Absence, Substitutability and Productivity: Evidence from Teachers

Asma Benhenda *

University College London, Institute of Education

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Abstract

Worker absence is a frequent phenomenon but little is known on its effects on productivity nor on organizations' strategies to cope with this temporary disruptive event through substitute workers. Using a unique French administrative dataset matching, for each absence spell, each missing secondary school teacher to her substitute teacher, I find that the expected loss in daily productivity from non-replaced days is on par with replacing an average teacher with one at the 30th percentile of the teacher value-added distribution. On average, substitute teachers are unable to mitigate this negative effect. There is substantial heterogeneity by substitute teacher quality: higher quality substitute teachers are able to compensate up to 25 % of this negative impact while lower quality substitute teachers do not have any statistically significant impact. **JEL**: I2, J2, M51.

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1 Introduction

Worker absence is frequent in many countries. For example, in the United Kingdom, the United States and France alike, every year, two to three percent of annual work time is lost due to worker absence (DARES, 2013; UK Office for National Statistics, 2014; US Bureau of Labor Statistics, 2016). Despite the importance of this phenomenon, empirical evidence on the causal effect of worker absence on productivity is scarce.[1] Even much less is known on organizations' strategies to cope with this temporary disruptive event through worker substitution. When a worker is absent, how does it hurt her productivity? How easily can organizations mitigate this effect with substitute workers? Several major economic issues, from the impact of worker health and effort on productivity (Lazear and Oyer, 2012) to the analysis of specific human capital (Jacobson et al., 1993; Altonji and Williams, 2005; Gathmann and Schönberg, 2010) and its relationship with worker substitutability (Stole and Zwiebel, 1996), depend on the answer to these questions.

I offer an empirical answer to these questions using a unique comprehensive administrative French panel dataset covering the 2007-2015 period and matching, for each absence spell, each missing secondary school teacher to her substitute teacher. This paper estimates, for Math, French and History ninth grade teachers and their students: a) the effect of the number of days of non-replaced teacher absence on student test scores ; b) how this impact can be mitigated by the assignment of substitute teachers; c) how the impact of substitute teachers depends on their quality, measured by their type (tenured vs contract teachers).

I implement a two-way fixed effect model with teacher and classroom-year fixed effects. I exploit the longititudinal dimension of the data with teacher-school fixed effects. I also exploit the cross-sectional dimension of the data: in secondary school, teachers are subject-specific and students stay with the same peers in the same classroom, throughout the school year and for all subjects. This allows me to use variation within classroom-year, across subjects. I perform several robustness checks to confirm that the results are not driven by a) reverse causality: teachers are more absent when assigned to low performing students and it is more difficult to find quality substitution for this type of students; b) the fact that absences are only a reflection of poor on-the-job teacher productivity; c) or the fact that replaced absence spells are not comparable to non-replaced ones.

[1] To my best knowledge, there are only four papers covering this question: Miller et al (2008); Clotfelter et al. (2009); Duflo et al. (2012); Herrmann and Rockoff (2012)

Based on the analysis of more than 100,000 teachers and three millions students, I show that teacher absence has a statistically negative impact on student test scores: the expected loss in daily productivity from non-replaced days is on par with replacing an average teacher with one at the 30th percentile of the teacher value-added distribution, which is consistent with the very few studies on this question (Herrmann and Rockoff, 2012). The fraction of absence spell replaced does not have any statistically significant compensating effect. However, when I make the distinction between the two type of substitute teachers, I find that one additional replaced day with a tenured substitute teacher (as opposed to a missed day at school) mitigates 26 % of the marginal impact of non-replaced days. The marginal impact of a replaced day with a contract teacher (as opposed to a missed day at school) is not statistically significant.

I also estimate heterogeneity by teacher and absence spell characteristics to provide suggestive evidence on the underlying mechanisms highlighted in a conceptual framework. I investigate the role of the gap in general human capital between the regular and the substitute teachers. The main prediction from the conceptual framework is that the larger this gap, the smaller the mitigating effect of substitution. I use teacher experience as a measure of general human capital because the link between teacher experience and teacher productivity is well established in the literature (see Koedel et al., 2015 for a review). I find that the mitigating effect of tenured substitution is not significantly impacted by the experience gap. This suggests that the results cannot be entirely explained by this mechanism. I also investigate the role of the specific human capital gap: teaching requires specific human capital which can be acquired only through prolonged and repeated interactions with students. This mechanism is supported by the heterogeneity analysis by month of the year: absence spells happening at the end of the school year have a larger impact than those happening at the beginning of the year, when the specific human capital gap between the substitute and the regular teachers is smaller.

