Abstract

While under the umbrella of temporary protection from 1983 to 1987, Harley-Davidson (Harley), the sole US motorcycle manufacturer, bridged the technology gap with foreign rivals by successfully introducing a new engine, called the Evolution. With the diffusion of this engine across its model range, Harley steadily increased its sales from a low level at the beginning of the policy intervention. This paper assesses the causal relationship between temporary protection policy and technology adoption in the US motorcycle industry. Based on a structural econometric models of multiproduct oligopoly, this paper first shows that technology adoption well explains Harley’s sales increase during the protection; in the absence of technology adoption, Harley’s sales would not have turned around but continued to decrease. I then model Harley’s adoption of Evolution engine taking the effect of learning-by-doing into account. Simulation results reveal a strong learning effect and the acceleration of the timing of adoption induced by the protection. However, the results also show that Harley would have successfully implemented the adoption of the new engine across its model range in the absence of the protection and thereby achieved the sales increase.

Keywords: Safeguards; Technology adoption; Learning-by-doing; Motorcycles

JEL Classification: F13; F14; L13; L62; O33

*I am grateful to Ujo Goto, Tobias Kretschmer, Hiroshi Ohashi, Yasuyuki Todo, Eiichi Tomiura, and Nobuaki Yamashita, seminar participants at the University of Tokyo, Nihon University, Tohoku University, Tokyo Metropolitan University, Kwansei Gakuin University, Sophia University and Toyama University, Osaka University and conference participants at meetings of the Japanese Economic Association (JEA), the European Association for Research in Industrial Economics (EARIE), and the European Trade Study Group (ETSG) for their helpful comments. Financial support from the JSPS is also gratefully acknowledged. All remaining errors are my own.

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1 Introduction

While under the umbrella of temporary protection from 1983 to 1987, Harley-Davidson (Harley), the sole US motorcycle manufacturer, bridged the technology gap with foreign rivals by successfully introducing a new engine, called the Evolution. With the diffusion of this engine across its model range, Harley steadily increased its sales from a low level at the beginning of the policy intervention. Because of the apparent coincidence of the safeguard and the recovery of Harley, the case is sometimes referred as an example of successful protection. For instance, in an article in the New York Times (March 18, 1987), some trade experts maintained that “[the case of the motorcycle safeguard] will strengthen those who argue that temporary protectionism can lead to successful adjustment.”

The example of Harley is consistent with the breathing room argument advocated by protectionists to justify the protection of lagging domestic industries, whereby temporary protection policies allows domestic industries to close technology gap with foreign rivals by giving time and resources to achieve innovation and technology adoption. In response, while economists admit the theoretical feasibility of the argument (Rodrick (1992); Miyagiwa and Ohno (1995); Miyagiwa and Ohno (1999)), they usually take a somewhat more skeptical view of the same argument, warning policymakers not to overvalue the effectiveness of temporary protection policy for industry growth. One concern with this protectionist argument relates to the situation known as the “pseudo-infant industry” (Corden (1974)) where, although industry growth is achieved in the presence of temporary protection policy, the policy intervention has little role.\(^1\) As this concern is outwardly plausible, it is obviously an empirical task to assess the validity of the argument.

The purpose of this paper is therefore to provide empirical evidence on whether the temporary protection policy was an effective device to promote the adoption of new technology in the US motorcycle industry. To achieve this goal, I specify a two-stage model

\(^1\)The other theoretical concern expressed in the literature is the time inconsistency problem faced by the government. See Matsuyama (1990), Tornell (1991), and Miravete (2003).
of technology adoption. In the first stage, Harley adopts the new engine across its range of models. In a second stage, the firms set their prices in the Bertrand fashion given the adoption decision. In the specification of adoption cost in the first stage, I account for the presence of learning-by-doing, a process known to play an important role in the early stages of the adoption of new technology. Investigating the effect of learning-by-doing is particularly important in assessing the role of temporary protection because the contribution of temporary protection policy in the initial accumulation of production experience associated with the new engine may result in the successful diffusion of the new technology (Krugman (1987); Dasgupta and Stiglitz (1988)). The second stage of the model draws on a structural econometric model of multiproduct oligopolistic competition in the presence of safeguard tariffs, where the random coefficient logit model is used for estimating the demand side. In a counterfactual experiment to reveal the effect of temporary protection, I first compute the returns from technology adoption without temporary protection using the estimates of the second stage, and then implement a counterfactual simulation to assess the role of temporary protection on technology adoption and sales growth.

The findings of the paper are as follows. First, the analyses of the second stage reveal that the adoption of the new Evolution engine well explains Harley’s sales recovery in the early 1980s. Indeed, in the absence of technology adoption, Harley’s sales would not have turned around but would have continued to decrease, even during the period of protection. Therefore, Harley recovered from the sales slump because of the introduction of the new engine. Second, the analyses of the first stage indicate a strong learning-by-doing effect, and the simulation results based on the estimates show the increase in the pace of adoption induced by the temporary protection. However, the results also show that the temporary protection was not the key to recovery, i.e., although the protection delayed the timing of the turnaround, Harley could still have adopted the engine across its model range and recovered sales in the absence of the protection. Note that, under a strong learning effect, it is possible that protected firms will never achieve recovery without temporary protection, although the
results of this analysis refute this possibility.

Given these findings, this paper makes three contributions to existing literature. First, this paper provides an additional evidence on the relationship between trade policy and industry development, which, despite the importance of empirical evidence, only a handful of studies have investigated. For example, Baldwin and Krugman (1988) examine the protection of random access memory (RAM) chips in Japan and suggests the possibility that protection policies contributed to industry development. On the other hand, Irwin and Knelow (1994) study seven generation of dynamic random access memory (DRAM) semiconductors over 1974-1994 and assess the effectiveness of the industrial policies designed to promote the semiconductor industry. Based on the empirical findings of strong learning effects within generations and weak intergenerational learning spillovers, Irwin and Knelow (1994) discuss that the policies are short-lived and hence likely to be inefficient measure to maintain domestic firms at dominant position. Similarly, the study on the tariff protection provided to steel rail in the US by Head (1994) and the study on export subsidies for Japanese steel by Ohashi (2005) show that the intervention policy played a minor role in inducing industry growth despite strong learning effects.

Second, this paper deepens the analysis of the US motorcycle case that has been the subject of the ongoing focus of the literature on international trade. For instance, Irwin (2009) actually questions the causal relationship between temporary protection and Harley’s recovery; Feenstra (1989) estimates the pass-through effect of the safeguard tariffs; Feenstra and Taylor (2007) investigate the welfare effect of the safeguard. In particular, one previous study, Kitano and Ohashi (2009), tackled a question similar to that in the present paper, namely, did US safeguards resuscitate Harley-Davidson in the 1980s? Based on the estimation results of structural econometric model of multiproduct oligopolistic competition, Kitano and Ohashi (2009) quantify the effects of the safeguard on the Harley’s sales and show that the contribution of the safeguard to the Harley’s sales was tiny. Therefore,

\[ \text{See also Feenstra (2004) for further discussion on the pass-through effect in the US motorcycle industry.} \]
Kitano and Ohashi (2009) conclude that competition with Japanese manufacturers was unlikely to threaten Harley in the early 1980s, and that the safeguard would have contributed little to Harley’s resuscitation. However, the analysis in this work is insufficient in terms of assessment of the protectionists’ argument because Kitano and Ohashi (2009) exclude the possibility of the indirect effects of temporary protection that protectionists presume, including the inducement of some kinds of efficiency gain and product upgrading, and instead assume that all other things remain equal. Therefore, the results would underestimate the effect of the safeguard if the indirect effects of the safeguard played an important role. In this paper, I assess the safeguard focusing on its indirect effects. To achieve this goal, I first reveal the reasons for Harley’s recovery in the 1980s and then investigate the indirect effect of temporary protection.

