It Matters How You Sell It: Lojack in Mexico[*]

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Abstract

Lojack was shown to have provided large positive externalities to vehicle owners who did not equip their vehicles with this tracking technology in the U.S. (Ayres and Levitt, 1998). This was the result of a large degree of uncertainty about which cars did and which did not have Lojack. The way Lojack was sold to the public was essential in achieving this result. We document how in Mexico the same device was sold in a different manner, generating much less ambiguity about which vehicles were equipped with the device. This led to the complete elimination of the positive spillover effect. For cars equipped with Lojack, theft rates fell by over 50%. However, the data also suggest that this deterrence effect could have been obtained with Lojack installed in 40% or fewer of the vehicles in which it was installed. We are able to test for the existence of externalities to vehicles without Lojack, both in states where Lojack operated and where it did not. We do not find much evidence for negative spillovers, although there is some indication that states that were close to those where Lojack operated saw an increase in theft rates coincidental with the introduction of the program.

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1 Introduction

In 1998, Ayres and Levitt published an article about the effects a new auto recovery technology had on theft rates in large cities in the U.S. The device, called Lojack, allowed the police to track stolen vehicles in which it was installed. The authors of that study found that the small proportion of car owners who bought the device provided a large positive externality to other car owners in terms of reduced theft rates for all of the vehicles in the city. Even though Lojack was marginally cost beneficial to the actual buyer of the device, the social effects of his actions were positive and quite large, around 10 times as large as the private benefit of having it installed in one's car. Some years after it was marketed in the U.S., the device was exported to a host of other countries around the world. However, the way it was commercialized varied according to the country. In this article we describe how Lojack was sold in Mexico, and how, derived from the different manner in which it was commercialized, the positive externalities identified by Ayres and Levitt (1998) completely disappeared.

In the U.S., Lojack was sold as an optional add on to any car. In consequence, in places where Lojack operated, thieves could not really know which cars did and which did not have Lojack. The effectiveness of the device in terms of rapid recovery of the vehicle coupled with the ambiguity of which cars were equipped with Lojack meant that the positive effects of the device were shared by all vehicles in the area. In contrast, in Mexico Lojack was offered in exclusivity for a determined set of Ford car models in some states. All of the participating vehicle models in states included in the program had Lojack installed in them. The fact that thieves could identify which cars had Lojack and which did not suggests that the positive externalities Lojack generated as it was sold in the U.S. should not be present in the Mexican case.

The purpose of this paper is twofold. First, it inquires whether Lojack was effective in reducing auto theft of vehicles equipped with it in Mexico. The problem of reducing auto theft in Mexico has been especially difficult to tackle because any serious effort to reduce auto theft is very likely to necessitate a politically challenging overhaul of the police and the judicial system. If Lojack is an effective tool in reducing auto theft in the context of corrupt police forces, it may suggest a feasible way of reducing auto theft in countries with a similar situation. The second question this paper focuses on regards the spillovers Lojack generated on vehicles not equipped with the device. As stressed by Clarke and Harris (1992) and Ayres and Levitt (1998), some anti-theft devices simply generate a displacement of theft to non protected vehicles. In this article we investigate the extent of positive or negative spillovers Lojack may have had on other vehicles not equipped with this recovery technology.

The main conclusions we arrive at are, firstly, that Lojack seems to have been very effective in reducing auto theft for vehicles equipped with it, reducing theft rates by around 50%. Regarding the measured spillovers to other vehicles, we find scarce evidence of these except for some indication of negative geographical spillovers, that is, increases in theft rates only in states that were close to those where Lojack was present. The final main finding is that for the set of vehicles identified to be equipped with Lojack, the deterrence effect obtained seems to peak at penetration levels of less than 40% of vehicles.

Our analysis suggests that although Lojack seems very effective in reducing theft rates, even in countries with a record of poor police performance, the way it is sold to the public is extremely important in terms of its effects on the general theft rate. If it is sold in such a way that thieves can reasonably identify which car models are equipped with Lojack, they will reduce the number of thefts they attempt *only* on this kind of vehicles. However, if the commercialization scheme makes thieves uncertain about which cars are equipped with Lojack, the effect on auto thefts per Lojack installed become much larger. The way Lojack is operated also seems important. In Mexico, Lojack tracking devices were operated by the company directly instead of being given to the police.

The rest of this paper is structured as follows: in section 2 we describe the technology, the way in which it was sold in Mexico and the institutional details that are relevant for the study. In section 3 we put forth the data and the empirical analysis. In section 4 we present a cost benefit analysis and compare our results to those documented for the U.S. Section 5 concludes.

2 Background

In Mexico, someone who has his/her car stolen reports it to the local state police. This generates an entry in the state auto theft registry. However, there does not exist a national police database of car robberies. The implication of this is that if a stolen car crosses the state border, the probability that it will be recovered drops substantially, since the police forces of different states do not usually share these reports with each other and state police forces are confined to their own territory. After a car is stolen, it is either robbed of valuable components and then abandoned, used for other crimes (such as kidnapping, bank robbery, etc.) and then abandoned, sold in the second hand market with or without the use of false documents, dismantled and sold for pieces (chopping), or exported to another country. The recovery rate for stolen vehicles is around 50% (AMIS (2006)).

Insurance is not mandatory in Mexico, and it is mainly offered in two flavors: “limited” and “full” insurance. Limited insurance covers auto theft and property damages to third parties. Full insurance includes in addition collision coverage and medical expenses for the vehicle occupants (bodily injury) in case of an accident. However, full insurance is required whenever a car is bought through an auto loan. Around 47% of all vehicles in Mexico are covered by insurance (Cabrera, 2007), with the vast majority of those insured being vehicles less than 5 years old.

Regarding the recent dynamics of auto theft, it is worth mentioning that the aftermath of the 1995 economic crisis brought about a large increase in auto thefts in the country, remaining fairly stable since around 1997 (AMIS, 2006). This can be seen in Figure 1, which displays total thefts of insured vehicles over time in Mexico. In this environment, a private car retrieval company established itself in the country in 1997. The Lojack technology they set to commercialize was developed in the United States in the late 80’s. First introduced in Boston and later on in other metropolitan areas of the U.S., its effects on auto theft rates in the U.S. have been well documented by Ayres and Levitt (1998).

Lojack is a small device about the size of a card deck which can be hidden in one of many places inside a car. It is dormant until the client calls Lojack and reports his/her car as stolen. At that point, the company sends a radio signal which turns the unit on, allowing the vehicle to be tracked. The company claims to have a recovery rate of 95% (Romano, 1991) and over 90% within 24 hours of the report (LoJack, 2006).[1]

Unlike the way Lojack operates in the U.S., Lojack in Mexico is in direct control of the tracking devices, not usually giving them to the police. Rather, they have cooperation agreements with local police authorities, whereby once a car is located, or as the car is being located, they coordinate with the police and indicate to them where the stolen car is. The fact that Lojack was in charge of the tracking instead of the police seems to have been crucial in determining its effectiveness in the context of unreliable police forces. It is worth noting that Lojack is the only available product for tracking stolen vehicles in the country with this technology.[2]

Ford became interested in the technology and decided that offering Lojack in its vehicles might give it an advantage over its competitors, given that in case of robbery, their vehicles would be very likely to be recovered. They agreed with Lojack to sign an exclusivity agreement. This agreement required that Lojack be offered exclusively in Ford vehicles, and that Ford would decide which vehicles the device would go into. Wherever Ford introduced the device, the company would provide the necessary coverage for the system to operate. Lojack was first implemented in the Ford minivan in the state of Jalisco. Ford minivans sold there advertised to the public as having the new recovery technology free of charge. Throughout the program, cars were sold in every state for the same price regardless of having Lojack installed or not. Selling all new cars for the same price regardless of location is common practice in Mexico, ensuring that one distributor does not cannibalize another's market based on price. Ford paid for the cost of installation and the first year service fee. The fee for the Lojack recovery service after that would be $100 per year and would be paid by the car owner if she wished to continue having the recovery service.

The consequence of prices being equal everywhere is that it is likely that the car was driven

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[1] The information on Lojack used in this paper is based on discussions with company executives in Mexico and on information from their web page whenever another source is not explicitly cited.

[2] GPS technology, also used for tracking vehicles, is not as useful for tracking stolen ones, given that the antenna is conspicuous, easily deactivated, and unable to track a vehicle if it is not in an open space.

in the same state where it was bought. Another important aspect to note is that having a car with Lojack in a state where Lojack was not offered in its dealerships provided no benefit to the consumer because of the lack of tracking devices in that state. This means that we do not have to worry about people having an incentive to buy the car in a Lojack state and driving it to a non Lojack state, and vice-versa. Hence, non-random migration does not seem to be a concern for this analysis. As in the U.S., vehicles equipped with Lojack had no decal declaring that the car was equipped with Lojack.

The way the agreement worked in practice is that once Lojack secured a cooperation agreement with the local authorities, Ford could go ahead and install Lojack for cars in that state. In our dataset, we have information on the theft rate for 9 Ford vehicles before and after they came equipped with Lojack. This allows us to identify the effect of Lojack via changes over time in the theft rate. Lojack was not introduced simultaneously in all models, rather, it was done in a sequential manner, allowing for a more credible identification over time, not likely to be confounded by other factors. Additionally, we have theft rate data on 4 Ford vehicles that over the same time period did not get Lojack (They got it after the end of the period under study) allowing us to identify the effects of Lojack in a Diff-in-Diff fashion. Finally, our dataset comprises and differentiates between theft rates for each of the 32 Mexican states. Of these, 4 offered Lojack while the rest did not. This allows us to identify the effect of Lojack in a triple-diff manner. The list of car models studied, the date, and state of introduction into the Lojack program are presented in Table 1.[3]

The commercialization strategy of Lojack in Mexico, in which Ford distributors announced which vehicles had Lojack, would lead us to expect lower theft rates only for those vehicles sold with this tracking technology. Moreover, the economic theory of crime (Becker, 1968) would suggest that Lojack in a state would lead to more thefts of non Lojack equipped vehicles in the state, and more auto thefts in neighboring states. We are able to test for the existence of these effects in our analysis.

