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The Direct and Indirect Effect of Safety Regulation on Service Quality: a Cautionary Tale from the French "Robien Law"

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Abstract

To deal with elevators accidents the French 'Robien law' mandated a modernization of 'old' elevators until 2008. Although available statistics suggest that the law led to a reduction of mortal accidents, a seemingly paradoxical side effects occurred: the modernization coincides with a unprecedented deterioration in service quality, doubling the average elevator downtime and tripling the number of breakdowns. We exploit a 10 years-panel database of more than 3500 elevators to investigate the impact of the law on quality. Using the elevators not targeted by the law as a control group ('new' elevators), our difference-in-difference approach shows that the law increased the number of failures by 15% and downtime by 45%. We consider these estimates to represent the lower bound of the overall effect, however, because we also identify an adverse quality spillover on our control group. This paper demonstrates how well intended safety regulations, involving substantial amounts of investment, can have unintended knock-on effects in the regulated area and even beyond.

Keywords: Regulation, Side Effects, Quality, Elevators.

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1 Introduction

The 'Robien law', enacted in July 2003, aimed at reducing fatal and serious accidents in the French elevators sector by imposing safety standards on elevators built before 2001 (the 'old' elevators, thereafter). As a consequence, for an estimated amount of 7.3 billion euros a large part of French elevators had to be modernized in order to meet the specified technical and safety standards.[1] Although an actual evaluation of the law effects on elevator related injuries was never conducted, there are some indications confirming that the law indeed fulfilled its intended purpose and reduced serious accidents.

However, a seemingly paradoxical side-effect occurred since the adoption of the law: the number of elevator breakdowns as well as the downtime of broken elevators, two important indicators of service quality, increased considerably. Ripple effects of this development can be seen in deteriorating tenant satisfaction surveys, press articles about elevators being out-of-service more often than not and even a public inquiry into the experienced 'difficulties' in the elevator sector.[2] This side-effect of the law on service quality is the central topic of this paper.

We argue that the modernization triggered a technological shock because elevators had to become more sensitive for safety reasons, eventually resulting in more frequent breakdowns. Coupled with an inelastic supply of labour in the short run, the higher sensitivity led to an steep hike in breakdowns and downtime. This adverse side-effect of the law is, however, not limited to the service quality of old elevators. As can be seen in the raw data, also the failure rate of elevators constructed from 2001 ('new' elevators, thereafter), therefore *a priori* not affected by the law, surged to unprecedented levels in the wake of the law. The key to understand this secondary effect lies in the firms reaction to the technological shock. With non-linear penalty schemes in place, firms had an incentive to shift maintenance capacity to achieve a balanced failure rate between old and new elevators. Since only old elevators were the designated aim of the law, we interpret this indirect effect as a spillover or general equilibrium effect *a la* Harberger (1962).

To examine the effect of the Robien law on elevator service quality empirically we use an original database from a public housing agency in Paris, which delegates the construction and the maintenance of its elevators to private operators. For each of the more than 3500 elevators, we know the monthly number of breakdowns and downtime between January 2004 and May 2013. Moreover, our data provides information about the construction year of the elevator, allowing us to distinguish old elevators from new elevators and, to use the latter as a control group. The results from a Difference-In-Difference (DID, thereafter) strategy suggest that the modernization significantly increased both the number of breakdowns and the downtime of old elevators. However, since we suspect that firms re-allocated maintenance capacity in favour of old elevators, our control group might also have been affected by the modernization, leading to an underestimation of the impact of the law. We provide evidence for spillovers from old to new elevators by exploiting the geographical organization of lift maintenance.

Our results show that modernizing existing infrastructures can have important and non-

1. The first step of modernization was supposed to be completed before July 2008, but it was finally postponed to December 2010 because of delays in the implementation of the law. According the a report made by the municipality of Paris, the law started to be seriously implemented around 2008 (Marie de Paris, 2010).

2. See, e.g., Marie de Paris (2010),Press Conference (2008).

negligible side effects on service quality. This relates to a large literature in the tradition of the seminal paper of Peltzman (1975) that shows how behavioural responses of agents to regulation can generate unintended side effects (see, *e.g.*, Viscusi (1985); Adda and Cornaglia (2006)). The insights from this literature are highly relevant also for current policy discussions as it helps to anticipate agents' reactions to changes in regulation (see, *e.g.*, Anderson and Matsa (2011)). In addition to focusing on the regulated perimeter, we show that service quality is affected also for elevators not targeted by the law. This spillover is in accordance with the general equilibrium effects in Harberger (1962), showing that behavioural reactions by agents make the final outcome of a regulation very hard to predict in practice. The case featured in this paper indeed shows that firms can react to regulation by reallocating their inputs between activities that are affected differently by the law. The spillover is therefore a natural consequence of the agent taking into account not only one but several, if not all activities, for an optimizing strategy.

On top of that, our paper contributes to the literature stressing the importance of maintenance in relation to investments in infrastructure. The fact that complementarities between infrastructure and maintenance are crucial has been addressed both in macro- as well in microeconomic research. Regarding the former, which is closely related to literature on the optimal mix of public spending, there is some reliable evidence that maintenance is a key factor for growth and development (Rioja, 2003; Kalaitzidakis and Kalyvitis, 2004, 2005; Devarajan et al., 1996). Kalaitzidakis and Kalyvitis (2005) even suggests that shifting public expenditure from capital outlays – classical infrastructure spending – to maintenance may have positive effects on growth.

In the microeconomic literature, Hart (2003) shows that coordinating the construction phase of an infrastructure project with the ensuing operation/maintenance phase is critical for the success of a project. In the same vein, this study represents one of the few micro studies on the subject, highlighting that the relationship between 're-investment' and maintenance is characterized by an important complementarity. From this perspective, the Robien law was insufficiently designed as it emphasized the modernization of the infrastructure and did not deal adequately with the additional needs for maintenance.

The paper is organized as follows. In section 2, we present the French elevator sector and the specifics of the Robien law. Section 3 is dedicated to the presentation of our data set and our empirical strategy to evaluate the direct impact of the law. In section 4, we investigate the existence of a spillover between modernized and non-modernized sectors. Our findings are discuss in section 5. Conclusions follow.