Finally, this paper is relevant to the several studies in empirical industrial organization that apply a two stage model. For example, Berry and Waldfogel (1999), Dutta (2006), and Maruyama (2011) estimate a structural model of multiproduct oligopolistic competition in the second stage and specify an entry problem to estimate an entry cost in the first stage, and Ho (2009) estimates a producer surplus in the second stage and investigates a bargaining game between insurance plans and hospitals in the first stage. With respect to an international trade literature, previous literature usually employ a single stage model focusing on the effect of trade policies on the sales and price based on the structural econometric

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3Kitano and Ohashi (2009) indicate the small substitutability between Harley and Japanese motorcycles as the reason for the ineffectiveness of the safeguards. Indeed, Kitano and Ohashi (2009) show that, with respect to an increase in the price of representative Japanese motorcycles with engine capacities over 700 cc, the cross price elasticities with other Japanese motorcycles exceed those with Harley motorcycles by about 20%. However, the results only show that the cross price elasticity between Harley and Japanese motorcycles tended to be smaller than that among Japanese motorcycles. To assess whether or not the safeguard contributed to the resuscitation, it has to be shown that the cross price elasticities were too small to induce Harley to improve its efficiency and upgrade its products, which together lead to its resuscitation.

4In addition to the studies listed here, several theoretical studies cite Harley-Davidson case as an evidence of technology adoption induced by trade policy. See Crowley (2006) and Ederington and McCalman (2011).

5While some of these papers investigate strategic interactions in the first stage, the structure of my model does not have a strategic interaction because only Harley moves in the first stage. Note that this structure is reasonable because the innovation of new engine is local in the sense that the innovation did not expand the technology frontier but was only beneficial for Harley and not for Japanese that had already adopted advanced engines. See also the discussion made in Section 2.2.
model of demand and supply as in the second stage of this study. For example, Goldberg (1995) and Berry, Levinsohn, and Pakes (1999) examine the role of Voluntary Export Restraints on Japanese automobiles in the 1980s, and Irwin and Pavcnik (2004) examine trade issues between Airbus and Boeing. The third contribution of this paper is to apply a two stage structural econometric model in an assessment of trade policies in an oligopolistic competition market.

The remainder of this paper is organized as follows. Section 2 describes the US motorcycle market of the 1980s, especially focusing on three key features: Harley’s sales turnaround, Harley’s engine innovation and the temporary protection policy. Section 3 shows the results of the second stage of the model that comprises demand and supply of the motorcycle market. In the section, I show the estimation results of the second stage and implement counterfactual simulation based on these results to see the impacts of the introduction of new engine on Harley’s sales in the 1980s. Given the findings at the second stage, Section 4 introduces the first stage of the model, i.e., a technology adoption model. I then implement the counterfactual simulation to assess the role of temporary protection in technology adoption. Section 5 gives further discussion on the role of the temporary protection, focusing on Harley’s financial condition during the safeguard. Section 5 provides further discussion about the effects of temporary protection on Harley’s profits, and Section 6 concludes the paper.

2 Three key features of the US motorcycle market

Over the years, five major manufacturers have operated in the US motorcycle market. Of these, Harley-Davidson is the last remaining US motorcycle manufacturer, while Honda, Kawasaki, Suzuki, and Yamaha are Japanese. During the 1980s, these five brands accounted for more than 95% of new motorcycle registrations in the US, and hence dominated the US market. In general, Harley produces only large engine displacement motorcycles, while the
four Japanese firms produce not only similar motorcycles, but also motorcycles with medium and small engine displacements, including dirt bikes and scooters.

I now introduce three key features of the US motorcycle market in the 1980s that relate to Harley: the sales turnaround, the adoption of the new engine, and the imposition of the safeguard.

2.1 Turnaround

Figure 1 graphs the number of new motorcycle registrations in the US and the market share of Harley from 1977 to 1993. As shown, Harley’s sales had been declining since the late 1970s, with sales in 1983 at only about 50% of their 1977 level. As a result, in the early 1980s, Harley faced the distinct risk of bankruptcy. Further, although some of the decrease in Harley’s sales related to the recession in the US economy in the early 1980s, the recession did not fully explain the sales decline because Harley’s market share had similarly decreased. According to Reid (1990), one explanation was that the decrease in sales related to an expansion in the quality gap with Japanese motorcycles. In particular, Harley’s engines had many problems at the time, including oil leaks, high fuel consumption, and vibration. According to some anecdotes, Harley riders required some engineering skills to deal with the engine troubles that often arose during their journeys.

However, this dire situation changed dramatically after the early 1980s. As shown, Harley’s sales recovered from their lowest level in 1983, and started reaching new highs thereafter. By 1990, Harley’s sales and market share exceeded their highest level in the late 1970s, and continued to gather pace. Harley’s successful recovery of Harley was also exceptional in the US economy in the 1980s because many other US industries, such as automobiles and steel, experienced reduced presence in their markets owing to the competition from Japanese rivals. Thanks to its immense success following the severe US economic situation in the early 1980s, Harley is now celebrated and people revere Harley as an American icon.
2.2 Introduction of the new engine

How did Harley recover from its bankruptcy crisis? One possible reason is the improvement in the quality of its motorcycles. According to Reid (1990), when faced with the risk of bankruptcy in the early 1980s, Harley accelerated its innovative activities to overcome the quality problems besetting its engines. Because of its increased effort in innovative activity, Harley successfully introduced a new engine, named the Evolution. Though it was still not comparable to Japanese engines in terms of the quality, the new engine then equipped with a computer-controlled ignition system produced more power at every speed, ran cooler, and improved oil tightness. In August 1983, Harley released the first motorcycles equipped with the Evolution engine, including the Soft Tail, now one of Harley’s most popular models. As shown by the sales-weighted share of Harley motorcycles equipped with the Evolution engine in Figure 1, the recovery in Harley’s sales growth appeared to follow closely the process of engine adoption, and hence it is likely that the adoption of the Evolution engine played an important role in the turnaround of the sales.

2.3 Safeguards

Around the time of the introduction of Harley’s new engine, the US government placed a safeguard on the import of motorcycles with engine capacities over 700 cc under the escape clause in Section 201. This took the form of tariff rate quota under which each country is required to pay a safeguard tariff (in addition to the normal rate of 4.4%) after the cumulative number of exports exceeds the assigned level of quota. While the tariff rate quota applied to all countries, the quota level was sufficiently high to allow all motorcycle manufacturers with the exception of Japanese firms to export without additional tariffs. The tariff rate schedule and quota number were set before the commencement of the safeguard. As shown

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6Reid (1990) argues that the recovery of Harley was not only the result of engine innovation. For example, Harley also introduced a new management system, similar to Toyota’s just in time approach, and new marketing strategies, which were encapsulated by the establishment of the Harley Owners Group (HOG).
in Table 1, the tariff rate was initially set at 45%, scheduled to decline over five years, while
the quota in 1983 was set at 6000 units for Japan, scheduled to increase over five years. Initially, the safeguard was scheduled to end in March 1988, but was removed early upon request by Harley. As a result, the safeguard was effective from April 1983 to October 1987.

3  Measuring the effects of technology adoption

In the previous section, I presented the aggregate evidence on the relationship between sales growth and technology adoption as evidenced by the release of the Evolution engine. This section introduces the second stage of the model, which allows me to assess the impact of technology adoption on sales growth.

3.1 Second stage: multiproduct oligopolistic competition model

I first introduce the structural econometric model of oligopolistic competition with differentiated products. The model introduced here is almost the same as that in Kitano and Ohashi (2009). The only difference is that the binary variable indicating the technology adoption is included in the demand and cost function in order to measure the effect of technology adoption on Harley’s sales.

I first derive the demand function for each motorcycle model based on the discrete choice model for product differentiation developed by Berry (1994) and Berry, Levinsohn, and Pakes (1995). In particular, I employ the random coefficient specification with income effect in order to allow a flexible substitution pattern among the competing products.