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[3] Mexico has 31 states and a Federal District (DF), in this article, the Federal District (DF) will be treated as a state. It is also worth clarifying that DF is a different entity than Estado de Mexico.

The manner in which Lojack was sold in Mexico is in stark contrast with the way it was sold in the U.S., where vehicles of all brands were offered the device as an add on to the car, at a one time cost of around $600. Ayres and Levitt (1998) find that selling Lojack in this way lead to large positive externalities for car owners who lived in cities where Lojack was offered but did not actually buy the device. The externality was estimated to be much larger than the private benefit to the Lojack owner, around 10 times as large. What is interesting here is the fact that the same theft prevention technology can have either positive externalities or not solely depending on how it is offered to the public.

Displacement of thefts is a valid source of worry when this kind of innovations appear on the market. For example, Romano (1991) raises the point that Lojack might have led local police forces to focus on recovering Lojack equipped vehicles in detriment of those without it or at the cost of reducing attention to other types of crime. In the case of Lojack in Mexico, we were concerned that decreased theft rates for Lojack equipped vehicles might have come at the cost of increasing theft of non-Lojack equipped cars, similarly to what Mayhew, Clarke, Sturman, and Hough (1976) find, namely, an increase in thefts for older cars once steering column locks were introduced into new ones.

From the point of view of car thieves, the amount of cars they steal of any given model in a state will depend on the benefits and costs of doing so. The benefits of a theft would include the monetary gains of selling the stolen car, and/or selling its parts. The costs would include the probability of apprehension and incarceration, the cost of inputs to steal it, for example specialized tools, and the time taken to find the vehicle. We can think of Lojack as both increasing the cost of stealing the car, by making the probability of apprehension more likely, and decreasing the benefits, since the car is more likely to be recovered before any of its proceeds are materialized. For a given demand for stolen cars, installation of Lojack in a model should decrease the number of stolen cars of that model in that state. The questions we are interested in are: Did Lojack decrease theft rates? And if so, by how much? To what extent did Lojack exert negative externalities on similar cars that did not have this protection?

Policymakers in Mexico are eager to find ways of reducing auto theft. For example, towards the end of 2005, the Mexico City police chief proposed making tracking devices obligatory for all cars with sales price in excess of \$20,000 (Padilla (2005)). Over and above investigating whether Lojack worked in Mexico, the research conducted here will suggest that a more random implementation of such tracking devices may provide superior results per device installed.

3 Empirical Analysis

3.1 Data

One important reason for the small amount of studies on crime in Mexico is the lack of reliable and comprehensive data. There are no national statistics on crime provided by the government. Some states make their statistics public, but they are not obliged to do so nor are they required to use any specific methodology. The only reliable source to measure auto theft is the one published internally by the Mexican Association of Insurance Companies (AMIS). The AMIS is an association whose objective is the compilation of industry wide statistics for use in calculating hazard rates which are used by the insurance companies to price insurance contracts. AMIS associated companies have a market share exceeding 80% of the automobile insurance market. Although the AMIS auto theft dataset is not public, they authorized its use for this study.

The auto theft statistics at AMIS are gathered in the following automatized manner: When the owner of an insured vehicle calls his insurance company to report that his car was stolen, an employee of the insurance company fills out a standardized electronic report for the company's use and a copy of this report is automatically sent to the compiling system at AMIS. The vehicle may later on be recovered or not, but the report of robbery is preserved in the system. The AMIS database consists of all the entries reported to them in Mexico during the period of January 1999 to August 2005. Each entry describes what make and model the car was, the date and state of robbery and the year the car was built. This is an excellent database to study auto theft, since the owner of an insured car will have strong financial incentives to report the theft to the insurance company in order to get the insurance money. Furthermore, this database has consistently measured auto theft of insured cars throughout the period of study. Given that any car that is robbed is captured in this dataset, as long as the owner reports it as stolen, a car equipped with Lojack that is robbed will still be counted as a robbery, regardless of whether Lojack recovers the car or not. For this reason, any decrease in thefts we identify from this program will refer solely to deterrence effects: Thieves attempting less robberies on this kind of vehicles.

In order to calculate the theft rates for Ford models before and after their inclusion in the Lojack program, we need to match the theft data with sales data. That is, with the AMIS data we know how many cars were robbed in a certain state but if there were many of those cars sold, the probability of theft, which is our variable of interest, may still be small. The sales data were provided by Ford and they consist of monthly sales in every Mexican state for each of the 13 car models that would be eventually included in the Lojack program, 9 of them during the period of study, and 4 of them after it. The sales data covers the same time period as the AMIS data set, that is, January 1999 to August 2005.

We are interested in the probability of theft for each car model over time in every state. This probability will be the dependent variable in the regressions below. The way we construct it is by defining the probability of theft during month t of car model i, in state j, which was made in year y, as:

$$P_{i,j,y,t} = \frac{Thefts_{i,j,y,t}}{Vehicles\ on\ Road_{i,j,y,t}} \tag{1}$$

The numerator represents number of thefts during month t of car model i in state j made in the year y. The denominator is a measure of the number of cars on the road. It consists of the cumulative sales of the vehicle in the state. The denominator grows during the first year due to new sales, and afterwards slowly falls at a rate of 3% per year, to take into account that every year a number of vehicles are naturally removed from the road.[4] The results of the analysis are not sensitive to the inclusion or not of this effect. Similarly, another version of the theft rate could have subtracted from the denominator the number of stolen cars. Since theft is such a low probability event, taking account of this in the data is completely inconsequential and we do not pursue it because it makes

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[4] The fact that roughly 3% of cars are removed from the road annually in the first five years of operation was obtained by Ayres and Levitt (1998) using the National Vehicle Population Profile of the Polk Company, which is based on a census of currently registered passenger vehicles and light trucks in the U.S. We use this estimate since we do not have this data available for Mexico.

the exposition more complicated.

Of course, for these probabilities to make sense, it is assumed that the probability that a car of a given model and year migrates from state j to state i is equal to the probability that a car of the same model and year migrates from state i to j. Two aspects of the construction of the database that should be mentioned are, firstly, that a car sold between September of year $y-1$ and August of year y is considered to have been a model year y. This is because manufacturers typically do not introduce their new models with the calendar year; rather, they present them around September due to the strong sales in that season. Secondly, since the dependent variable is a quotient, it makes sense to eliminate the cells with very small denominators, because they are likely to generate extremely high theft rates. Having our regressions trying to fit these outliers would not be reasonable. Due to this, the observations in which the denominator (sales of that model in a given state) were less than or equal to 5 vehicles were eliminated. Although this choice is arbitrary, other cutoff values were tested. This is dealt with in the robustness checks section.

Summary statistics for the theft rate variable and the other main variables are presented in Table 2, while theft probabilities by state are shown in Figure 2. In the graph, it can be seen that Lojack states are fairly high theft rate states. The non-Lojack states are a more heterogenous group. They include the highest theft state (Baja California), and the lowest theft states. Given that the selection of which states had Lojack is not random, the regressions we use below will not identify the effect of Lojack via cross state differentials in theft rates. Rather, the effect of Lojack will be identified off variations in the theft rate within states associated to participation in the Lojack program.

Working with theft rates instead of thefts as the dependent variable has the important advantage that that it allows Lojack to have had an effect on sales without affecting the outcome of interest. Nonetheless, the probabilities constructed using equation (1) are thefts of insured vehicles divided by accumulated sales. Ideally, we would have used total thefts (of both insured and uninsured vehicles), divided by total sales. However, total thefts is a statistic compiled by the state police, which is not available for the reasons explained above. Another measure we would have liked to use is thefts of insured cars divided by the number of insured cars. Nevertheless, automobile insurance data from AMIS is compiled at the national level, which precludes any analysis where the distinction is between states, like the one we perform here. The cost of not having any of these two measures is that the theft rate *level* is not accurate. The upside is that *changes* in the theft rate are adequately measured with the theft rates we have constructed here, which is ultimately the focus of this study. The fact that the percentage change is equivalent for these measures is a consequence of insured and uninsured vehicles being observationally equivalent from a thief's point of view. If both types of vehicles are perfect substitutes to a thief, the consequence is that any effect Lojack may have on theft rates will be equally obtainable from thefts of insured cars or uninsured cars. This assumption can be interpreted as saying that any heterogeneity between insured and uninsured vehicles does does not affect theft rates. It may be argued that uninsured cars are less well taken care of and this affects the rate at which they are stolen. The fact that we are dealing with cars with an average age of 2 in our sample suggests that this effect should not be of much importance.

3.2 Estimation Strategy and Results

Before laying out the estimation strategy, it is useful to see what the data looks like. Figure 3 depicts how the monthly probability of theft for the Ford minivan in the state of Jalisco evolved. The graph shows the monthly theft rate schedule for these minivans according to the year they were made in, from 1999 through 2004. The minivan made in 1999 did not have Lojack. All those made in 2000 and beyond had it. In the graph, it is clear that there is a drop in the theft rate schedule which coincides with the introduction of Lojack. If Lojack had been introduced simultaneously in the whole country for all 14 car models, we would not be able to differentiate whether the fall was due to to the introduction of Lojack, or whether it was due to some external factor that occurred during the same year. If the drop we observe coincides with the introduction of Lojack only in the models that got Lojack and only in the states where Lojack was offered, then any other hypothesis seems very unlikely to be the cause of the drop in theft rates.