2 The French elevator sector

Not only in France but also at the European and international level, the market for elevators is dominated by four large multinational enterprises. The market shares of Kone, Otis, Schindler and ThyssenKrupp in Europe amounted to approximately 77% (by volume) in 2003 (European Commission, 2007). In addition to the high market concentration, in 2007 these companies were fined a total of 992 million euros, a record figure at the time, by the European Commission for collusive practices in several countries between 1995 and 2005. While the firms have not been prosecuted for such practices in France, the market is still under the scrutiny from public authorities.

The four big firms are active in both construction and maintenance of elevators, while a larger number of small firms are active only on the maintenance market. The construction works are non-recurring events and involve either the installation of new elevators or the modernization of existing ones. In contrast, maintenance describes all obligations a supplier has to meet to ensure the continued functioning of an elevator. It involves not only corrective measures in the case of breakdowns but also preventive actions to ensure a smooth operation of the elevators.

Despite the potential for competition in the maintenance market, in reality it is limited because Kone, Otis, Schindler and ThyssenKrupp can source spare parts from their own production at lower prices that non-producing firms. Given that elevator servicing contracts typically demand replacement of materials, this represents an important competitive advantage. As a consequence, even if 'independent' smaller firms are active in the maintenance sector, they typically work as subcontractors for the four big enterprises.

Based on information from the public housing agency in Paris, the following observations regarding the contractual relationships can be made: elevators are bundled in geographical lots and these lots are awarded through auctions. The contracts typically bundle construction/modernization and maintenance, hence further favouring firms that have the capacity to both construct and maintain elevators. In most cases the contracts are long term (more than 5 years) and describe in a detailed way the technical standards that have to be met along with the permanent servicing requirements.

In order to incentivize firms to avoid breakdowns and deal with failures in a timely manner, the contracts include penalty clauses that are triggered if the monthly level of failures per elevator exceeds a contractually specified threshold. Although the occurrence of failures can be readily measured through an automated monitoring system, penalties do not appear to be applied systematically.

2.1 The Robien law

In the early 2000s, French elevators differed in two main respects from the rest of Europe. First, France had one of the oldest elevator structures in Europe, with a significant portion dating back to before World War II. Second, it had an particularly high rate of mortal/serious elevator related accidents (Marie de Paris, 2010).

In July 2003, after a renewed wave of serious and even fatal accidents, the federal government enacted the law *'urbanisme et habitat'*, also called the 'Robien law'.[3] It's main purpose was to reduce the number of elevator related accidents and it represents a crucial turning point for the elevator sector in France.

The law focused on upgrading the existing infrastructure through a modernization of all elevators built before 2001 and therefore did not live up to the requirements of the European Union directives guiding safety standards.[4] Most importantly, mechanisms had to be put in

3. The former minister Gilles de Robien is considered as being the instigator of this law.

4. For their implementation in the French law see: Décret numéro 2000-180 du 24 août 2000 relatif à la mise sur le marché des ascenseurs.

place to improve stopping accuracy of elevators in order to ensure that doors remain blocked unless the elevator arrives neatly at the floor. Inaccurate stopping that exceeds a threshold of 2cm or any forced opening or closing of the doors would henceforth lead to an emergency stop of the elevator, requiring service personnel to put the elevator back into operation. Business insiders report that these changes increased the sensitivity of elevators and led to more frequent emergency shut-downs.

The whole modernization process was intended to be implemented in three phases of five years each. Within each phase, a detailed list of measured had to be put in place by landlords, the most critical ones being required during the first phase. Regarding the first modernization phase, which we will focus on in the empirical analysis, it was initially provisioned to be completed until July 2008. As landlords were unable to implement the laws requirements until that date, however, it was finally deferred to December 2010.

With respect to the success of the law in terms of elevator safety, the European lift federation pronounced that the number of serious/mortal accidents dropped from around seven per year before the law to 3 in 2008, 0 in 2009 and 1 in 2010 (European Lift Association, 2013a). Despite these improvements, France still had one of the highest number of overall accidents in Europe between 2008 and 2011 (European Lift Association, 2013b). Therefore, the modernization, although apparently a success, did not solved all the problems of the *'French exception'*.

2.2 Side effects of the Robien law

Apart from the positive and expected effects of the law regarding serious accidents, at least two distinct types of adverse side-effects occurred with respect to service quality. [5] The first one is an effect of the law on the service quality for old elevators, *i.e.* those elevators targeted by the law. The second one refers to a spillover effect on the service quality for new elevators as firms reallocate maintenance capacity from new elevators to deal with the increased breakdowns by old elevators. Although the law was originally designed to affect old elevators only, the optimizing behaviour of the firms in response to the law leads to a change in the service quality of new elevators too.

The direct effect of the Robien law on maintenance quality The law is poised to have affected the service quality of old elevators through two potential channels. First, modernization makes old elevators more sensitive, generating *ceteris paribus* an increase in the number of failures. We interpret the modernization as a technological shock that decreased the output per maintenance employee compared to before the implementation of the law.

Second, it was estimated that an additional 1500 workers would be needed to implement the law as expected. While aggregate statistics show that indeed firm hiring along with turnover increased during the implementation phase (see Figure 4 in the appendix), business insiders report that firms did not meet this target and shifted labour resources from maintenance to the more lucrative modernization works (Press Conference, 2008). This shift occurred both in a qualitative and a quantitative way. On the one hand, firms had more workers on modernization.

5. We define service quality as the availability of a functioning elevator. It can be proxied by the number of breakdowns and the downtime.

On the other hand, particularly high skilled workers were used for modernization works, leaving the less experienced ones on the maintenance part. In the end, the labour resources dedicated to maintenance became insufficient as a result of the law, decreasing the service quality.

The indirect effect of the Robien law on maintenance quality In addition to the effect that the Robien law has had on the service quality for old elevators, this paper tries to make the point that the effects were reaching even further. Taking into account not only the elevators intended to be affected by the law, an additional effect materializes. The main driver of this effect lies in the optimizing behaviour of the firms, which have the possibility to shift staff between new and old elevators. Hence, instead of assuming that firms do not react, we postulate that as a result of the technological shock firms change the allocation of workers from new elevators to old elevators.