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7Irwin (2009) considers the strategy of Harley as rational because Harley gained some favorable publicity through its actions and the smaller tariff rate in place in the final year of the program brought few benefits to Harley.
3.1.1 Random coefficient logit model

I consider the current motorcycle owners as potential consumers of motorcycles and hence set the market size $M$ as the number of motorcycle owners. Each consumer then chooses the alternative that provides the highest utility from $J_t + 1$ alternatives: $J_t$ motorcycle models offered at time $t$, and an outside option representing the decision not to purchase. Consumer $i$’s indirect utility from purchasing motorcycle $j$ is (time subscripts omitted hereafter for convenience):

$$u_{ij} = x_j \beta + \beta_A A_j + \xi_j + \alpha \ln(y_i - p_j) + \sum_k x_{jk} \nu_{ik} \sigma_k + \epsilon_{ij} \quad j = 1, 2, \ldots, J,$$

and the utility from the outside option ($j = 0$) is:

$$u_{i0} = \xi_0 + \alpha \ln(y_i - p_0) + \sigma_0 \nu_{i0} + \epsilon_{i0},$$

where $p_j$ is the real price (adjusted by the CPI in 1983) of product $j$, and $p_0$ is the price of the outside option, which equals zero. $x_j$ is the $1 \times K$ vector of product $j$’s observed attributes including constant and period dummies, and the $k$-th component of this vector is denoted by $x_{jk}$. $\beta$ is the $K \times 1$ vector of parameters to be estimated, and its $k$-th component, $\beta_k$, represents the consumers’ average valuation of characteristic $k$. In addition, $\nu_{ik}$ are the consumer-specific taste for characteristics $k$, assumed to follow i.i.d. standard normal. $\sigma = (\sigma_1, \ldots, \sigma_K)'$ is the vector of parameters to be estimated, and its $k$-th component, $\sigma_k$, represents the standard deviation of taste on characteristics $k$. $A_j$ is a dummy variable that takes a value of one if the product $j$ is equipped with the Evolution engine and zero otherwise. The coefficient $\beta_A$ captures the consumers’ valuation of the new engine.

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8This assumption may be problematic in that there are no new motorcycle owners in each period. That said, the number of potential consumers approximately equals the number of current owners because some consumers also give up their motorcycles. Nevertheless, as Berry, Levinsohn, and Pakes (1995) discuss, the population sampling error is negligible if the market size is sufficiently large compared with that of those who choose inside options. Given the number of motorcycle owners was much larger than those who purchased new motorcycles for each period, this choice of market size makes some sense.
The variable $y_i$ is consumer $i$’s income and $\alpha$ is a parameter to be estimated. For computational purposes, I use the first-order approximation of a Cobb–Douglas utility function with respect to price in the estimation. The fourth part on the right-hand side of Eq.(1) is then rewritten as $\alpha_i p_j$, where $\alpha_i = -\alpha/y_i$, the price sensitivity of consumer $i$. Under this specification, the consumers’ price sensitivity is inversely proportional to their income, i.e., high-income consumers do not care about the price of products, unlike low-income consumers. I assume that income follows a log-normal distribution whose mean and standard deviation are computed from information about the owners of motorcycles from the Motorcycle Statistical Annual published by the Motorcycle Industry Council.9

$\xi_j$ represents the unobserved product quality of product $j$ with mean zero. Here, the unobserved quality of the outside good, $\xi_0$, is not separately identified with the intercept of the inside good. This is because the estimate of the intercept captures the difference in the average valuation between inside and outside goods. For the same reason, the coefficient on the individual-specific constant term, $\sigma_0$, is estimated as a standard deviation on the intercept. Accordingly, the estimate captures the variation in taste on choosing inside options, i.e., purchasing one of the new motorcycles.10

Following Berry (1994), I decompose the above utility function into two terms: the mean utility, $\delta_j$, and the deviation from the mean, $\mu_{ij} + \epsilon_{ij}$, where

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\delta_j = x_j \beta + \beta_A A_j + \xi_j, \quad \mu_{ij} = \alpha_i p_j + \sum_k x_{jk} \nu_{ik} \sigma_k.
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$\epsilon_{ij}$ is the idiosyncratic taste of consumer $i$ for product $j$, assumed to follow the Type I extreme value. Combining the distributional assumptions on $y$ and $\nu$, the market share of

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9 The mean and variance of the income distribution are, respectively, USD 24,487 and USD 15,434 (in 1983 prices).
10 The demand structure used in this paper is static, even though motorcycles are obviously a durable good. However, although I do not explicitly model the dynamic aspects of motorcycle choice, it is partly taken into account by the choice of the outside option that captures future purchases. See Goldberg and Verboven (2001) for more detailed discussion on the role of outside options. While the static models capture these effects in an incomplete way, recent studies provide demand models for durable goods that explicitly specify intertemporal consumer choice. See Melnikov (2001) and Gowrisankaran and Rysman (2009) for models of new durable products using aggregate data.
product $j$ is

$$s_j = \int \int \frac{\exp (\delta_j + \mu_{ij})}{1 + \sum_{l=1}^{J} \exp (\delta_l + \mu_{il})} P_{\nu} (d \nu) P_y (dy),$$

(4)

where $\nu = (\nu_1, \ldots, \nu_K)'$, and $P_{\nu} (\cdot)$ and $P_y (\cdot)$ are the cumulative distribution functions for $\nu$ and $y$, respectively. As a result, $q_j$, the demand for product $j$, can be derived by multiplying the market share by the market size $M$.

### 3.1.2 Oligopoly pricing in the presence of tariff protection

I now model the firm’s behavior. Although the motorcycle safeguard actually took the form of a tariff rate quota, I employ a simple tariff model. This assumption is not problematic because the level of quota was sufficiently small such that all Japanese motorcycle manufacturers were subject to the tariff at the margin, and hence the pricing equations derived from both the tariff and the tariff rate quota should be identical. One possible problem in the model of firm behavior is that it ignores the local production of Japanese firms. Indeed, two Japanese motorcycle manufacturers, Honda and Kawasaki, owned and operated production facilities in the US at the time. While local production effectively allows firms to avoid tariffs, in the counterfactual analysis of the assessment of the safeguard in the following sections, I assume that all Japanese motorcycles with engine capacities over 700 cc were subject to the safeguard tariffs. This necessarily results in an overestimation of the policy. In other words, the simulations potentially represent an upper bound effect for the safeguard.

The US motorcycle market is characterized as multiproduct oligopolistic competition. Once again, I omit the time subscript for simplicity. The variable profit function of firm $f$ is

$$\pi_f = \sum_{j \in J_f} \left[ \left( p_j \frac{1}{1 + \tau_j} \right) - mc_j \right] \cdot q_j,$$

(5)

where $J_f$ is the set of brands produced by firm $f$ and $\tau_j$ is the tariff rate imposed on product $j$. $mc_j$ is the marginal cost of product $j$ that is specified as below.

The marginal cost vector, $mc$, can then be derived from the first-order conditions for the
profit maximization problem:

\[ mc = (1 + \tau)^{-1} p - \Delta^{-1}(1 + \tau)^{-1} s, \]  

where \( p = (p_1, \ldots, p_J)' \), \( s = (s_1, \ldots, s_J)' \), \((1 + \tau)^{-1} = \text{diag} \left( \frac{1}{1+\tau_1}, \ldots, \frac{1}{1+\tau_J} \right)\), and \( mc = (mc_1, \ldots, mc_J)' \). Under Bertrand competition, \( \Delta \) is a \( J \times J \) substitution matrix whose \((j, r)\)-th element is \(-\partial s_r/\partial p_j\) if \( j \) and \( r \) are produced by the same firm, and is zero otherwise.