Most of the conclusions the regressions allow us to make can be previewed using Table 3, in which the mean theft rates for different groups are displayed. In order to make the comparison between groups simple, we defined the pos-Lojack period as cars made in the year 2003 and beyond. This is the relevant cutoff date since by the year 2003 all treatment cars had Lojack installed. [5]

In the table, we split the observations into two groups, those of Lojack and non-Lojack states. Each of these is then subdivided into Lojack and non Lojack model columns. The first two rows distinguish between the observations that occurred before and after the Lojack program was implemented. In the table, the first thing to notice is that for Lojack models in Lojack states there is a strong fall in theft rates over time. The second thing to notice is that this is not the case in the other three groups. This suggests that there was not much happening in terms of negative (or positive) externalities from the Lojack program to other cars.

Given the level of detail and structure of the theft rates available, we can pursue the identification of the effects of Lojack in various ways. We begin with a cross section regression, followed by a longitudinal regression, two Diff in Diff regressions, and by a triple-Diff regression. We explain each on in turn and report the corresponding results.

The cross-section regression uses data from Lojack states and compares the theft rates of Lojack versus Non-Lojack car models after the device was introduced. The analogous comparison in Table 3 would be taking the difference in theft rates after the program was introduced in Lojack states, between Lojack and non-Lojack models. The estimated model is

$$P_{i,j,t,y} = \alpha_j + \beta \cdot Lojack_{i,j,t,y} + \Gamma' \cdot \mathbf{x}_{i,j,t,y} + \epsilon_{i,j,t,y} \tag{2}$$

where $P_{i,j,y,t}$, constructed according to equation (1), is the monthly theft rate of car model i, in state j, during month t for a car made in year y. α_j is a state fixed effect, $Lojack_{i,j,t,y}$ is a dummy variable equal to one if the car model was sold with Lojack installed and $\mathbf{x}_{i,j,t,y}$ is a calendar month dummy and a year dummy. The results of the cross section regression are reported in the first column of Table 4. The Lojack coefficient, of -.17 percentage points, is much larger than the estimates of the other regressions we report below. A cross section regression coefficient is suspect

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[5] The same conclusions follow if we eliminate the observations in the transition period, as is reported in table 12.

of being biased if there was heterogeneity in the theft rates of models that got Lojack and those that did not. In effect, the first row of Table 3 confirms that ex-ante theft rates between Lojack and non-Lojack models were different to start with. In Lojack states, before the program began, theft monthly rate of vehicles that got Lojack was .12% while that of non Lojack vehicles was .22%.

We next report a regression that uses the variation over time in theft rates for Lojack models, which we label "longitudinal regression". The regression only uses data from Lojack car models in Lojack states and identifies the effect of Lojack from changes over time within this group. The analogous comparison using Table 3 would be taking the difference between the before and after rates in the first column. The estimated model is:

$$P_{i,j,t,y} = \alpha_j + \beta \cdot Lojack_{i,j,t,y} + \gamma_t + \epsilon_{i,j,t,y} \tag{3}$$

Where α_j is a state fixed effect, and the γ_t is a month fixed effect. $Lojack_{i,j,t,y}$ is defined as before. The results of this regression are reported in the second column of Table 4. The estimated Lojack coefficient suggests a drop of .065 percentage points in the theft rate. As is the case with any longitudinal regression, the estimate is subject to the criticism that the fall in the theft rate could have been shared by all car models, not only those with Lojack. To address these two concerns simultaneously, we turn to the Diff in Diff regressions.

A Diff in Diff regression compares the change in theft rate over time of one group to that of a control group. We have two reasonable control groups in our dataset. The first is Lojack models in non-Lojack states and the second is non-Lojack models in Lojack states. We work first with the former.

Using Lojack models in non-Lojack states as a comparison group has the advantage that they are the exact same cars except for not having Lojack. If we saw a significant fall in theft rates for the control group, we would have to worry about Lojack models having become more difficult to steal for reasons unrelated to Lojack, like better locks or alarms. Table 3 suggests that this was not the case, given that theft rates did not significantly change for this group. The disadvantage of this comparison group is that we observe these cars in non-Lojack states, which may have different theft dynamics than Lojack states. Nevertheless, this comparison allows us to rule out the hypothesis that the fall in theft rates in Lojack models was due to a safety (or desirability) aspect specific to the car but unrelated to Lojack.

Using only data from Lojack models, we estimate the following regression model:

$$P_{i,j,t,y} = \alpha_{i,j} + \beta \cdot Lojack_{i,j,t,y} + \Gamma' \cdot \mathbf{x}_{i,j,t,y} + \epsilon_{i,j,t,y} \tag{4}$$

The main change from the previous regressions comes from the inclusion of the $\alpha_{i,j}$, which is a fixed effect that captures the average theft rate of the specified car model in that state. The inclusion of this model-state fixed effect means that the identification of β comes from *changes* in theft rates within a car model in a state. Hence, the heterogeneity we are assuming across car models in different states takes the form of an additive fixed effect, so that differencing it out amounts to eliminating the heterogeneity. The $\mathbf{x}_{i,j,t,y}$ vector contains a dummy for the age of the car, which controls for changes in the theft rate as the car ages.[6] Also included is a year dummy, which controls for general changes in the theft rate over time; and a calendar month dummy, which controls for seasonal effects.

The results of this identification strategy can be found in Table 5. According to this model, the estimated effect of Lojack is -.058 percentage points, equal to a reduction of 49% in theft probability. The difference between the two columns is the kind of clustering we perform on the standard errors, one at the state level, the other at the state level for each year. Whichever is used is immaterial.

The second comparison group available is non-Lojack models in Lojack states. This group has the advantage of sharing with Lojack models the same state wide changes in theft rates over time. This strategy addresses the concern that Lojack states were cracking down on theft in general. This comparison group allows us to test whether there is evidence of this or not. If only Lojack vehicles were experiencing a fall in theft rates, but not non-Lojack models, this hypothesis would be rejected.

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[6] Age is set to 0 if the vehicle is less than 12 months old, 1 if it is between 12 and 24 months old, etc.

The model we estimate is the same as before except that now we have more freedom regarding which fixed effect to use. In Table 6 we report four regressions which vary in the kind of fixed effect they implement. Using a state fixed effect, as is done in column 1, or using a state-year fixed effect as is done in column 2 gives the same result: an estimated effect of Lojack of -.078 percentage points. However, using this sort of fixed effects identifies the effect from differences in theft rates of different car models, and we saw that non-Lojack models have a higher theft rate, thus biasing the results. Due to this, we only use model-state fixed effects in what follows, allowing the identification to come from changes over time within model state pairs. Using a model-state fixed effect in column 3 suggests an effect of Lojack of -.033 percentage points. This represents a drop in theft rates for Lojack equipped models of 28%. An almost identical impact is obtained in column 4, where we use a model fixed effect α_j disregarding which of the states the car is in.

Our preferred estimation strategy simultaneously addresses all of the concerns in the above regressions. It consists of a triple-Diff estimation which is analogous to comparing the relative changes between Lojack and non-Lojack models in two geographical regions: Lojack and non-Lojack states. This is analogous to the last row in Table 3, marked DDD. As in the diff in diff regressions, this type of estimation allows for factors that remain constant over time or change slowly in a given state, even if we do not measure them. The estimated regression is:

$$P_{i,j,t,y} = \alpha_{i,j} + \beta \cdot Lojack_{i,j,t,y} + \Gamma' \cdot \mathbf{x}_{i,j,t,y} + \epsilon_{i,j,t,y} \tag{5}$$

everything is defined as before except for the $\mathbf{x}_{i,j,t,y}$ vector. Apart from the dummies for age, and calendar month, it now includes a dummy for the car model being in a Lojack state, a dummy for the car being a Lojack model (which is an indicator variable for the car model being one of the 9 that get Lojack), and a dummy variable called *After*, which is one if the vehicle was produced in the pos-Lojack period. We also include all the interactions of these last three dummies. With this specification, the β coefficient captures the average treatment effect that having Lojack installed at the factory had on the theft rate of the car models that were included in the Lojack program.

Table 7 contains this specification in columns 1 and 2. The estimated impact Lojack had on theft rates is -.064 percentage points, representing a fall of 59% in theft rates. The clustering of the standard errors is done both at the state and at the state-year level with similar results. Given that the introduction of Lojack did not happen at the same time, in columns 3 and 4 we drop the $After$ variable and substitute it with year dummies. Furthermore, since the interactions with $After$ are completely insignificant, they are dropped from the specification. The difference between columns 3 and 4 is the clustering of the standard errors, whichever are preferred is not important for the results. The estimated impact is very similar to the one obtained in the first two columns, of -.061 percentage points, which represents a fall of 52% in theft rates.

As long as we assume that the changes in theft rates would not have been significantly different in Lojack vs non-Lojack states, this estimate can be interpreted as the causal effect of a car model having been included in the Lojack program. As Gruber (1994) points out, the DDD identifying assumption requires that there be no contemporaneous shock that affects the relative outcomes of the treatment group in the same state-years as the introduction of the intervention. The fact that we have various "introduction" dates, makes this assumption very likely to be satisfied.

