Variable	0.0274	2.43	0.834	0.0274
Galvanized Dummy Variable	-0.0445	-2.47	0.308	-0.0445

Note: *Indicates variables in log form. Dummy variables marginal effects are differences in the probabilities with and without the dummy effect. Hypothetical effect equals the impact of a one standard deviation change of the continuous independent variables on the probability that a production line will survive. For dummy variables, the hypothetical effect is equal to the marginal effect.

A one-percent increase in a production line's vintage increases the likelihood of exit by1.44 percent. In contrast, modernized lines were about 1.44 more likely to remain in operation. An increase in the log of production line capacity decreases the probability of exit by about 1.9 percent. However, the increase in the log of the rest of the firm's capacity increases the likelihood of exit by about 3.75 percent, with a one standard deviation increase resulting in a rise in exit probability that is equal to almost 19 percent.

Finally, the magnitude for the galvanized sheet dummy variable points to an increase in the probability of exit that is equal to about 4.5 percent (compared to steel rod lines), while lines that are operated by integrated firms were about 2.7 percent more likely to exit (compared to minimill lines), all else equal.

5. SUMMARY AND CONCLUSIONS

This paper investigates exit behavior of U.S. steel firms during the period 1978-2007. Our examination uses a novel data set that frames exit in terms of products that are produced by specific production lines within a plant. However, we also observe the totality of plants and ownership which allow consideration of how a firm's entire operations and portfolio of products affects specific product-line decisions.

We find strong evidence that as the capacity of the production line increases, the probability of exit falls. This is consistent with economies of scale at the production line, and is akin to a myriad of studies that find that increases in the capacity of a plant reduce the likelihood of exit. Moreover, our results indicate that production lines are more likely to be shut down in firms with greater total capacity across their remaining production lines. This result is possibly consistent with Ghemawat and Nalebuff (1985), who find that larger firms are more likely to exit, though firms in their model do not have multiple plants or production lines. The result is quite consistent with the empirical analysis of Bernard and Jensen (2007), who find that plant exit is more likely to occur for multi-plant firms. Finally, our results also reveal important product-specific and technology effects, with galvanized lines less likely to exit and integrated lines more likely to shut down.

The primary purpose of our analysis was to evaluate the role of antidumping protection in preventing exit. Our results, however, provide little evidence that antidumping has decreased production line exit in the steel industry. This finding is robust to a variety of controls for antidumping, including the duty level and the duty level interacted with time periods and segments of the industry in which protection was most active, as well as whether the line was owned by a petitioner that was involved in an affirmative, negative, or terminated case within the last five or ten years.

The lack of evidence with regard to the impact of AD and CV duties on exit may seem surprising, given the substantial resources that the steel industry channels into obtaining this form of protection. However, there is recent evidence that AD may not be that effective at preventing exits. The wave of bankruptcies in the U.S. steel industry in the early 2000s occurred despite relatively high levels of AD protection. Like this study, Feinberg and Hartigan (2007) find little evidence that the outcome of AD cases impacts exit behavior, and Blonigen *et al*. (forthcoming) do not find any evidence that AD and CVD duties raise market power in U.S. steel plants.

Taken as a whole, the lack of any evidence that AD/CVD protection affects exit is a puzzle. It may be that there somehow remain uncontrolled sources of endogeneity or measurement error that bias our estimates. A second possibility is that AD/CVD protection typically fails to improve the steel industry's performance, but efforts to obtain protection continue due to the misguided strategies of management and labor representatives, and/or because it supports cohesive relations between management and labor. Future analysis will hopefully shed light on these ongoing questions.

Acknowledgement: This project was supported under National Science Foundation Grant #27-3383-00-0-79-636. We thank Bob Feinberg, Gary Ferrier, Justin Pierce, and other participants of a Southern Economic Association session, as well as Larry White for helpful comments and suggestions. Any remaining errors are our own.

REFERENCES

Bernard, Audretsch, D.B. (1991). New-firm survival and the technological regime. Review of Economics and Statistics, 73(3), 441-449

Audretsch, D.B. & Mahmood, T. (1993). Entry, growth, and survival: The new learning on firm selection and industry evolution. Empirica, 20(3) 25-33

Baden-Fuller, C.W.F. (1989). Exit from declining industries and the case of steel casting. Economic Journal, 99, 949-961

Bandick, R. (2010). Multinationals and plant survival. Review of World Economics, 146, 609-32

Bandick, R. & Holger, G. (2010). Foreign acquisition, plant survival, and employment growth. Canadian Journal of Economics, 43(2), 547-573

Andrew B., & Jensen, J. B. (2007). Firm structure, multinationals, and manufacturing plant deaths. Review of Economics and Statistics, 89(2), 193-204

Bernard, A., & Sjöholm, F. (2003). Foreign owners and plant survival. NBER Working Paper 10039. Cambridge, MA

Blonigen, B. A., & Wilson, W.W. (2010). Foreign subsidization and excess capacity. Journal of International Economics, 80(2), 200-211

Blonigen B. A., Liebman, B.H., Pierce, J.R., & Wilson, W.W. (2013). Are all trade protection programs created equal? Empirical evidence for nonequivalent market power effects of tariffs and quotas. Journal of International Economics, 2, 369-378

Chen, M. Y. (2002). Survival duration of plants: Evidence from the US petroleum refining industry. International Journal of Industrial Organization, 20, 517-555.

Deily, M. E. (1988). Investment Activity and the Exit Decision. Review of Economics and Statistics, 70(4) 595-602

Deily, M. E. (1988b). Exit barriers in the steel industry. Federal Reserve of Cleveland Economic Review, QI, 10-18

Deily, M. E. (1991). Exit strategies and plant-closing decisions: The case of steel. RAND Journal of Economics, 22(2) 250-263

Dunne, T., Klimek, S. D., & Robert, M. J. (2005). Exit from regional manufacturing markets: The role of the entrant experience. International Journal of Industrial Organization, 23, 399-421.

Feinberg, R. M. (2010). Do international shocks affect small wholesalers and retailers? Review of World Economics, 146(2) 323-338

Feinberg, R. M., & Hartigan, J. C. (2007). Antidumping and plant closure. International Journal of the Economics of Business, 14(1) 99–109

Fudenberg, D., & Tirole, J. (1986). A theory of exit in duopoly. Econometrica 54(4) 943-960

Ghemawat, P., & Nalebuff, B. (1985). Exit. RAND Journal of Economics, 16(2) 184-194

Ghemawat, P., & Nalebuff, B. (1990). The devolution of declining industries. Quarterly Journal of Economics, 105(1) 167-186

Görg, H. & Strobl , E. (2003). Footloose multinationals. The Manchester School, 71(1) 1-19

Inui, T., Kneller, R., Matsuura T., & McGowan, D. (2009). Why causes plant closure within multi-plant firms? The University of Nottingham GEP Research Paper 2010/20.

Lieberman, M. B. (1990). 'Exit from declining industries: "Shakeout" or "stakeout"? RAND Journal of Economics, 21(4) 538-554

Pierce, J. R (2011). Plant-level responses to antidumping duties: Evidence from U.S. manufacturers. Journal of International Economics, 85, 222–233

Sabuhoror, J. B., Larue, B., & Gervais, Y. (2006). Factors determining the success or failure of Canadian establishments on foreign markets: A survival analysis approach. The International Trade Journal, 20(1) 33-73

Whinston, M. D. (1988). Exit with multiplant firms. Rand Journal of Economics, 19(4) 568-588