\( \Delta \) can be computed from the demand estimates. Therefore, the (unobserved) marginal cost vector can be recovered from the data on price, quantity, tariff rates, and the demand estimates. I can then estimate the marginal cost function based on the recovered marginal cost by specifying the cost function as follows.

\[ \ln(mc_j) = w_j \gamma + \gamma_A A_j + \omega_j, \]

where \( w_j \) includes the variables that shift the marginal cost and \( \omega_j \) is the unobserved productivity term of product \( j \). I include the dummy variables for the Evolution engine, \( A_j \), in the cost side specification to measure the effect of the new engine on cost.

3.2 Data

This paper constructs a product-level motorcycle dataset using several independent sources. The price and characteristics data for each motorcycle model are obtained from the NADA Motorcycle and Moped Appraisal Guide and the NADA Motorcycle, Moped and ATV Appraisal Guide, published by the National Automotive Dealers Association (NADA). These guides are updated three times a year, with Jan.–Apr., May–Aug., and Sep.–Dec. I hereafter refer to these periods as the first, second and third periods, respectively. The characteristics in the NADA data include such items as the engine displacement, the dry weight, and the issued year and month used in the computation of the age of each motorcycle. Unfortunately, a key characteristic—equipment of the Evolution engine—is not
included in NADA’s publication, but is added to the dataset as a binary variable using the 
*Harley-Davidson Data Book* (Conner (1996)).

NADA’s publications contain three types of price-related data; namely, the suggested list 
price, the average retail used value, and the prime retail used value. The average and prime 
retail used values are the prices of average- and best-conditioned used motorcycles, respec-
tively. Of the three prices available, I choose the prime retail used value because the price 
of best-conditioned used motorcycles are considered close substitutes for new motorcycles. 
Of course, the alternative candidate is the suggested list prices, but this price is not suitable 
because it is time invariant.\(^{11}\)

*Motorcycle Statistics by Make and Model*, one of the publications available from R. L. 
Polk, provides data on the (year-to-date) number of new registrations for each motorcycle 
model. The data are published monthly and are available from Jan. 1983 to May 1987. In 
order to adjust the data frequencies, I aggregate the quantity (number of new registrations) 
data into periodic data. As a result, the data contain 13 time series, starting from the first 
period in 1983 to the first period in 1987.

During the sample period, there were frequent model changes and new models were 
introduced into the US motorcycle market. NADA provides the data for each model of 
motorcycles in every model year, while R. L. Polk reports the quantity and model of each 
motorcycle without distinguishing the model year. I use the latest model of motorcycle if 
there are multiple models in NADA that correspond to the model name given in R. L. Polk. 
More specially, I matched the model using the model introduced last year rather than the 
latest if the model was replaced within the current period. For example, the models replaced 
in October are not used in matching the data in the third period. I consider this method of

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\(^{11}\)Problematically, the data do not include the prime retail values for newly introduced motorcycles, unlike 
the suggested list price, which covers all models. Where prime retail used values are unavailable, I interpolate 
the value by taking the product of the suggested list price and the ratio of the suggested list price to the 
prime retail used value computed using models introduced in the past. In constructing the ratio, I first 
compute the ratio of the models introduced one model year before and two model years before, and then 
compute the rate of change. The ratio used in the interpolation is the product of the ratio computed from 
one model year before and the rate of change.
construction to be reasonable because the quantity data indicate that the registration of new models includes some lag, say, 2-3 months. By construction, the number of models offered in each period draws on the list in R. L. Polk.

In addition to the product-level data, I use some information relating to the US motorcycle market, such as the motorcycle population and the income distribution of motorcycle owners. The data are obtained from the *Motorcycle Statistical Annual*, published by the Motorcycle Industry Council. I use exchange rate data from the *International Financial Statistics* published by the International Monetary Fund.

Because I focus on the effect of temporary protection on Harley-Davidson, and given that at that time Harley was only engaged in the production of motorcycles with large engine displacements (at least 883 cc), I limit the data to motorcycles with engine displacements exceeding 450 cc. Table 2 provides summary statistics of the data. In the estimation, I incorporate period dummy variables, the trend and squared trend variables, and a Harley dummy and its interaction with trend and squared trend variables in the estimation, in addition to the data listed in the table.

### 3.3 Estimation results: demand and marginal cost

As is usual in the existing literature, I estimate the demand side parameters from the moment condition on $\xi$: $E[\xi_j | x_1, \ldots, x_J] = 0$ for all $j$. Given the identification assumption, the characteristics of all other products are valid instruments of $\xi_j$ because the characteristics of the other products are correlated with the price of product $j$ under multiproduct oligopolistic competition. Although there are many possible sets of instruments, I use the first-order approximation of optimal instruments following Berry, Levinsohn, and Pakes (1995), which, for product $j$ produced by firm $f$, is the sum of characteristic $k$ across the other products manufactured by firm $f$, $\sum_{i \in \{J \setminus j\}} x_{ik}$, and the sum of the characteristic across the competing firms, $\sum_{i \notin J_f} x_{ik}$. In addition to the instruments that relate to these characteristics, I also specify the exchange rate as an instrument because the changes in the exchange rate
affect the Japanese firms’ pricing and are likely to be independent of the unobserved demand shock, $\xi$.

Since the supply side is likely to be misspecified because of the ignorance of local production, I estimate the demand and marginal cost separately. The marginal cost function is estimated by a heteroscedasticity robust OLS given the demand estimates.

The demand estimation results are summarized in Table 3. As shown, the coefficient on price is negative and significant (-52.19), and the consumers’ price sensitivity of consumers with respect to mean income takes the value -0.0021 ($= -52.19/24487$). Of particular interest is the effect of innovation on demand, i.e., the coefficient on the Evolution engine dummy, which determines the effect of the technology adoption. Given that the estimate is positive and significant, Harley’s new engine is valuable for consumers.

In the estimation, I account for taste heterogeneity using three variables: the Harley dummy, engine displacement, and constant. First, the standard deviation of the Harley dummy is significant (2.847), which implies the existence of taste heterogeneity for Harley’s motorcycles. Therefore, the substitution between Harley and Japanese motorcycles is less than that for Harley motorcycles and that among Japanese motorcycles. This result is plausible because market sources frequently cite the interest of enthusiasts in Harley’s motorcycles. Second, the estimated mean coefficient on the engine displacement is positive and weakly significant (4.019) and the standard deviation is significant (2.456). Therefore, although consumers prefer motorcycles with larger engine displacement, the valuation on the size of engine displacement varies among consumers; some consumers prefer motorcycles with small engine displacements, while others prefer motorcycles with large engine displacements. This result is also reasonable because motorcycles of different sizes are often used for very different purposes; for example, the motorcycles with smaller engine displacement are for city driving, whereas those with larger engine displacement are for long road trips. Finally, the standard deviation of the constant is also weakly significant (1.138). This indicates the heterogeneous taste for the outside option, which implies that some consumers are more likely to purchase
the inside option, i.e., one of the new motorcycles offered in a given period. Note that the estimated mean coefficient on the constant takes a highly negative significant value. This is likely because most consumers do not purchase new motorcycles in a given period, i.e., choose the outside option.

Note that the $J$-statistic in the random coefficient specification rejects the hypothesis $J = 0$. The result is then problematic because it implies a misspecification of the model. However, because the finite-sample properties of the $J$-test imply that it rejects too often (Hayashi (2000), Ch. 3), I accept the results of the model and employ them in the following simulation analysis. Note also that the partial $F$-statistic in the first-stage regression takes a sufficiently large value in terms of results in Staiger and Stock (1997).

Table 4 provides the estimation results for the cost function. The coefficients on engine displacement, dry weight, number of forward speeds, and the number of cylinders are all positive and significant. The coefficient on the Evolution engine dummy is also significantly positive, and this implies that the production cost of the Evolution engine is higher than that of its predecessor.