Panel data fixed effects regressions come at a cost. The condition on the error term becomes more stringent than in the simpler regressions. In the fixed effects regressions, the error term is assumed independent of the regressors and uncorrelated over time within car models in a state. The strict exogeneity assumption[7] necessary for consistency of fixed effects estimation in our context can be interpreted as requiring that shocks to the theft rate are uncorrelated with the acquisition of Lojack. This is a very reasonable assumption in our context given the manner in which Lojack was allocated. Furthermore, the uncorrelatedness of errors within car models in a state over time seems to be satisfied in our data. For more on this, see the robustness checks section.

It should be noted that fixed effect estimators in the presence of externalities may be biased downwards (if the externality is positive) or upwards (if the externality is negative), as Miguel

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[7] The strict exogeneity condition can be stated as: $E(\epsilon_{i,j,t,y})|\mathbf{x}_{i,j},\ Lojack_{i,j,t,y},\ \alpha_{i,j}) = 0$ for all i, j. This condition implies that $E(Lojack_{i,j,t,y} \cdot \epsilon_{i,j,s,y}) = 0$ for all t and s, which is the interpretation we refer to above.

and Kremer (2004) make clear. What we do to address whether this is the case in our data is to split our control sample into two, states that are contiguous to those with Lojack, and those further away. Under the assumption that any geographical spillovers affect mainly nearby states, we can run our preferred regression with two different control groups: only contiguous states, and only distant states. If we found a larger estimated impact of Lojack using the contiguous states as control, this would suggest the existence of negative spillovers. We ran these two regressions and found an almost identical estimated impact from Lojack, suggesting that not much in the form of geographical spillovers was going on.

In Table 8 we report the impact of Lojack for each of the car models. Of the 9 treatment car models, a significant effect is found for 6 of them. The results of these regressions indicate that the associated coefficient is negative for all but one case, which is not significantly different from 0. This exercise also suggests that our results are not being driven by any specific car model.

We now turn to the interesting question of what the estimated impact of Lojack was as time went by. Although the regression above captures the *average* effect the installation of Lojack had on the theft rate of these vehicles, we are also interested in measuring how the effect changes as the car ages. This is interesting because, as explained in the background section, the subscription to the Lojack service after the first year was voluntary. Lojack executives calculate that roughly 60% of Lojack equipped vehicles enroll at the end of the first year, and the proportion falls to 40% at the end of the second. The interest in comparing the effects of Lojack over time comes from the fact that there was a falling *proportion* of cars that effectively had Lojack. However, which did and did not can have it can be thought to be random. This experiment is closely linked to the way in which Lojack was sold in the U.S., only here we can observe a car model that had a proportion of Lojack coverage equal to 100%, 60% and 40%. Ayres and Levitt (1998) were only able to observe Lojack equipped vehicles in the range of 0-2%, and found large but rapidly decreasing marginal effects. The experiment in Mexico allows us to calculate the effect at much larger Lojack proportion rates.

In order to measure this, we modify the model above, where instead of using a general *Lojack* indicator variable, we run the regression with the following dummy variables: $Lojack_{age=0}$ is 1 if the car is less than one year old and has Lojack, $Lojack_{age=1}$ is 1 if the car is between one and two years old and had Lojack installed when it was sold, and analogously for $Lojack_{age=2}$ and $Lojack_{age=3}$. The actual estimated model is:

$$P_{i,j,t,y} = \alpha_{i,j} + \sum_{z=0}^{2} \beta_z \cdot Lojack_{Age=z} + \Gamma' \cdot \mathbf{x}_{i,j,t,y} + \epsilon_{i,j,t,y} \tag{6}$$

where $\mathbf{x}_{i,j,t,y}$ is defined as in the last specification in Table 7. Table 9 reports the results of the estimation. What is surprising from the table is that the estimated effect is around -.060 percentage points regardless of whether the car is new, one or two years old. An F-test of equality of coefficients was not rejected for any pairwise or joint comparison. This finding suggests that the 59% reduction in theft rates obtained as a deterrence effect by installing Lojack in *all* of the vehicles in a model could have been obtained by a random installation of a proportion less than one. This result is related with what was found in Ayres and Levitt (1998). Although they could not extrapolate from their data with much confidence because their penetration rates were so low, they estimated an effect of Lojack of around -50% if the Lojack penetration rate was 1.5% of vehicles. They also noted that the marginal effect would have to to decrease rapidly. If the effects estimated here lie on the same curve as the one proposed by Ayres and Levitt (1998), we would conclude that the maximum effect is reached with a Lojack penetration rate of between 2% and 40%.

The final part of our analysis deals with measurement of the externalities Lojack had on non-Lojack equipped vehicles. The externalities Lojack generated on other vehicles that were not included in the Lojack program can be divided into three: Geographical spillovers to cars in other states, spillovers to other car models in the same state, and spillovers to older versions of the car model that got Lojack in the same state.

Geographical spillovers to cars in other states may arise because the introduction of Lojack in a given state makes stealing vehicles in states where cars do not have Lojack more attractive. We would expect this externality to be negative and stronger for states that are closer to those that got Lojack. We can go about capturing this type of externality by adding the *Geographical Externality* regressor into equation 5). The idea is that this variable will capture any change in theft rates in non Lojack states contemporaneous with the introduction of Lojack in Lojack states.[8]

The second kind of spillover we inquire about is whether within a state, the implementation of Lojack had an effect on other car models without Lojack. This will be captured by the $Within\ State\ Externality$ which is an indicator equal to one if some other car model in the same state has Lojack, and zero if the car model gets Lojack itself. We would expect this externality to be negative if the elasticity of substitution between Lojack and non-Lojack models is positive.

The last type of externality we investigate refers to older car versions of the ones that got Lojack. The expected direction of this spillover is not ex-ante obvious. If a car model is not changed very much between the years just before it got Lojack and the years after it got it in such a way that it is difficult to distinguish between those that came equipped with Lojack and those that did not, or even if they are distinguishable but thieves are not sure when the program started, we would expect some positive spillover effect of having Lojack installed in future versions of it. However, if there is little confusion for thieves about which models had Lojack and they are close substitutes, we could find negative spillovers along this dimension too. To capture this effect, we introduce the $1\ Year\ Pre\ Lojack$ regressor, which is one if the car was built one year before the model came equipped with Lojack, and a similar $2\ Years\ Pre\ Lojack$ regressor.

The effect of the different externalities generated by the introduction of the Lojack program to other cars are shown in Table 10. The first two columns investigate the existence of spillovers to slightly older versions of Lojack models. The question we want to answer here is if once auto thieves realize, for example, that Ford Windstars model 2000 have Lojack, do they increase or decrease theft of close substitutes, like a Ford Windstar 1999 in the same state? The first two columns of the table suggest that this type of spillover was non existent or not large enough to be detected. It seems that within Lojack states, there was no displacement towards older cars. In the U.S., Ayres and Levitt (1998) found that thefts of older cars became larger as a proportion of all thefts with the introduction of Lojack. This could have come about because of an increase in theft rates for

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[8] More precisely, the indicator variable will be equal to one in non-Lojack states for car models built after the vehicle came equipped with Lojack in Lojack states. It will also be one for non-Lojack car models built after 2003 in non-Lojack states.

older cars, or simply by a decrease in thefts for newer cars, leaving thefts of older cars constant, as is suggested by this regression.

In column 3 of the table we investigate the existence of spillover effects, both across states lines and within the state. We add to the baseline specification the *Geographical Externality* and the *Within State Externality* regressors. The sign of the externality coefficients in this regression suggest that theft rates increased for both groups but the measured effect is not statistically significant. However, it should be noted that, for lack of data, we are not able to measure any possible effects on non Ford car models that may well have experienced a negative spillover. To test whether the geographical externality becomes apparent in closer states, in column 4 we multiply the Geographical Externality by a measure of distance, $(1-d)$. d is the distance between the largest city in a state and the largest city of the closest Lojack state,[9] normalized to be at most 1. When we scale the *Geographical Externality* regressor in this way, we find that states with the shortest distance to Lojack ones seem to have experienced an increase in theft rates.

In column 5 of Table 10 we include all of the externalities mentioned above. The regression results suggest that Lojack generated a large fall of 52% in the theft rate of cars that came equipped with it, but no significant changes in theft rates of non-Lojack states, nor car models in the same state not equipped with Lojack. The last column of the table allows us to conclude that we find very little evidence of spillovers of the Lojack program, either negative (geographical or to other car models in the same state) or positive (to predecessors to the car models equipped with Lojack), but a very consistent estimated impact of the Lojack program on vehicles equipped with it. The only significant spillover that was found was to the closest states to Lojack ones. However, even this result was found to be sensitive to deletion of some states. We would conclude that the evidence for negative spillovers was weak, but that the elimination of positive spillovers found in Ayres and Levitt (1998) seems very robust.

Regarding the fixed effect estimations we have used, Bertrand, Duflo, and Mullainathan (2004)

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[9] Distance was calculated as taking the shortest route between the two cities using data from Guia-Roji (2007) maps.

have warned about the importance of clustering the standard errors. We have paid special attention to this in the regressions and also adopt their recommendation of summing up the treatment and control groups into two blocks as we did in Table 3 above. In the same vein, Deaton (1997) warns that panel data estimators are biased toward zero in the presence of measurement error. In order to address this, we have used different identification strategies like the longitudinal OLS regression and the cross section to check that the different regressions give a coherent picture about the impact Lojack had on theft rates. However, the data used here is more likely to have measurement error on the left hand side variable, which, assuming is additive and uncorrelated with regressors, causes no problems because it is absorbed into the error part of the equation, only decreasing the preciseness of the estimates.