As mentioned previously, contracts include penalty clauses that are triggered if the number of breakdowns (or the downtime) exceeds a specified thresholds. Moreover, the penalties are progressive, which means that the marginal penalty is increasing with the number of failures. As a results of this non-linear penalty scheme, situations with a very unbalanced failure distribution among elevators are likely suboptimal.

In the particular case of the Robien law which led to a surge in failures of old elevators, firms reacted by shifting maintenance capacity from new elevators to old elevators. The law, through the optimizing behavior of the firms, therefore generated a spillover effect from old to new elevators. Hence, the new elevators, not subject to the law, were nevertheless affected through the allocation of maintenance resources within the firms.

Given the regional nature of the maintenance activity, part of the shift may also be an automatic response from employees. They indeed have to address failures in a geographical perimeter, including both old and new elevators. Consequently, a maintenance employee simply deals with elevators failures according to chronological order of occurrence. For this reason, an increase in downtime of new elevators as a result of the law may be a mix of deliberate re-allocation of maintenance staff and also the organization of failure management.[6]

To sum up, we argue that the Robien law has generated two types of side effects with respect to maintenance quality. On the one hand, the law had a direct impact on the maintenance of old elevators by making them more sensitive and decreasing the maintenance output per employee. On the other hand, because of the re-allocation of the maintenance staff, the law has indirectly affected the service quality of new elevators. The decrease of quality for old elevators constitutes a direct effect in the sense that the very elevators specified by the law were adversely affected. In contrast, the suspected indirect effect implies that the law influenced the servicing of elevators that were not targeted by the law: the new elevators.

6. That the whole effect is a mechanical result of the chronological organization of failure management is, however, unlikely because this should affect only downtime but not the number of breakdowns. In addition, as the empirical results show new elevators followed the failure increase of old elevators with a lag, suggesting more than a mechanical relationship that would have synchronized the trends immediately.

3 Empirical Analysis

3.1 Data and Descriptive statistics

We have access to an original database from a public local agency, Paris Habitat-OPH, which is in charge of social housing in Paris. It owns around 5 082 elevators [7] and delegates their modernization and maintenance to private firms. The elevators in our dataset are managed by three firms, which are among the four major firms of the sector.

From January 2004 to May 2013, we know the monthly number of breakdowns and the downtime for a sub-sample of 3607 out of 5082 elevators in total. [8] To avoid our results to be driven by extreme values, we use the logarithm of maintenance quality variables. Moreover, we limit the maximal monthly number of breakdowns to 50. [9] Descriptive statistics are displayed in Table 1.

Table 1: Descriptive statistics

Variable	Mean	Std. dev.	Min	Max	N
$\log(NbBreakdowns_{it})$	0.45	0.86	0	3.93	404 771
$\log(Downtime_{it})$	1.41	2.93	0	10.71	404 771

	$\log(NbBreakdowns_{it})$		$\log(Downtime_{it})$	
	$AFTER_t$=0	$AFTER_t$=1	$AFTER_t$=0	$AFTER_t$=1
OLD_i=1 (3 413 elevators)	0.28	0.64	0.71	2.19
	N=204 780	N=180 889	N=204 780	N=180 889
OLD_i=0 (194 elevators)	0.38	0.57	1.01	1.94
	N=8 844	N=10 258	N=8 844	N=10 258

In our database there are 3413 elevators constructed before 2001 (the ‘old’ elevators) and 194 elevators constructed from 2001 (the ‘new’ elevators). The dummy variable OLD_i is equal to one if the construction year of the lift i was before 2001, zero otherwise. Regarding the year of implementation, we distinguish the period before and after 2009. [10] The variable $AFTER_t$ is equal to one if the year of observation t is equal or greater than 2009, and zero otherwise.

The raw data for breakdowns and downtime before and after the law’s implementation are given in Table 1. Figures 1 and 2 distinguish the evolution of the average downtime and number of breakdowns for treated an non-treated elevators. First, in each figure, the curves tend to have similar sense of seasonal variations. Second, although these variations seem to be larger for new elevators (especially before 2008), their curves look indifferently flat before 2007. The graphs indicate no violation of the common trend assumption that may confound our empirical

7. There are around 420 000 elevators in France (Marie de Paris, 2010).

8. The elevators not comprised by our data are elevators that are connected to another monitoring system. The monitoring system for an elevator depends on the district and the monitored elevators do not change during our sample period.

9. Un-plausibly high breakdown figures can arise as a result of the automated monitoring system. The results are, however, hardly affected either by dropping or by using the original values.

10. According to Paris Habitat, the law started to be seriously put into practice around 2008.

Figure 1: Average downtime

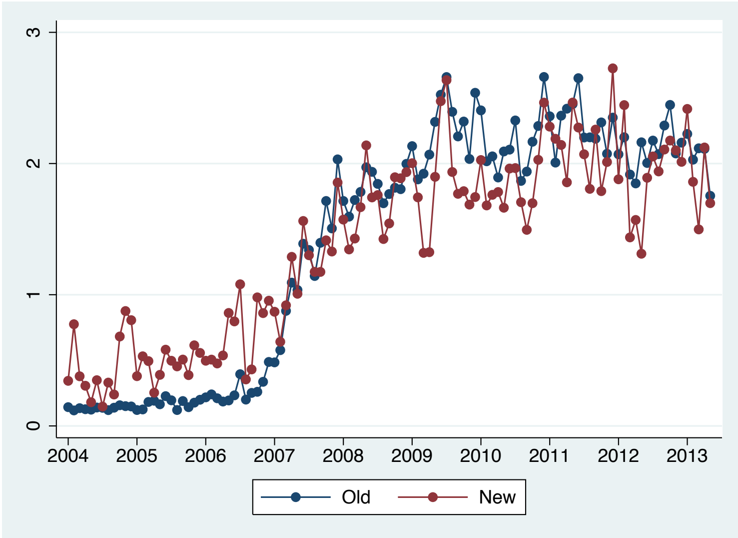
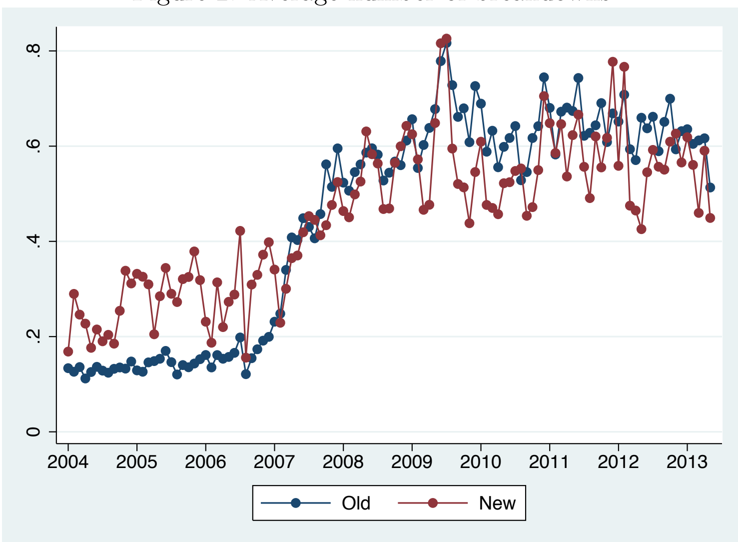