The estimates obtained here are incorporated in the simulation in the following section. However, before the simulation, it is important to assess the validity of the estimates by comparing the marginal costs recovered from the model and the actual marginal costs. To do this, I refer to external information on the cost of production by Paul Dean, the editor of the motorcycle magazine, *Cycle World*. According to this information, Harley’s marginal cost of production ranged from 4000 to 10,000 USD, whereas the marginal cost of comparable Japanese motorcycles was up to 50% lower. The recovered marginal costs of Harley and Japanese motorcycles in 1983, at about 5555 USD and 3746 USD, respectively, from this analysis clearly lie in the range suggested in that article. Therefore, the estimates obtained here are comparable to the figures from an external source, which in turn places some credence on the simulation analysis using these estimation results.

To summarize, the demand and cost estimates indicate that, although innovation pushes
up demand, it requires some additional production costs. In the following section, I simulate the effect of technology adoption on sales growth using these demand and supply estimates.

### 3.4 Effect of the adoption of the new engine

Harley-Davidson recovered dramatically after 1983. In this section, I analyze whether the adoption of the new Evolution engine was an important factor in the sales turnaround. To do this, I dissect the sales growth resulting from the direct effect of the safeguard and that resulting from the technology adoption in order to understand the effect of the safeguard. First, I simulate the counterfactual in which the safeguard is absent, i.e., $\tau_j$ takes the value of the standard tariff rate—4.4%—for the targeted Japanese motorcycles. Second, I simulate the other counterfactual of no technology adoption, i.e., $A_j = 0$ for all Harley motorcycles in order to measure the effect of innovation on sales.

When computing the equilibrium in the counterfactual, I assume that the distribution of the characteristics (other than the installation of the new engine) and the set of products introduced during the sample period is the same as the actual. However, this assumption may be inadequate because some of these characteristics may have changed in response to the temporary protection. For example, Suzuki and Yamaha introduced motorcycles with displacements of 699 cc in place of motorcycles with displacements of slightly over 700 cc in order to avoid the tariffs. Although this implies the characteristics are endogenous, I maintain this assumption because small changes in the characteristics have little effect on the equilibrium outcome.

The simulation results are summarized in Figure 2. To compare the results of the counterfactual simulation with sales before and after the introduction of the Evolution engine, I plot the counterfactual movement in yearly and actual yearly sales. Because the data used in the estimation is periodic, I aggregate the periodic sales to annual sales. With respect to the figure for 1987, I cannot obtain the yearly sales because my dataset only contains information for the first period of 1987. Therefore, I infer the annual sales in 1987 based
on the sales of the first period in 1987 by assuming that the ratio of sales for the periods in 1986 are the same as in 1987.

The slashed line below the actual sales shows the counterfactual sales movement when the safeguard tariffs are set to the standard tariff rate, given that the adoption of the new engine has taken place in the same way as in reality, which I call exogenous adoption, contrasting with the case of endogenous adoption introduced in the following section. This simulation and the results are very similar to previous work in Kitano and Ohashi (2009), i.e., the safeguard slightly increased Harley’s sales, but it does not appear to be a key factor behind Harley’s recovery.

In the second simulation, I assume that not all of Harley’s motorcycles are equipped with the Evolution engine in order to see the effect of technology adoption. The long slashed line in the figure depicts the results of this simulation. As shown, the technology adoption had a large impact on Harley’s sales recovery. Indeed, without the technology adoption, Harley’s sales did not turn around but continued to decrease in line with the pre-1983 trend.

Note that Harley’s actual sales increased even after the termination of the safeguard. Although I cannot extend the simulation analysis after 1987 because of data limitations, the increase in sales after 1983 should be attributed to the factors other than the effect of the introduction of the new engine because all of Harley’s motorcycles were equipped with the Evolution engine by the end of the intervention period. In this regard, many of the studies on Harley, such as Reid (1990), suggest the importance of strategies by Harley other than the adoption of the new engine. These include the introduction of a new marketing strategy operating through the renowned HOG (Harley Owners Group), which further enhanced the value of Harley’s motorcycles. The sales increase after the removal of the safeguard was likely the result of these factors.\footnote{Several studies on the Harley’s business success usually refer three important innovations in the 1980s. One of them is the focus of this paper, the introduction of the new engine. The second innovation is the introduction of HOG. The last one is the restructuring of management including the introduction of Material-As-Needed inventory control method similar to Toyota’s Just-In-Time and a statistical operator control system. I will discuss the role of the safeguards in the restructuring of the management in Section 5.}
The two simulation results indicate the importance of the technology adoption in the assessment of Harley’s resuscitation as a business. Importantly, Kitano and Ohashi (2009) conclude that the protectionist safeguard was unlikely to trigger restructuring in Harley, but this conclusion may change if the indirect effect of the safeguard, i.e., its effect on technology adoption, is considered. In the following section, I introduce the model of technology adoption and implement further counterfactual simulation to reveal the effect of the safeguard on technology adoption. This allows me to assess whether or not the temporary protection did indeed resuscitate Harley-Davidson.

4 Did the temporary protection induce technology adoption?

The simulation results in the previous section reveal that technology adoption explains the recovery in Harley’s sales. This section turns to an analysis of the role of the safeguard in the technology adoption. I first introduce the model of technology adoption to estimate the adoption cost function. I then implement a counterfactual simulation based on the estimates of the adoption cost to unravel the effect of the safeguard on the technology adoption.

Note that this paper focuses on the diffusion of the new engine across its model range rather than the innovation itself. This is because the development of the Evolution was started in 1997, and the engine had been innovated before the start of the safeguard. Therefore, the safeguard should have little to do with innovating the new engine, but it could contribute to diffusing the new engine.

4.1 First stage: the model of technology adoption

During the sample period in this study, the motorcycle manufacturers frequently revised existing line-up and introduced new models. In fact, a typical has shelf life of one to two years. In particular, Harley replaced models or introduced new models every year on regular
occasions, usually September or October, before and after the safeguard. Accordingly, because the decision to adopt a new engine was determined to coincided with the introduction of new models or during the replacement of incumbent models, the adoption decision would be on a yearly basis. Therefore, in the model of technology adoption, I aggregate the periodic data to yearly data. For this reason, the subscript $t$ does not represent the year-period combination but rather simply the year, and hence the variable profits $\pi$ and quantity $q$ are not the same as those in the second stage. To be precise, while I should introduce a new set of notation, I do not do so in order to avoid unnecessary complexity.

Here, $J_{Harley,t}$ is the set of Harley’s models introduced or replaced at year $t$. I assume the number of motorcycle models in the set is determined before the adoption decisions are made. Harley then obtains a profit:

$$\Pi_t(A_t) = \pi_t(A_t) - \sum_{j \in J_{Harley,t}} A_{jt} * C_{jt}^A,$$

from the vector of adoption $A_t = \{A_{jt}\}_{j \in J_{Harley,t}}$, where $A_{jt}$ is an indicator of technology adoption as is defined before.

Further, $C_{jt}^A$ is the adoption cost for model $j$, which is specified as:

$$C_{jt}^A = \exp(\tilde{\theta}_1 + \tilde{\theta}_2 \ln(1 + N_t) - \eta_{jt}),$$

where $N_t = \sum_{s=1}^{t-1} \sum_{j \in J_{Harley,s}} A_{js}$ is the cumulative number of motorcycle models equipped with the Evolution engine and $\eta_{jt}$ is the unobserved cost of adoption. $\tilde{\theta}_1$ and $\tilde{\theta}_2$ are the parameters, where $\tilde{\theta}_2$ in particular captures the effect of the accumulation of the adoption experience, i.e., the effect of learning-by-doing. This type of dynamic effect is known to play an important role during the early stages of the introduction of a new technology.