In this study, we have worked under the assumption that Lojack had no effect on the likelihood of the vehicle being insured. We now overview the evidence to see if this is the case, because the results do hinge on the validity of this assumption. If having Lojack installed in the car made its proprietors less likely to buy insurance, this would reduce the number of thefts that would show up in our dataset, regardless of a change in the theft probability, since it only captures thefts of insured vehicles. Fortunately, AMIS collects data that allows us to corroborate if this occurred during the period we analyze. Lojack states command 40% of nationwide sales of the vehicles we study. If there was a diminution in the percentage of these cars that were insured due to them being equipped with Lojack, it would show as a drop in the insurance rate at the national level, for which we have data. In Table 11, the results of a variety of regressions that correlate introduction of Lojack with the national insurance rate of the different vehicle models are reported. In these regressions, the dependent variable is the percentage of cars in the whole country model i made in year y that were insured during year z. The independent variables are a dummy for whether the car came equipped with Lojack, and a set of age and year dummies, to flexibly capture the average effects of aging and trends over time.

The first column in the table is a cross section regression. It uses data from the years 2003, 2004 and 2005. In these years, Lojack models were all already equipped with Lojack. The coefficient on the Lojack regressor suggest no difference in the insurance rate between the Lojack and non-

Lojack models in the years following the introduction of the program. In column (2) of the table we consider only Lojack models before and after the introduction of the program and test whether Lojack was associated to a fall in coverage rates. Again we obtain an insignificant coefficient. In the third column, we run a fixed effects regression, in which each model has an average coverage rate. We find no differential between changes in coverage rates of Lojack versus non-Lojack car models. Column (4) runs the same regression but includes year dummies. Again, we find no significant effect of Lojack. One might worry that these result are driven by the small number of observations in the regressions (78 for the cross section and 317 for the fixed effects regressions). In order to address this concern we calculate the power of the Lojack coefficient we estimated for each of the regressions. This is reported in the last row of the table. These power test suggest that all regressions except the first have good power against a false conclusion. The scarce evidence that substitution of Lojack for car insurance took place may be explained by the fact that 80% of new vehicles are bought with financing loans, which require insurance coverage during the life of the loan.

3.3 Robustness Checks

In this section we perform a series of robustness checks to the analysis reported above. The first thing we inquire is if the results of Table 7 are robust to using a time trend specific to every state instead of common year effects for the whole country. We do this in the first column of Table 13. Since identification comes from changes in theft rates over time, and an ever larger proportion of models becomes included in the Lojack program, adding state specific time effects should decrease the magnitude of the coefficient. Indeed the Lojack coefficient is reduced to -.027 percentage points in this specification, but it is still statistically significant. In column (2) of the Table, we use year dummies at the state level. The coefficient on Lojack is significantly different from zero with an estimated effect of -.029.

Another alteration that the results should be robust to is to eliminate all observations in which the vehicle is less than a year old. During the first year a car model is in the road, large changes in theft rates can come about both because of changes in thefts or because sales are changing (This changes the denominator). However, after the first year, the changes in theft rates occur because of changes in total thefts. For this reason, we rerun the baseline regression without observations in which the vehicle is less than 12 months old in column (3) of Table 13. In this regression, the Lojack coefficient maintains its high significance, and its magnitude, of -.045, is slightly smaller than the one reported above.

The reason for choosing to ignore observations in which sales of a model in a state were less than 5 in a given year was to reduce volatile theft rates due to small denominators. Since our regressions are unweighted, a high theft rate due to this reason could possibly drive the results. However, setting 5 observations as the cutoff was arbitrary. The cost of setting a higher cutoff value is the loss of observations. In column (4) of Table 13, we report the result of running the regression with a cutoff of 10 instead of 5. The result is practically identical to the one reported above. This suggests that there is not much reason to worry about the cutoff level.

Another exercise we performed although we do not report here for space reasons is to run the baseline regression sequentially deleting all of the observations of one of the car models. This would confirm that it is not one car model that is driving the results. The coefficients are not very different from our baseline specification, being all highly significant and varying from a low estimated effect of -.041 to a high of -.070.

Bertrand, Duflo, and Mullainathan (2004) warn that the presence of serial correlation of the errors when using fixed effect estimators can lead to misleading estimated standard errors. In order to measure whether the residuals showed signs autocorrelation we performed the test suggested in Wooldridge (2002) (pp. 274), which consists of regressing the residuals on lagged residuals and testing whether the coefficient is significantly different from what is expected when there is no autocorrelation in the residuals of the model. The tests rejected the presence of autocorrelation in our data.

When we defined the *Within State Externality* in Table 10, we were looking for an effect on *all* vehicles starting the moment when one of the treatment models gets Lojack. In the first column of Table 14, we redefine the *Within State Externality* to be equal to one only for vehicles that are the same age as those that got Lojack. The results of this regression again suggest no spillover to this subgroup. This means that the result presented above was not due to looking at all cars instead of those of the same age as those that got Lojack.

We were also interested in the results being robust to a redefinition of the *Geographical Externality*. Previously, we defined this externality to be one for non-Lojack models built after 2003. In the second column of Table 14 we check whether the result is the same when we focus on the theft rates of Lojack models only. The results are unchanged from what we reported in Table 10, namely, we find no evidence of externalities along this dimension.

4 Cost Benefit Analysis

In this section we present a simple cost benefit analysis of the Lojack program. For the purposes of the evaluation, we exclude the welfare of criminals and only consider monetary costs and benefits. We also exclude any psychic costs incurred by the victims of auto theft. The reason being that although these costs may be substantial, they are difficult to measure. On the other hand, we must also ignore any benefits derived from incarceration of criminals due to Lojack. The reason for this is again lack of adequate data. The details of the calculations can be found in the Appendix.

The main components in the analysis are the value of the stolen vehicle, the theft rate, and the change in the theft rate due to the introduction of the Lojack program. We exclude spillover considerations given the weak evidence for these that we found. Using our dataset, the theft rate for Lojack models in Lojack states before the introduction of the program was .014 annually. As explained in the data section above, this theft rate is an underestimation of the true theft rate. For the cost benefit analysis it is important to use a more accurate one. Given that 83% of the automobiles analyzed here were insured during the years we study, a more accurate estimate of the theft rate level would take this into account. Under our maintained assumption that insured and uninsured vehicles share the same theft probability, the true theft rate should be 1.2 times as large as the one obtained from our dataset. For this reason, we will work under the assumption that the theft rate prevalent for Lojack models in Lojack states before the introduction of the program was .017 annually.[10] Compared to the theft rate used by Ayres and Levitt of 5%, we are on the conservative side, considering that some sources of evidence suggest a higher general theft rate in Mexico than in the U.S. (See ICESI (2004), NATS (2004)), and Ruiz-Harrell (2006) for this).

Our preferred impact estimate from Table 7 suggests a fall in the theft rate for Lojack models of 52%. According to this estimate, the annual theft rate went from .017 to .008 because of the introduction of Lojack. The decrease in the theft rate means that 1 auto theft was averted for every 114 Lojacks. This effect per Lojack is disappointingly small, and is a consequence of two factors. Firstly, that there are no positive externalities. The installed Lojacks only affected the theft rate of the Lojack program vehicles. Secondly, that Lojacks were installed in all participating models. This is especially important given the evidence found above that the same deterrence effect could have been obtained with less than half (and possibly much less) of the Lojacks that were installed.

In comparison, Ayres and Levitt (1998) find that in the way Lojack was sold in the U.S., every three Lojacks prevent one auto theft. The large effect per Lojack found in the U.S. can be attributed to two reasons. On the one hand, the existence of positive externalities; ie, although Lojack was installed in typically less than 2% of cars, it provided deterrence effects to all cars in the same city. On the other hand, the rapidly decreasing returns to Lojack penetration. Ayres and Levitt (1998) suggest that theft rates fell by around 24% with 0.5% of vehicles equipped with Lojack. In Mexico, we found a larger decrease of 52%, but with 100% of the participating vehicles equipped with Lojack. These factors combined account for the small effect per Lojack found in this analysis.

Given that in Table 9 we only found significant effects of Lojack for vehicles aged zero, one, and two years old, the cost-benefit calculations will focus on a three year window. When new, the value of the average Lojack car was $21,092, meanwhile, it was it was $14,121 after a year, and $11,884 during the second year. When we use a discount rate of 5% per year, an average recovery rate without Lojack of 50%, and a 95% recovery rate with Lojack, coupled with an average damage

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[10] .017=.014*1.20482

for a recovered vehicle of \$500, we obtain a total benefit from the fall in theft rates and higher recovery rates due to Lojack of \$357 per vehicle.

The cost of the program per vehicle was around \$300 during the first year, which included installation and the service fee. Assuming a renewal rate for the recovery service of 60% during the first year and a 40% renewal rate during the second year, the total cost of the program was \$393 per vehicle. In consequence, the cost benefit analysis performed here suggests that the social costs of Lojack were slightly larger than the social benefits. In contrast to this, the net social benefits in the U.S. were calculated by Ayres and Levitt (1998) to be around \$1,400 per year per unit installed.

The result implies that selling Lojack to a discernible set of cars limits the potential positive spillovers unnecessarily. However, selling Lojack to a distinguishable set of cars leads to a substantial free rider problem. It seems then that one possible solution to this would be to for the government to buy the amount of Lojacks that equate the marginal social benefit to the marginal social cost and allocate them to car owners in a way that maximizes theft reduction, perhaps randomly.

5 Conclusion

The data analyzed in this paper allow us to conclude that the Lojack program in Mexico generated a fall in auto theft rates of 52% in vehicles in which it was installed. As expected, we found no evidence of positive externalities to other vehicles, and found some weak indication that theft rates increased in states neighboring those that were part of the Lojack program. Furthermore, the fact that the effect on theft rates was stable at around -50% despite a falling probability of having Lojack installed suggested that the maximal effects of Lojack are obtained with installation rates of less than 40% of all vehicles. That is, if the objective was to maximize the welfare of those with Lojack models taking into account the cost of doing so, there was in all likelihood an overprovision of Lojack, generated by coverage rates of 100% when the same deterrence effects could have been achieved with much lower rates of vehicles equipped with Lojack.