Figure 2: Average number of breakdowns



strategy. Third, there is a kind of transition period between 2007 and 2009: while both curves increase, the failures of old elevators start to exceed the failures of new elevators. And fourth, this tendency persists from 2010 to 2013: on each figure, the curves related to old elevators tend to be above those related to new elevators. Finally, these simple graphs appear to suggest that the law had severe consequences on the service quality of elevators, both old and new elevators.

3.2 Methodology

The empirical strategy employed in this paper follows a simple Difference-in-Difference approach. To evaluate if the law had an effect on service quality we will compare the over time change for elevators targeted by the law (old) and those not targeted by the law (new). The simple estimating equation is therefore:

$$Y_{it} = \beta_0 + \beta_1 OLD_i + \beta_2 AFTER_t + \beta_3 OLD_i * AFTER_t + u_{it} \quad (1)$$

where Y_{it} is the proxy for service quality, OLD_i and $AFTER_t$ are the dummy variables indicating whether an elevator is built before 2001 (targeted by the law) and whether the observation is before or after the implementation of the law. Most importantly, β_3, the coefficient on $OLD_i * AFTER_t$, represents the treatment effect, *i.e.* the estimated effect of the law on service quality for old elevators. To control for seasonal effects, we also include a set of month fixed effects. We calculate cluster robust standard errors at the elevator level to account serial correlation across time.

As the underlying dataset represents elevator-level panel data, we can estimate a generalized version of the above model by adding an elevator fixed effect. This yields the following model:

$$Y_{it} = \eta_0 + \eta_1 AFTER_t + \eta_2 OLD_i * AFTER_t + c_i + u_{it} \quad (2)$$

where the treatment status indicator (OLD_i) is absorbed by the fixed effect c_i. Similar to before, η_2 represents the quantity of interest, the effect of the law on service quality. The main advantage of equation 2 over equation 1 is that it controls for time-invariant confounding factors related to elevator characteristics but also the location/neighbourhood of the elevator.

Another concern may be related to the indicators of service quality, the number of failures and the duration of immobilization, which are strictly positive. As the above linear models may be a bad representation of the non-linear relationship – because the range of the dependent variable is limited – we also estimate a Tobit model with left truncation at 0. [11]

Finally, as reported in the previous subsection, the implementation of the law did not occur in a single year but was rather effected sequentially until 2009. To analyse the dynamics of the implementation, we therefore re-estimate the models in equation 1 and 2 with a full interaction of time year effects instead of a single dummy indicator:

$$Y_{it} = \beta_0 + \beta_1 OLD_i + \lambda_t + OLD_i * \lambda_t \gamma + u_{it} \quad (3)$$

$$Y_{it} = \eta_0 + \lambda_t + OLD_i * \lambda_t \delta + c_i + u_{it} \quad (4)$$

where λ_t represents the time year effects that replace $AFTER_t$. Consequently, instead of a single treatment effect we obtain an estimate for the difference between old and new elevators for every year. This allows us to look at the evolution of the difference between the treated and non-treated elevators over time. We would expect to find a significant increase in the difference between old and new elevators during the year where the law is implemented: around or after the year 2008.

Table 2: Baseline DID Estimations

	$\log(NbBreakdowns_{it})$			$\log(Downtime_{it})$		
	(1)	(2)	(3)	(4)	(5)	(6)
	DID	FE	Tobit	DID	FE	Tobit
OLD_i	-0.092***		-0.384***	-0.288***		-1.962***
	(0.023)		(0.083)	(0.060)		(0.339)
$AFTER_t$	0.195***	0.227***	0.495***	0.945***	1.030***	4.087***
	(0.026)	(0.028)	(0.076)	(0.086)	(0.090)	(0.337)
OLD_i*$AFTER_t$	0.166***	0.134***	0.598***	0.535***	0.450***	2.869***
	(0.027)	(0.029)	(0.078)	(0.088)	(0.092)	(0.345)
N	404771	404771	404771	404771	404771	404771
Month FE	Yes	Yes	Yes	Yes	Yes	Yes

Cluster robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.3 Results

Table 2 exhibits the first DID results for the effect of the Robien law on the number of breakdowns and elevator downtime. The coefficient on $OLD_i * AFTER_t$ in column (1) suggests that the law increased the number of breakdowns by roughly 17%. The FE specification in column (2) yields a similar but slightly smaller effect and the Tobit model in column (3) also supports the conclusion that the law had a significant and positive effect on the number of breakdowns. [12] Looking at elevator downtime, it appears that the effect of the law was even more pronounced than for the number of breakdowns. The models in column (4) and (5) suggest that downtime increased by 54% and 45%, respectively. Although again the FE estimate is somewhat smaller, the overall impact of the law on downtime is significant not only in a statistical sense but also in magnitude. The Tobit model in column (6) supports these findings.