In the equilibrium, Harley optimally adopted the Evolution engine across its range of motorcycles. I assume that the unobserved demand and cost shocks, $\xi$ and $\omega$, respectively, are not realized and only their distributions of them are observable in the first stage. In
equilibrium, Harley adopts the Evolution engine for its motorcycle models by maximizing the expected profit. The optimal vector of adoption is then:

$$A_t^* = \text{arg max}_{A_t \in \{0, 1\}} \sum_{\text{Harley}, t} E [\Pi(A_t)],$$

(10)

where the expectation is over $\xi$ and $\omega$. The optimality of $A_t^*$ implies that Harley cannot increase its profits by altering the adoption decision from the optimal. In particular, I focus on the deviation of one product from the optimal:

$$E [\Pi(A_t^*) - \Pi(A_{jt}, A_{t-j,t}^*)] \geq 0, \forall j,$$

(11)

which yields:

$$A_{jt}^* = 1 \left[ \ln \left( E [\pi_{jt}(A_t^* - j, t)] - \pi_{jt}(A_{t-j,t}^*) \right) + \left( \tilde{\theta}_1 + \tilde{\theta}_2 \ln(1 + Q_t) + \eta_{jt} \right) \right] \geq 0 \forall j.$$  

(12)

The first term in the indicator function is the log of the expected return from adopting the Evolution engine to product $j$, where

$$\pi_{jt} = \pi_t(A_{jt} = 1, A_{t-j,t}^*), \quad \pi_{jt} = \pi_t(A_{jt} = 0, A_{t-j,t}^*).$$  

(13)

I compute these using the simulations based on the second stage estimates. Note that the expected return is the key variable in the assessment of the effect of the temporary protection on the timing of adoption because changes in the returns capture the effect of the policy.

The model introduced here is static; however, the technology adoption problem is usually a dynamic decision (Rust (1987)). In addition, the presence of learning-by-doing would induce Harley to adopt the Evolution engine for a larger number of models during an earlier stage of diffusion in order to step down the learning curve. In other words, Harley has an incentive to adopt the Evolution engine to those models whose returns from technology
adoption are lower than the adoption cost (Benkard (2000), Benkard (2004)).

Although the omission of dynamics should make the estimation and simulation results to be biased, I consider that such an effect is likely to be limited. This is primarily because Harley’s dire financial situation caused by an ownership change, and sluggish sales in the early 1980s. According to Reid (1990), although Harley survived owing to generous financial support by Citibank, Harley understood that the prospects of ongoing funding from this source were limited because the funding was both less than what it initially wanted and because the financing required payment of a special fee of 5 million USD over and above the prevailing interest rate. The attitude of Citibank toward the transaction also made Harley keenly aware that Citibank maintained a detailed plan about the debtor’s prospective liquidation, which it could use to terminate the vulnerable company at any moment. The static adoption model causes serious bias if Harley gave great consideration to its future profits in its adoption decisions, but the assumption is reasonable because the severe financial crunch did not allow Harley to make an investment in future profit by sacrificing its current profit.\footnote{From a practical perspective, it is difficult to apply dynamic models for the following reasons. First, there is nonstationarity in the product space, i.e., the set of models in the choice set is different from period to period because of the frequent revisions to the model line-up. Second, my dataset includes only five years in the time series. Together, the above data limitations make it difficult to implement the estimation of dynamic models.}

\subsection{Technology adoption}

The estimation is based on the unobserved cost of adoption $\eta_{jt}$. In particular, I assume $\eta_{jt}$ to be follow a Type I extreme value with scale parameter $\zeta$.\footnote{The location parameter is normalized to zero.} I then have the following equation for the probability of adoption:

$$
\Pr(A_{jt} = 1) = \frac{\exp \left\{ \theta_0 \ln \left( E \left[ \pi_{jt}(A_{jt}^*, A_{jt}^*) - \pi_{jt}(A_{jt}^*) \right] \right) - (\theta_1 + \theta_2 \ln(1 + Q_t)) \right\}}{1 + \exp \left\{ \theta_0 \ln \left( E \left[ \pi_{jt}(A_{jt}^*, A_{jt}^*) - \pi_{jt}(A_{jt}^*) \right] \right) - (\theta_1 + \theta_2 \ln(1 + Q_t)) \right\}},
$$

(14)

where $\theta_0 = 1/\zeta$, $\theta_1 = \tilde{\theta}_1/\zeta$ and $\theta_2 = \tilde{\theta}_2/\zeta$. 

\[13\]
The problem in the estimation is, of course, the endogeneity. More specifically, $\eta_{jt}$ is likely to be correlated with the expected return $E[\pi_{jt}(A_{j,t}^*) - \pi_{jt}(A_{-j,t}^*)]$. For example, consider the case where the positive $\eta_{jt}$ induces the adoption of the new engine in product $j$. Then, the adoption of product $j$ decreases the returns from adoption in other models, and hence Harley may withdraw the Evolution engine from some other products. In turn, the decrease in the number of other models with the Evolution engines increases the return of product $j$. Therefore, a positive $\eta_{jt}$ is likely to increase the expected return of the product. Accordingly, there exists a positive correlation between $\eta_{jt}$ and the return from adoption, which results in the estimate of $\theta_0$ being biased upwards. A typical solution to this endogeneity problem is to use instrumental variables that are correlated with the expected return and uncorrelated with the shocks on the adoption cost. However, finding variables that vary across motorcycle models while still satisfying the requirements of instruments is difficult. For this reason, and despite the endogeneity problem, I employ standard logit models to estimate the parameters in Eq.(14). Of course, because of the bias, the results of the counterfactual simulation in the following section could overestimate the effects of the protection policy on adoption because the effects appear through the expected return from technology adoption. In other words, the simulation reveals the effects of the protection at an upper-bound.

Under the independence assumption between $\eta_{jt}$ and the expected return, I can estimate the parameters in Eq. (14) using maximum likelihood. Note that the expected return, $E[\pi_{jt}(A_{j,t}^*) - \pi_{jt}(A_{-j,t}^*)]$, does not have a closed-form solution. Therefore, I employ Monte Carlo methods for the computation of the integers. In the computation, I assume that $\xi$ and $\omega$ follow a normal distribution with a mean of zero and a variance computed from the residuals $\hat{\xi}_{jt}$ and $\hat{\omega}_{jt}$ obtained from the demand and cost estimation results.

### 4.3 Estimation results: technology adoption

Table 5 provides the estimates of the adoption cost function. As shown, all of the parameters are significant, and take their intuitively correct signs, i.e., the scale parameter is
positive and the accumulation of adoption experience decreases the adoption cost.

The adoption cost is initially high but decreases with the adoption of the Evolution engine. The extent of the decrease is summarized in the learning rate, the magnitude of the cost fall with the doubling of experience (the cumulative number of models equipped with the Evolution), which is 26% based on my results and larger than the average rate, around 20% reported in the previous study (Argote and Epple (1990)). The high learning rate evidences the possibility that the temporary protection played a critical role in the recovery of Harley because the initial accumulation of adoption experiences strongly contributed to the reduction of adoption cost. Therefore, Harley may have failed to diffuse the new engine across its range and consequently never recovered its sales without temporary protection.

4.4 Simulation

In the previous section, I found that the recovery of Harley’s sales from 1983 to 1987 was primarily because of the adoption of the Evolution engine. I investigate here whether the temporary protection policy was an effective inducement for technology adoption.

Based on the estimates of the adoption cost function, I implement the counterfactual simulation to assess whether or not the policy played an important role in the introduction of the Evolution engine. In the simulation, I use the demand estimates, the recovered marginal cost, and the adoption cost for each model of motorcycle. To recover the adoption cost, I draw the unobserved component in the cost, \( \hat{\eta}_{jt} \), from the Gumbell distribution, conditioning the draws satisfy the observed adoption decision, i.e., \( \hat{\eta}_{jt} < \ln \left( E \left[ \pi_{jt}(A_{\ast-j,t}) - \pi_{jt}(A_{\ast-j,t}) \right] \right) - (\theta_0 + \theta_1 \ln(1 + N_t)) \) if product \( j \) adopts the Evolution engine; the converse is held otherwise.