The fact that the same theft prevention technology can be either unobservable or observable depending on the way in which it is sold allowed us to compare the effects of selling the device in both manners. In the U.S., where it was indeterminate whether a car had Lojack or not, the benefits were distributed amongst all car owners. However, there was a serious problem of free riding, resulting in an underprovision of the socially optimal amount of Lojack (Ayres and Levitt (1998)). Some states in the U.S. have mandated insurance reductions for vehicles that have Lojack. However, the discounts are too small to be equal to the marginal social benefits the device provides. In Mexico, on the contrary, where it was much more predictable whether a vehicle had Lojack or not, the benefits were constrained to the car models included in the program, eliminating the positive externalities associated with Lojack. It could be argued that signing the exclusivity agreement with Ford may have provided the Lojack selling company the necessary scale and scope to make the system operational if they had limited funds, especially considering the fact that the strategy of operating the tracking devices directly would be at a higher cost than giving them to the police. However, once the necessary fixed costs have been incurred, it would be a socially desirable change if the company moved to a marketing strategy where the product was offered to all vehicles. This would generate the kind of positive externalities that were lost by making Lojack observable for Ford vehicles. There is some evidence that this is the new strategy Lojack is following in Mexico. If this is the case, it would be interesting for future research if the effects could be empirically identified, especially given the fact that the larger the proportion of cars with Lojack, the greater the incentives for criminals to find a way around the technology.

Succinctly, selling Lojack directly to the public has the problem of underprovision due to the substantial positive externalities the device generates. On the other hand, selling Lojack only to a distinguishable set of cars has the problem of eliminating the positive externalities completely. Given this, a possible solution would be for governments to randomly assign the device to a proportion of vehicle owners, in such a way that the marginal social benefits were equated to the marginal social costs. If the implementation was random, it would be ex-ante fair. The results presented here suggest that such a policy could have a strong impact in theft rates of states that pursued such a strategy.

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6 Tables and Graphs

Figure 1: Thefts of Insured Vehicles

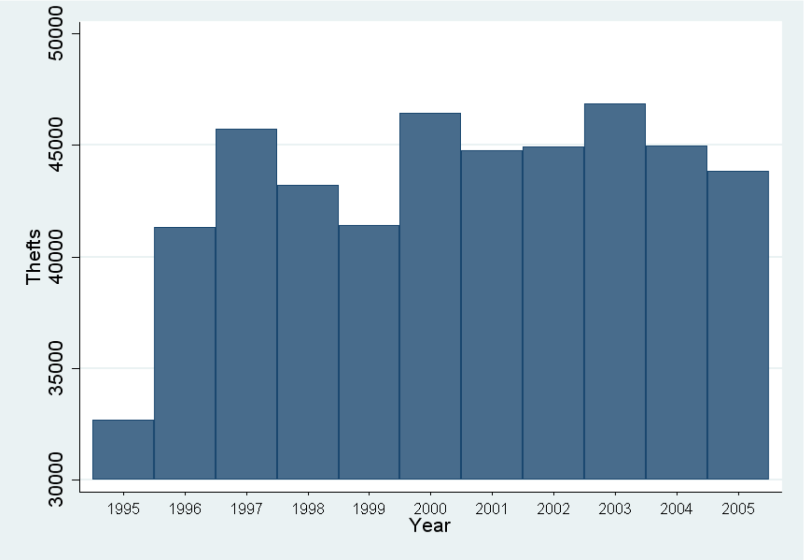
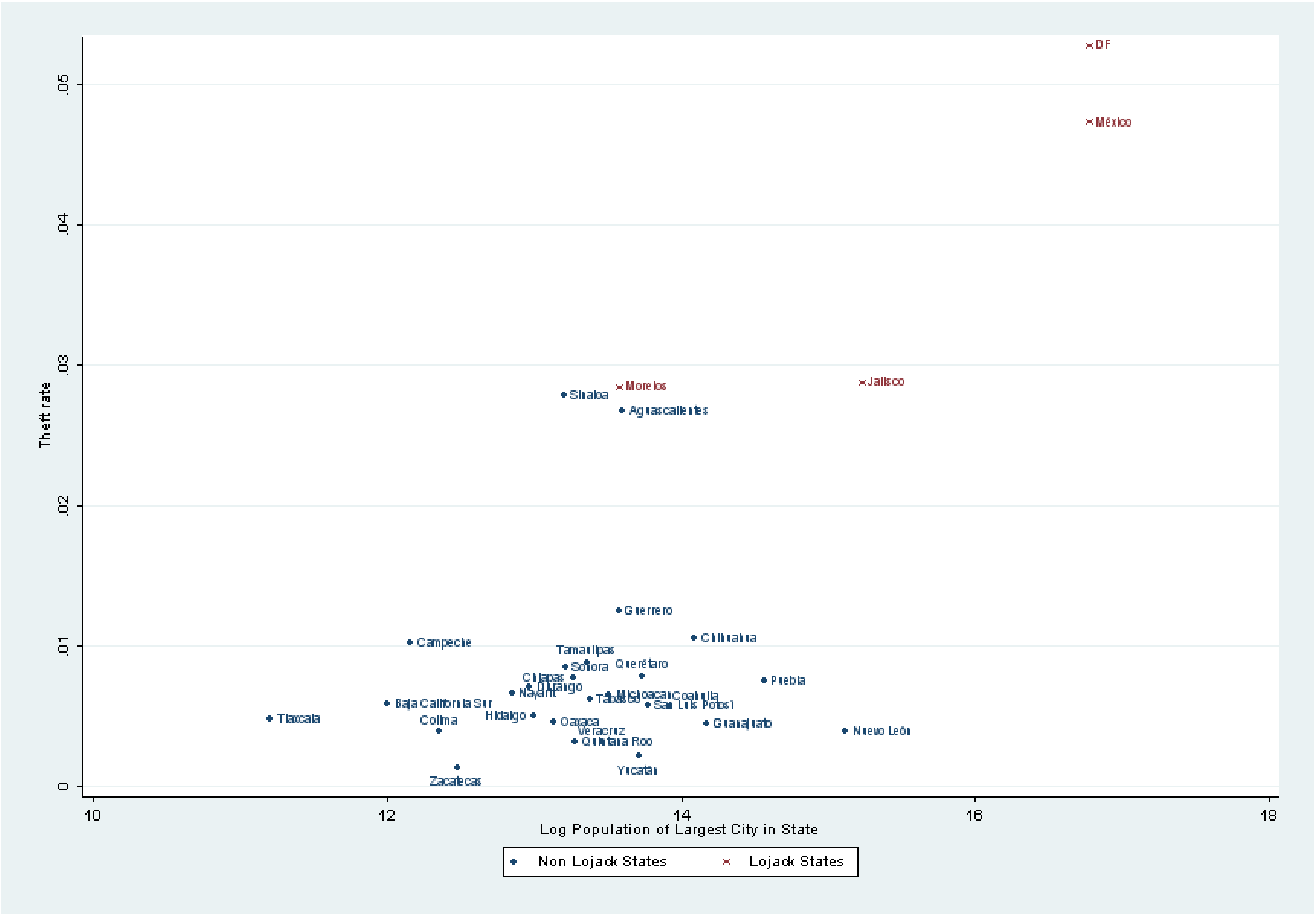


Table 1: States, Dates and Models where Lojack was Introduced

	Lojack Introduction Dates			
	States			
	Jalisco	Estado de Mexico	DF	Morelos
Model				
Treatment Group				
Windstar	Sep 2000	Mar 2002	Mar 2002	Mar 2002
Explorer	Jun 2002	Jun 2002	Jun 2002	Jun 2002
Escape	Sep 2002	Sep 2002	Sep 2002	Sep 2002
Mondeo	Dec 2002	Dec 2002	Dec 2002	Dec 2002
Expedition	Sep 2002	Sep 2002	Sep 2002	Sep 2002
Focus	Mar 2003	Mar 2003	Mar 2003	Mar 2003
Excursion	Sep 2002	Sep 2002	Sep 2002	Sep 2002
Grand Marquis	Sep 2002	Sep 2002	Sep 2002	Sep 2002
Sable	Sep 2002	Sep 2002	Sep 2002	Sep 2002
Control Group				
Mustang	Sep 2004	Sep 2004	Sep 2004	Sep 2004
Lobo	Sep 2004	Sep 2004	Sep 2004	Sep 2004
Town Car	Jun 2005	Jun 2005	Jun 2005	Jun 2005
Navigator	Jun 2005	Jun 2005	Jun 2005	Jun 2005

The study covers car models 1999-2004 observed over the period January 1999-August 2005. Hence, the control group did not get Lojack during the period we study, only later.

Figure 2: Probability of Theft by State: Ford Vehicles



Theft rate is for Ford models, and is obtained for each state from dividing thefts of models sold in 1999-2004 by sales in 1999-2004. Baja California excluded from graph due to theft rate being much higher than for other states. Population data from Census 2000 (INEGI).

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max	Obs
All States					
Theft Rate	.052	.523	0	25	88512
Lojack	.026	.160	0	1	88512
Age Car	2.0	1.6	0	6	88512
Lo Jack States					
Theft Rate	.140	.610	0	14	13231
Lojack	.176	.381	0	1	13231
Age Car	2.0	1.6	0	6	13231

The theft rate refers to the rate per month and is expressed in percentage.