An important observation relates to the 'main' coefficients, OLD_i and $AFTER_t$, in Table 2. It is interesting to note that old elevators appear to have had a lower failure rate and less downtime before the implementation of the law. Hence, in contrast to the safety issues, old elevators seem to have been less prone to failures than new ones in the past. Turning to the coefficient $AFTER_t$, the results show that not only the service quality of old elevators changed strongly but that also the control group (new) experienced a substantial increase in the number of breakdowns and downtime. Columns (1) and (4) suggest that the number of breakdowns and downtime increased by 20% and 95% respectively, even for elevators not subject to the law.

A simple before-after (law) comparison would find that breakdowns for old elevators have increased by 17%+20%=37% and downtime by 54%+95%=149%. Although we deliberately partial out the 'overall changes' by having the new elevators that are not subject to the law as a control group, at the outset it is not clear why there is such a pronounced change for new

11. Given the large number of fixed effects and the absence of a standard procedures to implement a fixed effect Tobit model, equation 1 will be used for the Tobit model.

12. The raw coefficients of the Tobit model cannot be directly interpreted in terms of magnitude but confirm that the conclusions from the other models are still valid when taking the bounded nature of the dependent variable into account.

elevators. In any case, the 17% and 54% increases in breakdowns and downtime should be considered as lower bound estimates. We will further investigate this surprising finding in the following section, after looking at the dynamics of the law's effect.

Table 3: Dynamics

	$\log(NbBreakdowns_{it})$		$\log(Downtime_{it})$	
	(1)	(2)	(3)	(4)
	DID	FE	DID	FE
OLD_i	-0.103***		-0.314***	
	(0.026)		(0.065)	
2005.year	0.075***	0.086***	0.019	0.041
	(0.026)	(0.028)	(0.073)	(0.081)
2006.year	0.058*	0.097***	0.243***	0.373***
	(0.032)	(0.034)	(0.093)	(0.102)
2007.year	0.164***	0.237***	0.760***	0.991***
	(0.036)	(0.037)	(0.122)	(0.139)
2008.year	0.304***	0.397***	1.244***	1.531***
	(0.045)	(0.047)	(0.158)	(0.181)
2009.year	0.353***	0.446***	1.409***	1.693***
	(0.043)	(0.045)	(0.141)	(0.162)
2010.year	0.295***	0.385***	1.402***	1.680***
	(0.043)	(0.050)	(0.146)	(0.175)
2011.year	0.376***	0.467***	1.705***	1.984***
	(0.047)	(0.050)	(0.157)	(0.172)
2012.year	0.328***	0.418***	1.459***	1.738***
	(0.039)	(0.044)	(0.139)	(0.161)
2013.year	0.322***	0.413***	1.561***	1.840***
	(0.044)	(0.048)	(0.159)	(0.178)
OLD_i*2005.year	-0.063**	-0.075***	0.014	-0.008
	(0.026)	(0.028)	(0.074)	(0.081)
OLD_i*2006.year	-0.024	-0.063*	-0.112	-0.242**
	(0.032)	(0.034)	(0.093)	(0.102)
OLD_i*2007.year	0.126***	0.053	0.318**	0.088
	(0.037)	(0.038)	(0.124)	(0.141)
OLD_i*2008.year	0.124***	0.031	0.423***	0.136
	(0.046)	(0.048)	(0.161)	(0.183)
OLD_i*2009.year	0.193***	0.101**	0.704***	0.420**
	(0.044)	(0.046)	(0.144)	(0.165)
OLD_i*2010.year	0.191***	0.101**	0.613***	0.334*
	(0.044)	(0.050)	(0.149)	(0.177)
OLD_i*2011.year	0.151***	0.060	0.457***	0.178
	(0.048)	(0.051)	(0.160)	(0.175)
OLD_i*2012.year	0.179***	0.088*	0.522***	0.243
	(0.041)	(0.045)	(0.143)	(0.164)
OLD_i*2013.year	0.164***	0.073	0.443***	0.164
	(0.045)	(0.049)	(0.163)	(0.182)
N	404771	404771	404771	404771
Month FE	Yes	Yes	Yes	Yes

Cluster robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3 presents the results from models 3 and 4 where the $AFTER_t$ dummy variable is replaced by time year effects. Focusing on the interaction effects in Table 3 – which are contrasted to the base year 2004 – the results show that there is a strong increase in breakdowns and downtime of old elevators (relative to new elevators) starting in 2007 and peaking in 2009.

After 2009 the difference in service quality between old and new elevators decreases to some extent, more strongly for downtime than for the number of breakdowns. The coefficients on the interaction terms are consistently smaller for the FE models in columns (2) and (4) compared to the standard DID models but the dynamics and the qualitative interpretation are the same.

It is interesting to note that the main performance shortfall arises at the same time as firms' business activity peaks (see Figures 3 and 4 in the appendix) around 2009. Therefore, this period appears to correspond to the most intense phase of the law implementation during which the lack of labour resources was especially significant. This lack of workforce should have been transitory, decreasing after the modernizations were finished. However, the technological shock is expected to be persistent since the new safety requirements remain in place well beyond the modernization phase. The differential effect over time we see in Table 3 supports the idea that the law affected service quality through both channels and that the technological change generated long run consequences on service quality.

Another feature that carries over from the results in Table 2 is the fact that also the new elevators as control group experienced a substantial increase in breakdowns and downtime from 2007 to 2009 but a little less strong. It seems that service quality for new elevators followed those of old elevators with a lag, catching up in 2011. This apparent connection of failure patterns between new and old elevators is analysed in more detail in the ensuing section.

To summarize, the results from the empirical analysis in this section show that the Robien law has had a negative effect on elevator service quality. Using elevators not subject to the law as a control group, the law is estimated to have increased the number of breakdowns between 14% and 17% and downtime between 45% and 54%.

4 The indirect impact of modernization: a general equilibrium perspective

A critical question in every DID strategy is the appropriateness of the control group. Several assumptions relate to the link between the control and treatment group. The exogeneity assumption for instance rules out selection into either of the two groups and is rather innocuous here because the treatment group was decided after the realization of the construction year. More relevant to the present paper is the 'Stable Unit Treatment Value' assumption (SUTVA) that rules out interactions between the units in the population.