The demand estimates and the recovered marginal cost and adoption cost allow me to compute the optimal vector of adoption in equilibrium without tariffs. However, in practice, it is difficult to derive the vector of adoption because Harley introduced a number of models for each period and hence has a large number of possible adoption choices. To the best of my knowledge, there is no efficient algorithm to compute the optimal vector of adoption in
such a situation.\footnote{In recent work, Jia (2008) analyzes the entry decision of Wal-Mart in multiple locations. She proposes a solution algorithm to compute the optimal vector of the entry decision in the multiple locations based on Tarski’s fixed-point theorem. In this paper, however, this method cannot be applied. This is because Tarski’s fixed-point theorem requires the complementarity of the adoption decision among products, i.e., the return from adoption for each product has to be a (weakly) increasing function of the adoption of the other product. In my application, the demand for a particular product decreases in response to the adoption on the other products, which results in a decrease in the return from the adoption in the product and hence indicates a substitutability among products.} I therefore compute the counterfactual in a single step. Starting from the observed adoption decision $A_\ast^t$, I compute the expected profit for each model of Harley’s motorcycle in the absence of temporary protection: $E \left[ \pi^0_{jt}(A_\ast^t - j;t) - \pi^0_{jt}(A_{-j,t}^t) \right]$, where $\pi^0_{jt}$ and $\pi^0_{jt}$ denote the variable profits without the additional safeguard tariffs. I then construct a new vector of adoption, $A^{0*}_t$, based on the expected return and the adoption cost. The results reported in the following are based on the prices and quantities computed using the new vector of adoption.

Note that because of this single step approach, the new adoption vector would not be optimal, and hence it is important to discuss how my approach biases the assessment of the protection policy. In general, the number of models equipped with the Evolution should be larger in the presence of the protection rather than in its absence. This means that the expected return from the adoption in counterfactual should be underestimated because it is based on $A_\ast^t$, the optimal vector of adoption in the presence of protection. The underestimation of the expected return leads to a lesser number of models being equipped with the Evolution in the counterfactual. Therefore, this simulation is likely to overestimate the difference in technology adoption between actual and counterfactual. Once again, the simulation made in this study indicate the effect of temporary protection at the upper bound.

The simulation results are summarized in Figure 3. The bars on the left in the figure are the proportion of Harley models equipped with the Evolution engine in the counterfactual. When compared to the actual, the pace of Harley’s technology adoption is delayed during the middle phase of the intervention, but by the end of the intervention, the proportion of models with the Evolution engine is almost 100% in both the actual and the counterfactual. Note that, under a strong learning effect, it is possible, at least in theory, that the domestic
industry would achieve industry growth only in the presence of the temporary protection policy. However, the simulation result shown here denies this possibility.

Next, I report the equilibrium quantities in the counterfactual computed from the adoption vector in the counterfactual. The results are shown using the short slashed line and, for the purpose of comparison, the sales movements of the actual and the counterfactual in Section 3 are also shown. Consistent with the effect on adoption, the intervention increased Harley’s sales larger in the middle phase of the intervention. In particular, without temporary protection, Harley’s sales did not turnaround but instead stagnated until 1985. However, Harley achieved a V-shaped recovery of sales after 1986 and, as is obvious from the adoption vectors of the actual and counterfactual, by the end of the protection, the sales in the counterfactual and actual were almost equal. Therefore, although the temporary protection allowed Harley to achieve recovery more quickly, Harley could have recovered by itself regardless of the presence of the safeguard.

5 Discussion

The results presented in the previous section indicate that the safeguard was not key to recovery but imply that Harley could have achieved the sales turnaround in the absence of the safeguard. However, this result is not sufficient to say that the safeguard had nothing to do with the Harley’s recovery because the simulation implicitly assumes that Harley could survive in the absence of the safeguard. As mentioned, Harley faced severe financial difficulties and only survived because of generous funding from Citibank. Therefore, the contribution of the safeguard to the improvement of the financial situation was the key to saving Harley from bankruptcy because further financial deterioration may have encouraged Citibank to liquidate Harley. To assess this argument, I focus on Harley’s net income and investigate the effect of the safeguard on the financial condition. The net income is total revenue and gains minus all expenses and losses for a reporting period, and thereby provides
an indication of the firm’s financial health. The profit from selling its products is, of course, part of net income, and hence, using the results of the counterfactual simulation, I can quantify the effect of the safeguard on net income based on the profit in Eq.(8).

Table 6 shows the net income for the actual and the counterfactual. The counterfactual net income is computed by subtracting the difference in variable profits of the actual and the counterfactual from the actual net income. The table has two features: one of the features is that the safeguard allowed Harley to earn a positive net income after 1983 and, without the safeguard, Harley would have lost money until 1985. Therefore, although Harley could earn a positive net income after 1986 without the safeguard, it is possible that Citibank would have considered the return to a positive net income as a sign of recovery and hence the safeguard may have acted as a key inducement for its ongoing finance. However, this argument is in all likelihood not plausible because the safeguard contributed less to improve the financial situation, while factors quite unrelated to the safeguard contributed significantly to the improvement in the financial situation, as I show the other feature.

The second feature in Table 6 is that Harley had a large deficit in 1982, but recovered dramatically in 1983, from –25.077 to 0.937 million USD. According to Reid (1990), the improvement in net income might be attributable to the result of the successful restructuring of the management, including the introduction of a Just-In-Time inventory system and a statistical operator control system. Focusing on the magnitude of the improvement in the financial condition, the effect of the restructuring is much more significant than that of the safeguard; therefore, although the safeguard turned Harley’s net income to positive, it is unlikely that Citibank would terminate financing for a firm that achieved such a drastic improvement.

Note that the timing of the recovery is different from the sales turnaround that occurred one year after the recovery of net income. Therefore, when Harley improved the net income, sales were still trending downwards and eventually bottoming out. This implies that the recovery of the net income primarily contributed to the reduction in the fixed cost but not
of the variable cost that pushed sales up. Since the returns from the restructuring, i.e., the return from fixed cost reduction should be unrelated to the safeguard that could have only influenced variable profit, the safeguard would not be an inducement of the restructuring.

To summarize, the simulation results reveal that the safeguard accelerated technology adoption and allowed Harley to recover sales earlier. However, regardless of the presence of the safeguard, Harley would eventually adopt the Evolution engine in all its models and could therefore achieve recovery even in the absence of the safeguard. Although this discussion on Harley’s revival are conditional on Harley’s survival in the absence of the safeguard, it is unlikely that the safeguard was a key determinant of saving Harley from bankruptcy because the contribution of the safeguard to Harley’s financial condition is limited. Note also that the simulation results presented here shows the effects of the safeguard at the upper-bound because of the ignorance of the local production, the bias in the parameter in adoption cost, and the method of simulation employed in the construction of the counterfactual adoption vector. For this reason, the contribution of the safeguard should be even lower than the results presented in Figure 3, which casts further doubt on the effectiveness of the temporary protection policy. Therefore, although Harley recovered on the back of the technology adoption in the presence of the temporary protection, it is reasonable to conclude that the case of US motorcycle protection is likely an example of a pseudo-infant industry.

6 Conclusion

The temporary protection policy has been advocated as an instrument to decrease the lags in domestic industries by providing them with the time and resources to catch up. By studying the experience of Harley-Davidson in the 1980s, this paper examines the impact of technology adoption on motorcycle sales, and assesses whether the temporary protection policy was an effective inducement for technology adoption. In order to analyze the motorcycle industry, I estimate a two-stage model of adoption using a structural econometric
Based on the estimation results, I first show that the adoption of the Evolution engine explains the drastic recovery of Harley-Davidson in the 1980s; without this process of technology adoption, Harley’s sales would have continued to follow the downward trend starting in the late 1970s and would have never recovered. I then explore the relationship between the technology adoption and the temporary protection policy operating from 1983 to 1987 by using the estimation of adoption cost. In the adoption model, I take account of the possibility of learning-by-doing that usually plays an important role in the early stages of technology adoption. The estimation results reveal the strong learning effect and hence the temporary protection might have played a key role in diffusing the new technology. However, the simulation shows that Harley would adopt the new engine to all its models of motorcycles and recover its sales eventually by itself, though the protection accelerated the timing of adoption and the sales turnaround by 2 years. Therefore, this paper supports the pseudo infant industry argument: the domestic industry can bridge the technology gap regardless of the presence of the policy interventions.