Lojack variable equals one if the car model was equipped with Lojack.

Age of car is in year terms and is 0 if the car is less than 12 months old.

Figure 3: Windstar Theft Schedule in Jalisco According to Year Made

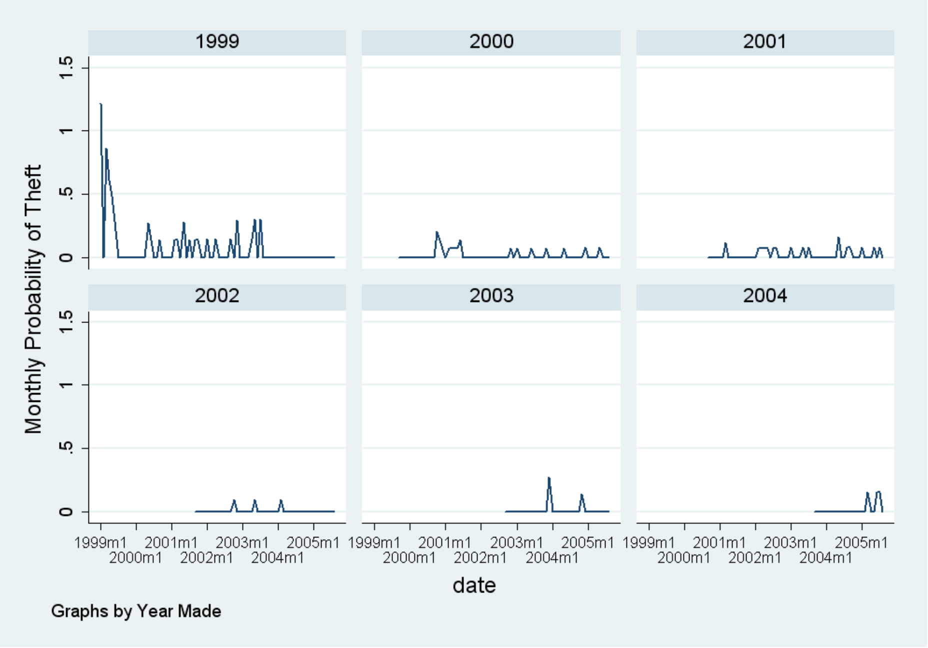


Table 3: Mean Theft Rates

	Lojack States (4)		Non Lojack States (28)	
	Lojack Model	Non Lojack Model	Lojack Model	Non Lojack Model
before	.116*** (.005) [6928]	.219*** (.015) [3573]	.039*** (.003) [44238]	.036*** (.004) [15581]
after	.044*** (.004) [1971]	.230*** (.037) [759]	.029*** (.003) [12116]	.043*** (.008) [3346]
Difference over time:	-.073*** (.010) [8899]	.011 (.037) [4332]	-.011 (.005) [56354]	.007 (.008) [18927]
Difference in Difference:	-.084*** (.029) [13231]		-.018 (.011) [75281]	
DDD:	-.066*** (.027) 88512			

Each cell contains mean probabilities for the specified group. Standard errors are in parentheses, and number of observations are reported in brackets. "After" is defined as vehicles produced in the year 2003 and beyond, since by that year all of the treatment car models had gotten Lojack. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Longitudinal and Cross Section Identification

Dep. Var: Monthly Theft Rate				
	Cross Section		**Longitudinal**	
Lojack	-0.170***	(0.022)	-0.065**	(0.013)
Feb	0.050	(0.057)	-0.038**	(0.011)
Mar	-0.044	(0.040)	-0.028**	(0.007)
Apr	0.047	(0.064)	-0.045*	(0.015)
May	0.053	(0.048)	-0.048***	(0.007)
Jun	-0.050	(0.046)	-0.062***	(0.007)
Jul	-0.067	(0.033)	-0.065**	(0.012)
Aug	-0.037	(0.020)	-0.072***	(0.012)
Sep	-0.019	(0.034)	-0.029	(0.025)
Oct	-0.022	(0.037)	-0.023	(0.021)
Nov	-0.066	(0.031)	-0.049**	(0.011)
Dec	-0.042	(0.050)	-0.042*	(0.015)
DF	0.226***	(0.031)	0.240***	(0.033)
Jalisco	0.205***	(0.032)	0.138***	(0.005)
Estado de Mexico	0.247***	(0.032)	0.170***	(0.005)
Morelos	0.164**	(0.035)	0.133***	(0.005)
Age car= 1	0.110*	(0.039)		
Age car= 2	0.130	(0.059)		
Year=2004	-0.026	(0.055)		
Year=2005	-0.109	(0.077)		
Obs	2730		8899	
R^2	0.0321		0.0118	
Clusters	4		4	

Dependent variable is monthly theft rate. Robust standard errors clustered at the state level in parenthesis. Cross section regression only uses data from Lojack states after Lojack was introduced in all treatment car models. Omitted dummy categories are, for month: January, for age of car: age=0 and for year: Year =2003. Full set of state dummies included. Longitudinal regression only uses data from Lojack models, comparing before and after introduction of Lojack. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: Diff in Diff regression: Control group is Lojack models in Non-Lojack states

Dep. Var: Monthly Theft Rate	**model-state FE** state clustered s.e.	**model-state FE** state-year clustered s.e.
Lojack	-.058*** (.014)	-.058*** (.014)
Year Dummies	YES	YES
Calendar Month Dummies	YES	YES
Age of Car Dummies	YES	YES
Observations	65253	65253
R^2	0.081	0.081
Clusters	32	191

Robust standard errors in parentheses. Dependent variable is monthly theft rate. Regression only used date from Lojack models, in states that got Lojack (Treatment) and states that never got Lojack (Control). * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: Diff in Diff Regression: Control group is non-Lojack models in Lojack states

Dep. Var: Monthly Theft Rate	**State FE**	**State-year FE**	**Model-state FE**	**Model FE**
Lojack	-.078*** (.019)	-.078*** (.019)	-.033* (.018)	-.034* (.018)
Year Dummies	YES	YES	YES	YES
Calendar Month Dummies	YES	YES	YES	YES
Age of Car Dummies	YES	YES	YES	YES
Observations	13231	13231	13231	13231
R^2	0.0676	0.0715	0.0955	0.0905
Clusters	28	28	28	28

Dependent variable is monthly theft rate. Robust standard errors adjusted for state-year clusters in parentheses. Regressions only use data from Lojack states, but includes both treatment (Lojack models) and control models (Lojack not introduced in these mdoels). * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 7: Triple Diff Regression

Dep. Var: Monthly Theft Rate	**Model-State F.E.** state clustered s.e.	**Model-State F.E.** state-year clustered s.e.	**Model-State F.E.** state clustered s.e.	**Model-State F.E.** state-year clustered s.e.
Lojack	-.064*** (.022)	-.064*** (.021)	-.061*** (.014)	-.061*** (.013)
Lojack Model	.155*** (.006)	.155 (.102)	.157*** (.005)	.157 (.102)
Lojack State	.156*** (.005)	.156* (.085)	.150*** (.002)	.150* (.083)
After	-.005 (.010)	-.005 (.009)		
Lojack Model*Lojack State	-.155*** (.007)	-.155 (.121)	-.151*** (.006)	-.151 (.119)
LJmodel*After	-.018 (.013)	-.018 (.010)		
LJstate*After	-.003 (.018)	.025 (.026)		
Year Dummies	NO	NO	YES	YES
Calendar Month Dummies	YES	YES	YES	YES
Age of Car Dummies	YES	YES	YES	YES
Observations	88512	88512	88512	88512
$R2$	.072	.072	.063	.063
Clusters	32	223	32	223

Robust standard errors in parentheses. Dependent variable is monthly theft rate. Relative change in theft probability between Lojack and non-Lojack models in Lojack states are compared to the same relative change in non-lojack states. *After* variable defined as models made in the year 2003 and beyond. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 8: Diff in Diff: Effect of Lojack for Every Car Model

	Escape	Excursion	Expedition	Explorer	Focus
Lojack	-.061** (.028)	-0.048 (.039)	-.025 (.026)	-0.161*** (.037)	.029 (.025)
Observations	5220	2308	9436	9873	7610
R-squared	0.052	0.0227	.01014	.0838	.1317
$\frac{\Delta P}{\Delta LJ}\frac{1}{P}$	-23%	-32%	-12%	-41%	38%

	Windstar	G. Marquis	Mondeo	Sable
Lojack	-0.044*** (.013)	-.053** (.025)	-.049** (.024)	-.056** (.027)
Observations	9804	8194	4732	8076
R-squared	0.0620	0.040	.021	.053
$\frac{\Delta P}{\Delta LJ}\frac{1}{P}$	-42%	-40%	-110%	-73%

Robust standard errors in parenthesis, corrected for clustering at the state-year level.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 9: Triple Diff Regression: Effect of Lojack as Car Ages

Dep. Var: Monthly Theft Rate	
$Lojack_{Age=0}$	-.058*** (.014)
$Lojack_{Age=1}$	-.067*** (.014)
$Lojack_{Age=2}$	-.060*** (.015)
$Lojack_{Age=3}$	-.040 (.048)
Lojack Model	.157 (.102)
Lojack State	.150* (.083)
Lojack Model*Lojack State	-.151 (.119)
Year Dummies	YES
Calendar Month Dummies	YES
Age of Car Dummies	YES
Car model-state fixed effects	YES
Observations	88512
R^2	.073
Clusters	223

Robust standard errors in parentheses, corrected for clustering at the state-year level. $LJage = i$ variable is equal to one if car model has Lojack and has been on the streets between $12 * i$ and $12 * (i + 1)$ months. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 10: Triple Diff Regression: with Externalities