In the previous section we saw that after the implementation of the law not only the service quality of the old elevators was adversely affected but that breakdowns and downtime increased also strongly for new elevators, not subject to the law. There are actually two readings for this finding: First, the similar movements in failure rates may increase our confidence in the common trend assumption that in the absence of treatment both groups would have had the same time trends. The second interpretation is that in the current case SUTVA simply does not hold. As outlines in the previous chapters, if the allocation of workers – and therefore also failure rates – between new and old elevators is subject to optimizing behaviour by the operating firm, we may expect that the law has triggered a reaction that will affect not only the old but also the new elevators.

Unfortunately controlling for such general equilibrium effects to calculate an unbiased treatment effect is not possible with the available data. As suggested by Miguel and Kremer (2004) or Blundell et al. (2004) a potential solution would lie in the use of conducting experiments with group randomization or at least the existence of a firm or group that was not affected by the law. This is not possible in the present paper as all elevators are managed by the same three firms that operate both new and old elevators. We will return, however, to the possibility of getting a less biased estimate by differentiating firms with more or less shifting potential at the end of this section.

Before that we will try to make the case that the law actually had significant spillover effects from old to new elevators. To this end, we will show that there is a strong and robust relationship between the failure rates of new elevators and old elevators. If the portrayed channel through the constraints on labour are indeed present, we would expect that more breakdowns by old elevators also increase the breakdowns by new elevators because the maintenance staff has to deal with more failures by old elevators increasing the response time to service new elevators.

Given that maintenance is typically organized in spatially separate areas, these failure spillovers should be regional or local in nature and we estimate the following spatial autoregressive model:

$$Y_{it}^{new} = \eta_0 + \rho W_{ij} Y_{jt}^{old} + c_i + u_{it} \quad (5)$$

where W_{ij} is the spatial weight matrix that defines the neighbourhood relationship between elevators. We use two different concepts of neighbourhood and therefore two different weight matrices. On the one hand, we define all elevators in the same district as neighbours and weight them equally regardless of their distance. On the other hand, we use a weight matrix that considers all elevators within 1 km as neighbours and weigh the elevators within this radius depending on the distance. The closer an elevator the higher the weight.[13] The overall term $W_{ij} Y_{jt}^{old}$ is simply a weighted average of the breakdowns or downtime of neighbouring elevators. As we are interested in the spillover from old elevators to new elevators, the weighted average is calculated on the basis of old neighbouring elevators only (Y_{jt}^{old}). Naturally, only elevators from the same firm are considered relevant for spillovers.[14]

As spillover patterns may arise for a variety of reasons, a number of different specifications are estimated to ensure that the spillover is not simply the result of common shocks. These specifications will contain different subsets of elevator FE, elevator-year FE, month fixed effects and month-year fixed effects. Finally, we will estimate a specification where we control for overall spillovers by adding another spatial term:

$$Y_{it}^{new} = \eta_0 + \rho_1 W_{ij} Y_{jt}^{old} + \rho_2 W_{ij} Y_{jt}^{all} + c_i + u_{it} \quad (6)$$

This last specification includes the weighted average of all neighbouring elevators $W_{ij} Y_{jt}^{all}$. If the coefficient on ρ_1 remains statistically significant, it can be considered as a very strong

13. Both matrices are row normalized so that the sum of each row in W adds up to one.

14. We estimate a model by OLS, knowing that the spillover creates a potential endogeneity between neighbouring elevators. Estimations using the failure rates of all neighbouring elevators managed by other firms as an instrument for Y_{jt}^{old} yields similar results.

confirmation of spillover effects between old and new elevators.

After establishing the existence of the spillover effects, we will return once more to the baseline DID framework to test if the general equilibrium effects vary between firms. Depending on the initial allocation of labour forces among old and new elevators the firms may have different degrees of leeway when shifting between the two groups. If really general equilibrium effects are the reason for the increase in breakdowns for new elevators, we would expect this increase to be smaller if less shifting is possible. The share of new elevators may therefore be pivotal. We will analyse this separating the three firms and estimating a DID for each of them separately.

4.1 Testing the idea of spillover as the main mechanism for general equilibrium effects

Table 4: Spillover effects on new elevators: within district

	$\log(NbBreakdowns_{it})$			
	(1)	(2)	(3)	(4)
$W.Y^{old}$	0.766***	0.487***	0.378***	0.081
	(0.077)	(0.081)	(0.081)	(0.078)
$W.Y^{all}$				0.758***
				(0.103)
	$\log(Downtime_{it})$			
	(1)	(2)	(3)	(4)
$W.Y^{old}$	0.862***	0.656***	0.378***	0.212***
	(0.065)	(0.083)	(0.070)	(0.078)
$W.Y^{all}$				0.697***
				(0.095)
N	18595	18595	18595	18595
Elevator FE	Yes	Yes	No	Yes
Elevator-Year FE	No	No	Yes	No
Month FE	Yes	No	Yes	Yes
Month-Year FE	No	Yes	No	No

Cluster robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 shows the results from estimating the spatial model in equation 5 when considering all elevators within a district as neighbours. In columns (1), (2), and (3) the specifications with different sets of FE are exhibited. Not surprisingly, moving from the baseline model with elevator and month FE to a specification with elevator and month-year FE (column (2)) or a specification with elevator-year and month FE (column (3)) captures more and more variation and consequently reduces the size of the spatial spillover. The coefficient on the spatial lag remains, however, statistically significant and of considerable size. Even when allowing the elevator FE to vary each year the estimated ρ_1 suggests a breakdown or downtime spillover of 38%. This means that increasing the number of breakdowns of neighbouring old elevators by 1% is expected to increase the breakdown by a new elevator by 0.37%.