Given its findings, this paper contributes to the literature on trade policies and industry growth that has been an important topic in the study of international trade. One of the recent studies, Konings and Vandenbussche (2008) found, in a study of firm-level productivity growth in the US, that the firms in the industries with protection had lower productivity growth compared with those that never experienced protection. As shown in this paper, the presence of the case of a pseudo infant industry strengthens the findings of Konings and Vandenbussche (2008) because some of the firms in the industries experienced protection might achieve the productivity growth regardless of the presence of the protection. To be precise, the productivity growth in the industries experienced protection may be overestimated and thereby there may be a larger gap in productivity growth between industries experienced protection and never experienced protection.
References


Table 1: Safeguard: tariff-rate-quota

<table>
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<tr>
<th>Year</th>
<th>Tariff rate(%)</th>
<th>Quota(units)</th>
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<tr>
<td>1983</td>
<td>45</td>
<td>6000</td>
</tr>
<tr>
<td>1984</td>
<td>35</td>
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<td>1987</td>
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<td>10000</td>
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Table 2: Summary statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Harley-Davidson</th>
<th>Japanese firms</th>
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<tbody>
<tr>
<td>Price (USD)</td>
<td>6268</td>
<td>1314</td>
</tr>
<tr>
<td>Share</td>
<td>0.00019</td>
<td>0.00015</td>
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<tr>
<td>Engine displacement (in '000cc)</td>
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</tr>
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<td>Dry weight (in '000 kg)</td>
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</tr>
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<td>Cylinders</td>
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<td>0</td>
</tr>
<tr>
<td>Age</td>
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<tr>
<td>Tariff</td>
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<tr>
<td>Evolution</td>
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<td>0.501</td>
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</table>

Number of observations 162 623
Table 3: Estimation results: demand

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coef.</th>
<th>S.E.</th>
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</thead>
<tbody>
<tr>
<td><strong>Price</strong></td>
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<td>23.43 **</td>
</tr>
<tr>
<td><strong>Mean (β)</strong></td>
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<td></td>
</tr>
<tr>
<td><em>Evolution</em></td>
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<td>0.419 ***</td>
</tr>
<tr>
<td><em>Engine Displacement</em></td>
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<td>2.085 *</td>
</tr>
<tr>
<td><em>Dry weight</em></td>
<td>12.837</td>
<td>4.709 ***</td>
</tr>
<tr>
<td><em>Forward speeds</em></td>
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<td>0.092 ***</td>
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<tr>
<td><em>Cylinders</em></td>
<td>0.037</td>
<td>0.054</td>
</tr>
<tr>
<td><em>Age</em></td>
<td>-0.076</td>
<td>0.018 ***</td>
</tr>
<tr>
<td><em>Harley</em></td>
<td>0.479</td>
<td>1.374</td>
</tr>
<tr>
<td><em>Harley</em>Trend*</td>
<td>-0.105</td>
<td>0.490</td>
</tr>
<tr>
<td><em>Harley</em>(Trend)^2*</td>
<td>-0.004</td>
<td>0.074 ***</td>
</tr>
<tr>
<td><em>Trend</em></td>
<td>-1.124</td>
<td>0.295 ***</td>
</tr>
<tr>
<td><em>(Trend)^2</em></td>
<td>0.178</td>
<td>0.057 ***</td>
</tr>
<tr>
<td><em>Constant</em></td>
<td>-11.864</td>
<td>1.621 ***</td>
</tr>
</tbody>
</table>

| Std. Deviations (σ)       |        |       |
| *Harley*                  | 2.847  | 1.322 ** |
| *Engine Displacement*     | 2.456  | 0.600 *** |
| *Constant*                | 1.138  | 0.661 *  |

| J-statistic (degrees of freedom) | 29.52(12) |
| 1st stage $R^2$                 | 0.93      |
| 1st stage $F$-test              | 61.24     |

| Number of observations       | 785      |

Note: The variables for engine displacement and dry weight are divided by 1000. ***, **, and * indicate significance at the 99, 95, and 90% confidence levels, respectively. The period dummy variables are included in the estimation, but not reported here.
Table 4: Estimation results: marginal cost

<table>
<thead>
<tr>
<th></th>
<th>Coef.</th>
<th>S.E.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution</td>
<td>0.047</td>
<td>0.020</td>
<td>**</td>
</tr>
<tr>
<td>Engine displacement</td>
<td>0.549</td>
<td>0.064</td>
<td>***</td>
</tr>
<tr>
<td>Dry weight</td>
<td>0.925</td>
<td>0.109</td>
<td>***</td>
</tr>
<tr>
<td>Forward speeds</td>
<td>0.303</td>
<td>0.093</td>
<td>***</td>
</tr>
<tr>
<td>Cylinders</td>
<td>0.070</td>
<td>0.030</td>
<td>**</td>
</tr>
<tr>
<td>Constant</td>
<td>8.424</td>
<td>0.176</td>
<td>***</td>
</tr>
</tbody>
</table>

$R^2$ 0.87  
Number of Observations 785

Notes: ***, ** and * indicate significance at the 99, 95, and 90% confidence levels, respectively.
Engine displacement, dry weight, forward speeds, and cylinders are in logarithms.
The make dummy variables are included in the estimation, but not reported here.
Table 5: Estimation results: adoption cost

<table>
<thead>
<tr>
<th></th>
<th>Est.</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_0$</td>
<td>5.961</td>
<td>2.803 **</td>
</tr>
<tr>
<td>$\theta_1$</td>
<td>-92.102</td>
<td>43.077 **</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>-2.570</td>
<td>0.894 ***</td>
</tr>
<tr>
<td>Learning Coef.</td>
<td>-0.431</td>
<td>0.126 ***</td>
</tr>
<tr>
<td>Learning Rate</td>
<td>0.258</td>
<td>0.117 **</td>
</tr>
</tbody>
</table>

Number of Observations 45

Notes: ***, ** and * indicate significance at the 99, 95, and 90% confidence levels, respectively.
The learning coefficient, $\tilde{\theta}_2$, is calculated by dividing $\theta_2$ by $\theta_0$. The learning rate is calculated as $1 - 2^{-\theta_2}$, the magnitude of the cost fall with the doubling of experience (the cumulative number of models equipped with the Evolution engine).
Table 6: Actual and counterfactual net income

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>Counterfactual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>-25.077</td>
<td>-25.077</td>
</tr>
<tr>
<td>1983</td>
<td>0.937</td>
<td>-0.301</td>
</tr>
<tr>
<td>1984</td>
<td>2.637</td>
<td>-0.752</td>
</tr>
<tr>
<td>1985</td>
<td>3.000</td>
<td>-1.858</td>
</tr>
<tr>
<td>1986</td>
<td>4.871</td>
<td>2.193</td>
</tr>
<tr>
<td>1987</td>
<td>21.215</td>
<td>20.750</td>
</tr>
</tbody>
</table>

Note: The values for actual net income from 1982 to 1984 and from 1985 to 1987 are from Reid (1990) and Harley’s Investors Relations(IR) available at Harley’s web site, respectively.
Figure 1: Harley’s sales and market share
Note: Exogenous adoption means that the adoption of new engine has taken place in the same way as in reality.
Figure 3: Endogenous technology adoption

Note: Exogenous adoption means that the adoption of new engine has taken place in the same way as in reality. Actual and counterfactual share indicate the share of Harley’s motorcycles equipped with the Evolution engine in actual and counterfactual, respectively.