Dep. Var: Monthly Theft Rate	(1)	(2)	(3)	(4)	(5)
Lojack	-.063*** (.013)	-.065*** (.013)	-.055*** (.013)	-.051*** (.014)	-.060*** (.014)
Geographical Externality			.007 (.006)		-.030 (.020)
Geographical Externality$*(1-d)$				.022** (.009)	.054* (.027)
Within State Externality			.011 (.020)	.011 (.020)	.007 (.020)
1 year PreLojack	-.022 (.030)	-.024 (.030)			-.020 (.030)
2 years PreLojack		-.035 (.022)			-.032 (.023)
Lojack Model	.157 (.102)	.157 (.102)	.158 (.102)	.157 (.102)	.153 (.103)
Lojack State	.150 (.083)	.150* (.083)	.145* (.084)	.145* (.084)	.147* (.083)
LojackModel*LojackState	-.209 (.140)	-.205 (.139)	-.209 (.138)	-.206 (.139)	-.200 (.140)
Year Dummies	YES	YES	YES	YES	YES
Calendar Month Dummies	YES	YES	YES	YES	YES
Age of Car Dummies	YES	YES	YES	YES	YES
R^2	.0726	.0726	.0726	.0727	.0727
Clusters	223	223	223	223	223
Observations	88512	88512	88512	88512	88512

Robust state-year clustered standard errors in parenthesis. Dependent variable is monthly theft rate. $WithinStateExternality$ is a dummy variable equal to one in month t if the vehicle model has not been introduced into the Lojack program but another vehicle model in the state has. $GeographicalExternality$ is equal to one if car model does not have Lojack in this state, but does have it in Lojack states. For non-Lojack models it is equal to one for models made after 2003. d is a continuous variable between 0 and 1 which denotes the distance between state i and the closest state that has Lojack in that model. $1YearPreLojack$ refers to Lojack car models in Lojack states that were the immediate predecessors to those that got Lojack. Analogously for $2YearsPrelojack$.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 11: Effect on Insurance Coverage

Dep. Var: Proportion of cars insured

	Cross Section [1]	Longitudinal [2]	Diff-in-Diff [3]	Diff-in-Diff [3]
Lojack	.002 (.071)	.014 (.081)	-.011 (.074)	.131 (.081)
Lojack Model Dummy	NO	NO	YES	YES
Car Model F.E.	NO	NO	YES	YES
Year Dummies	YES	NO	NO	YES
Age Dummies	YES	YES	YES	YES
Observations	78	206	317	317
R^2	.893	.735	.784	.808
$P(\widehat{\beta_{Lojack}} = 0 \mid \beta_{Lojack} \neq 0)$ [4]	.92	.20	.16	0

Robust standard errors in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%.

[1] The Cross Section regression uses data from the 2003, 2004 and 2005 years for all car models.

[2] The Longitudinal regression only uses data from Lojack models for the years 1999-2005.

[3] The Diff-in-Diff regressions use data from all car models for the years 1999-2005.

[4] Probability of type II error on the Lojack coefficient. That is, the probability of accepting that the effect of Lojack is 0 when in fact it is different from 0 (Assuming a probability of type I error of 0.1).

Table 12: Mean Theft Rates: Eliminating Transition Period

	Lojack States		Non Lojack States	
	Lojack Model	Non Lojack Model	Lojack Model	Non Lojack Model
before	.198***	.294***	.047***	.047***
	(.011)	(.029)	(.005)	(.007)
	[2094]	[1226]	[13423]	[5137]
after	.047***	.233***	.030***	.036***
	(.005)	(.039)	(.004)	(.006)
	[1726]	[694]	[11098]	[3093]
Difference over time:	-.153***	-.061	-.017***	.011
	(.013)	(.048)	(.007)	(.010)
	[3820]	[1920]	[24521]	[8230]
Difference in Difference:	-.093**		-.007	
	(.019)		(.013)	
	[5740]		[32751]	
DDD:	-.086***			
	(.033)			
	38491			

Each cell contains mean probabilities for the specified group. Standard errors are in parentheses, and number of observations are reported in brackets. "After" is defined as the period in which Lojack was being installed in all treatment models (starting March 2003), while "Before" is defined as the period when Lojack had not been introduced in any car models (before March 2002). All observations of Windstar in Jalisco are dropped for this table since it took place much before the program was phased in in a larger scale.

* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 13: Robustness Checks

Dep. Var: Monthly Theft Rate	(1)	(2)	(3)	(4)
Lojack	-.027** (.009)	-.029*** (.011)	-.045*** (.012)	-.063*** (.013)
Lojack Model	-.072 (.228)	.164* (.085)	.095 (.080)	.441* (.231)
Lojack State	-.228 (.214)	.789*** (.116)	.125*** (.044)	.021 (.018)
Lojack Model*Lojack State	.077 (.009)	-.439*** (.149)	-.134 (.103)	-.377 (.237)
Year Dummies	NO	NO	YES	YES
State Specific Time Trend	YES	NO	NO	NO
State Specific Year Dummies	NO	YES	NO	NO
Calendar Month Dummies	YES	YES	YES	YES
Age of Car Dummies	YES	YES	YES	YES
Observations	88512	88512	70856	80823
R^2	.076	0.0791	0.0818	0.079
Clusters	223	223	223	223

Robust standard errors clustered at state level in parentheses.
Dependent variable is monthly theft rate.
The regression in column (1) includes a time trend specific to every state.
The regression in column (2)includes year dummies specific to every state.
Column (3) is the baseline specification but deletes all observations where the vehicle is less than 12 months old.
The regression in column (4) uses a dataset that excludes observations of state-model-year made triplets where sales are less than 10 (instead of 5 as in the baseline regression).
* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 14: Robustness Checks: Externalities

Dep. Var: Monthly Theft Rate	(1)	(2)
Lojack	-.055*** (.015)	-.058*** (.014)
Within State Externality	.017 (.033)	.011 (.020)
Geographical Externality	.008 (.006)	.003 (.006)
Lojack Model	.158 (.1502)	.157 (.102)
Lojack State	.145* (.083)	.145* (.084)
Lojack Model*Lojack State	-.213 (.138)	-.209 (.139)
Year Dummies	YES	YES
Calendar Month Dummies	YES	YES
Age of Car Dummies	YES	YES
Observations	88512	88512
R^2	0.0726	0.0726
Clusters	223	223

Robust standard errors clustered at state-year level in parentheses. Dependent variable is monthly theft rate.

In column one the Within State Externality is redefined to be one only for same aged car models as those with Lojack.

In the second column the Geographical Externality is equal to one only for Lojack models.

* significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix

Cost Benefit Analysis

Here we present the details of the calculation of the cost benefit analysis reported in section 4. All values are in 2004 U.S. dollars. We use a discount rate $\delta = .95$. Given that we will focus on three periods, the calculations are not very sensitive to this parameter. We use an average damage when a vehicle is recovered of $\gamma = 500$, which is taken from Ayres and Levitt (1998). In our calculations, we are interested in the value of a generic Lojack protected car. Since 9 car models were included in the program, we use a weighted average value, with weights corresponding to sales.

The value of the average new car is simply the price the vehicle was selling for in dealerships in October 2004. To estimate what these vehicles would be worth when aged one, we used car price data for 2003 models in October 2004. Finally, we estimated the value of the average car when aged two with used car price data From October 2004 of the 2002 models. The data are taken from Guía Autométrica, which uses transactions data from many sources to make its assessments. These assessments are used by insurance companies when calculating the value of a used car. Denoting by V_i the value of the average vehicle when it is i years old, we have: $V_0 = 20,266$, $V_1 = 14,404$, and $V_2 = 11,807$.

The baseline theft rate is calculated from the first cell in Table 3 by turning it into a yearly theft rate, and then by multiplying it by 1.20, to correct for the fact that our database does not include uninsured cars. This allows us to use a more realistic theft rate to measure the overall effects of the Lojack program. Denote by P the baseline theft rate, before the Lojack program in Lojack states. $P = .00116 * 12 * 1.20 = .017$. This theft rate is saying that in Lojack states before the program, the theft rate for Lojack models was 1.7% per year. The regression in Table 7 suggests that Lojack generated a fall in theft rates of 52% in the vehicles in which it was installed. The post treatment theft rate is then $P' = P(1 - \beta_{Lojack}) = .017(.48) = .008$. As described in section 2, the average recovery rate for stolen vehicles in Mexico is around 50%. Denote this rate by r. According to Lojack, the recovery rate for vehicles equipped with Lojack is 95% . We assume that this is accurate, and denote it by r_{LJ}.

The benefit of Lojack can be then quantified as:

$$Benefit = P\left\{[(1-r)V_0 + r\gamma] + \delta[(1-r)V_1 + r\gamma] + \delta^2[(1-r)V_2 + r\gamma]\right\}$$
$$-P'\left\{[(1-r_{LJ})V_0 + r_{LJ}\gamma] + \delta[(1-r_{LJ})V_1 + r_{LJ}\gamma] + \delta^2[(1-r_{LJ})V_2 + r_{LJ}\gamma]\right\} = 357$$

The costs associated to the program per vehicle are \$300 for the installation and one year service. Given that at the end of the first year 60% of people renovated their service at a cost of \$100, the average person spent \$60 on Lojack at the end of the first year. At the end of the second year, around 40% of people renovated the Lojack service, giving an average expenditure on Lojack per vehicle of \$40. Summing these up using the discount factor gives a total cost of \$393 per vehicle over the first three years. Comparison to the calculation above yields a net annual social benefit of \$-12 per Lojack.