Table 5: Spillover effects on new elevators: within 1 km radius

	$\log(NbBreakdowns_{it})$			
	(1)	(2)	(3)	(4)
$W.Y^{old}$	0.379***	0.268***	0.230***	0.093*
	(0.036)	(0.043)	(0.041)	(0.047)
$W.Y^{all}$				0.265***
				(0.034)

	$\log(Downtime_{it})$			
	(1)	(2)	(3)	(4)
$W.Y^{old}$	0.301***	0.124***	0.080***	0.173***
	(0.025)	(0.026)	(0.021)	(0.030)
$W.Y^{all}$				0.167***
				(0.031)

N	19102	19102	19102	19102
Elevator FE	Yes	Yes	No	Yes
Elevator-Year FE	No	No	Yes	No
Month FE	Yes	No	Yes	Yes
Month-Year FE	No	Yes	No	No

Cluster robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As shown in column (4), adding the second spatial lag to control for overall spillovers further decreases the size of the effect and the ρ_1 becomes insignificant for the number of breakdowns, but not for downtime. Very similar results are obtained when using the second weight matrix, that considers elevators as neighbours if they are within a one km radius. [15] The results in Table 5 basically confirm the previous findings. Moreover, the ρ_1 remains weakly significant in column (4), suggesting that some smaller spillovers are also present in the number of breakdowns. On the other hand, the much larger effect for downtime, both in Tables 4 and 5, can be interpreted as evidence that the spillover works more strongly through delays in repair than through the mere occurrence of a breakdown.

To conclude, there is consistent evidence of failure spillovers, meaning that an increase in

15. Here the elevators j are also weighted according to their distance to elevator i. Using a linear decay function gives an elevator that is 50m away twice the weight of an elevator with a distance of 100m.

the failures of old elevators increase breakdowns and downtime for new elevators. Although these cross-sectoral spillovers are not direct evidence of the general equilibrium effects that are expected to have been caused by the Robien law, these findings strongly suggest the channel through which the law on old elevators may have affected new elevators. If the failure rate of old elevators doubles as a result of the law, the observed spillovers would unquestionably lead to a decrease of service quality for new elevators.

4.2 Enterprise specific DID: the shifting potential

Since labour resources in general and maintenance and repair capacity in particular appear to be the key to the observed spillovers, this final part of the empirical section repeats the initial DID for each firm separately. The three firms in the sample are expected to react differently to the law, depending on their initial allocation of resources between old and new elevators. Despite that we don't observe the actual number of employees servicing old and new elevators, we know the number of old and new elevators that a firm is servicing. [16]

The results in Table 6 show a widely varying treatment effect of the law. Firm 1 exhibits a very strong effect of more than 20% and roughly 100% in breakdowns and downtime, respectively. In stark contrast, the coefficients on the interaction effects is much smaller and typically not statistically significant from zero in the case of Firm 2 and 3. The main reason for the difference between the firms can be found when looking at the estimates for $AFTER_t$: the control group (the new elevators) experienced no statistically significant increase after the implementation of the law for Firm 1, whereas Firms 2 and 3 show a large and significant increase in the failure rate for new elevators.

Given that these two firms have a much larger share of new elevators in the total number of elevators that they service – both roughly 10% compared to only 2% for Firm 1 – the results seem to suggest that the shifting potential for Firm 1 was already limited and therefore it was not possible to reduce the servicing for new elevators significantly. Conversely, the shifting effects appear to have been strongest for Firms 2 and 3, which exhibit a much more balanced increase of breakdowns and downtimes – the difference between the increase in old and new elevators not being statistically significant – as a result of the law.

Given that the control group of the DID strategy is contaminated through spatial spillovers, our baseline results from section 3 may underestimate the true effect of the law. If we use firm 1 as a case where the contamination is limited due to smaller shifting potential, the actual effect of the modernization is closer to 20% for breakdowns and 100% for downtime instead of 13% and 45% as indicated in the baseline DID (see Table 2).

5 Discussion

This paper highlights the side effects of a safety regulation on the provision of service quality. In Figure 7 in the appendix, we can see that contract prices for elevator maintenance

16. Our data, however, comprises only those elevators that are services by a firm on the basis of a contract with the housing agency. Contracts outside public housing are not covered by the data.

Table 6: DID per firm

	log($NbBreakdowns_{it}$)					
	Firm 1		Firm 2		Firm 3	
	(1)	(2)	(3)	(4)	(5)	(6)
	DID	FE	DID	FE	DID	FE
OLD_i	-0.251***		0.066*		-0.031	
	(0.068)		(0.037)		(0.025)	
$AFTER_t$	0.079	0.065	0.251***	0.187***	0.158***	0.169***
	(0.054)	(0.052)	(0.044)	(0.063)	(0.034)	(0.036)
OLD_i*$AFTER_t$	0.232***	0.204***	-0.012	0.067	0.090**	0.052
	(0.054)	(0.053)	(0.049)	(0.076)	(0.036)	(0.038)

	log($Downtime_{it}$)					
	Firm 1		Firm 2		Firm 3	
	(1)	(2)	(3)	(4)	(5)	(6)
	DID	FE	DID	FE	DID	FE
OLD_i	-1.171***		0.214		-0.086	
	(0.253)		(0.162)		(0.064)	
$AFTER_t$	0.244	0.137	0.784***	0.487*	0.923***	0.837***
	(0.195)	(0.181)	(0.185)	(0.259)	(0.111)	(0.114)
OLD_i*$AFTER_t$	1.106***	0.986***	-0.140	0.214	0.337***	0.184
	(0.196)	(0.183)	(0.202)	(0.297)	(0.118)	(0.121)
N	234319	234319	22739	22739	107342	107342
share of new lifts	0.022		0.108		0.107	

Cluster robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

did not increase in the wake of the modernization. However, it is not obvious why the laws effects materialized only in quality and not in price. In this final section, we discuss potential structural characteristics of the underlying case that may explain the observed phenomenon.

One explanation lies in the characteristics of the landlord we study, which is not a 'classic' landlord. As a public buyer, Paris Habitat-OPH has not only to comply with the safety regulation, but also with public procurement rules (European Commission, 2004). As previously stated by Chong et al. (2013), for instance, these rules encourage the use of open competition that are expected to provide strong incentives for competitive bids in terms of low prices while generating quality enforcement issues (See, *e.g.*, Bajari and Tadelis (2001) or Calzolari and Spagnolo (2009) for theoretical discussions on this issue and Iimi (2013) for empirical evidence).

To deal with quality problems, most of the public contracts include penalty clauses that can be used to punish suppliers if performance shortfall arises. Nevertheless, not only in the current case but more as a general tendency there is evidence that penalty clauses are not rigorously enforced (Spagnolo, 2012). One of the main reasons given in the literature are the costs associated with the use of courts and juridical instruments (Coviello et al., 2013). Firms are likely to anticipate this phenomena by posting aggressive bids (to increase their winning probability) and then shirking on quality (to not damage their profits), explaining why public procurement rules may be prone to generate low price/low quality equilibria.

In our case, enforcement costs may especially arise from the non-verifiability of service quality. [17] In the elevator sector, disentangling who or what is responsible for a performance shortfall is made difficult because it can have several causes, like elevator misuse, bad maintenance, bad infrastructure or difficulty to find replacement material. In particular the extent to which suppliers' effort is responsible for the shortfall in service quality gives rise to intense debates. [18]

Consequently, as long as firms' effort is not related through a stable/transparent relationship to service quality, which is the only measurable dimension of the production process, shirking by the private firm is hard to prove. The non-verifiability therefore explains buyers' reluctance to apply penalty clauses as firms may challenge penalties in court. Empirical evidence of such reluctance is provided by Girth (2012) who studies survey data and interviews with public managers. She derives the conclusion that despite public managers having powerful sanctioning tools at their disposal, the burdensome and the discretionary nature of the sanctioning process lead agents to refrain from applying penalties.

Specifically for the Robien law, as the higher sensitivity of elevators became a new source of failures, it has contributed to the overall uncertainty. The additional difficulties to identify the source of the failures makes enforcing penalties even more delicate, thus potentially reinforcing the side effects of the law.

Because of the costs associated with contract enforcement, one solution suggested by the procurement literature is to allocate more discretionary power to the public buyer at the awarding stage. The public buyer may indeed have some (unverifiable) information about firms' efforts and/or expertise. If the public buyer was allowed to use this information to select the contract provider, the latter would have incentive to not shirk on quality so as to avoid an exclusion from the future tendering processes (Kim (1998); Doni (2006); Calzolari and Spagnolo (2009)). However, due to the fear of abuses in discretion and the need to preserve public buyers' accountability, the current European regulation drastically limit the possibility to exclude firms from an auction based on past performance (European Commission, 2004).

6 Conclusion

This paper deals with the question of safety regulation and its impact on service quality. We analyse a particular law in the French elevator sector, that led to a substantial modernization of the existing infrastructure to decrease fatal injuries. The focus of this paper is on the unintended side effects of the law on the quality of the provided service. The theoretical channels through which the modernization can affect service quality, are shown to be empirically relevant. The Robien law analysed in this paper has both short and long term effects on service quality through

17. According to Laffont and Martimort (2002),*It is often the case that, when two parties engage in a relationship, they are uncertain about the values of some parameter which will affect their future gains from trade*' (chapter 6, page 240). These situations refer to a non-verifiability problem.

18. In the report from the Marie de Paris (2010), many different reasons are given by stakeholders to explain the bad performances in the elevator sector.

additional modernization works and the technological shock due to the higher sensitivity. Not only old elevators, which are targeted by the law, are affected but also the quality for new elevators decreases significantly. The latter constitutes a spillover effect that results from firms adapting to quality problems associated with the modernization. We also show that the spillover effect is particularly relevant for firms which have a larger shifting potential as measured by the share of new elevators.

Modernizing infrastructures to make them adapted to technological or safety standards is likely to become a growing concern, especially in developed countries. Our paper highlights that such type of change should be accompanied by a reflection on recurring events like maintenance, that might determine to a large extent the proper functioning of infrastructure. If it is known that quality issues are a relevant feature, designing policies that affect the service provision is such a substantive sense should consider more profoundly the complementarity between investment and maintenance.

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7 Appendix

Figure 3: Firms' turnover

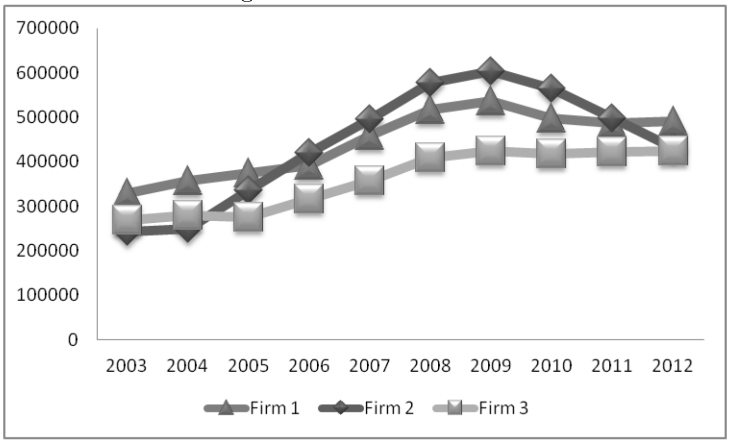

Figure 4: Firms' number of employees

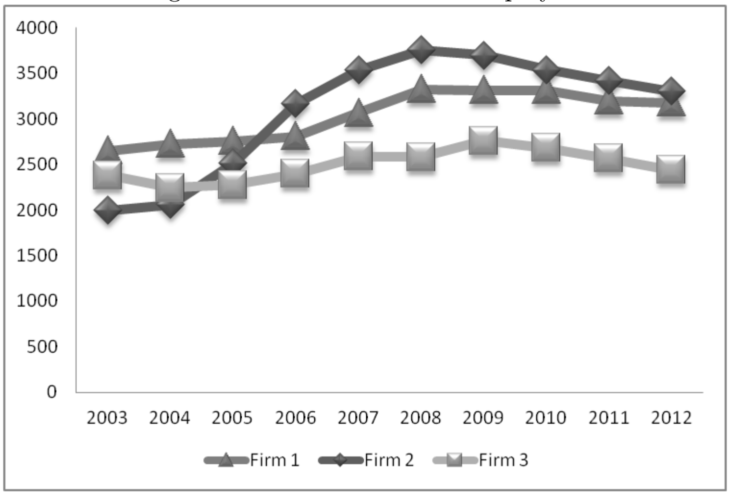

Table 7: Maintenance price

Awarding year	2005	2006	2007	2010	2011
Annual price per elevator (in €)	1 897	1 647	1 406	1 540	1 323