This paper contributes to several strands of the literature. First, this paper contributes to an emerging empirical literature on worker substitutability. Hensvik and Rosenqvist (2016) show that worker sickness absence is lower in positions with few internal substitute and give evidence that firms try to keep absence low in positions with few internal substitute. Jäger (2016) analyzes the effect of unexpected worker deaths in the German private sector and shows these worker exits on average raise the remaining workers' wages and retention probabilities. While these papers use wage and retention as proxies for worker productivity, I measure it based on an actual and multidimensional output, student outcomes. I can rely on an important literature which

consistently finds teachers to be the most important determinant of student outcomes, both in the short and long run (Rockoff, 2004; Rivkin, Hanushek and Kain, 2005; Chetty, Friedman and Rockoff, 2014a;b). Moreover, because teaching is a complex, multidimensional task, based on direct, personal and prolonged interactions with the "output" (students), it requires specific human capital (student-specific, grade-specific etc., see Ost, 2014), which makes it particularly well suited to the analysis of the relationship between human capital specificity and substitutability.

Second, it contributes to the very small literature on the effect of worker absence on productivity (Miller et al., 2008; Clotfelter et al., 2009; Duflo et al., 2012; Herrmann and Rockoff, 2012). This literature focuses on teachers and finds that the expected loss in daily productivity from teacher absence is on par with replacing a teacher of average productivity with one at the 10th-20th percentile of productivity. One of the most important limitation of this literature is that it does not provide any empirical evidence on the impact of substitute teachers and the channels through which teacher absence affects students.

Third, this paper contributes to the small literature on contract teachers, which focuses on developing countries. The main paper on this question is Duflo et al.(2012), which shows that, in Kenyan primary schools, contract teachers are more efficient than regular teachers when their hiring is more closely monitored and they have higher incentives to exert effort. The French context analyzed in this paper is very different because the requirements to become a contract teacher are very low and contract teachers do not seem to have higher incentives than regular teachers to exert effort.

Finally, this paper contributes to the literature on instruction time (Pischke, 2007; Lavy, 2015). This literature finds that longer instructional time has a positive impact on student test scores and one-time grade progression. While these papers focus on variations in planned instruction time defined by law, I go a step further and analyze the impact on student outcomes of variations in the actual amount of instruction hours, and of variations with whom they are actually spent (regular or substitute teacher).

The remainder of the paper is organized as follows. Section 2 describes the French educational context, highlighting its relevance to the analysis of worker absence and substitutability. Section 3 presents a highly stylized conceptual framework to illustrate the mechanisms through which teacher absence and substitution affect student outcomes. Section 4 presents the data and some descriptive statistics. Section 5 exposes the empirical strategy, section 6 the baseline results and section 7 the robustness checks. Section 8 shows the hetergoneity analysis. Section 9 concludes.

2 Institutional Setting

To provide context for the empirical analysis, this section describes the main relevant features of the French educational system. It focuses more specifically on describing the different types of teachers and the teacher assignment system.

2.1 Secondary School Teachers in France

The public French educational system is highly centralized. Schools have little autonomy and they are in particular, all required to follow the same national curriculum. School principals cannot hire nor fire their teachers. The French territory [2] is decomposed in 25 large administrative school districts, called *académies* (hereafter regions).

Secondary school teachers are selected through a subject-specific national competitive examination, which is very demanding academically and has low passing rates (between 15 and 30 %). There are two main certification levels: basic, called CAPES (*Certificat d'aptitude au professorat de l'enseignement du second degré*) and advanced, called *Agrégation*. Conditional on passing this examination, teachers become civil servants and are managed by the government. They have a permanent position and cannot be fired.

Certified teachers are assigned via a centralized point-based system (called SIAM, *Système d'information et d'aide aux mutations*) with two rounds: the inter-regional round and the regional round. Candidates submit a rank-ordered list of choices and are assigned according to a modified version of the school-proposing Deferred Acceptance mechanism (Combes, Tercieux and Terrier, 2016). Teachers' priorities are mostly determined by their number of years of experience. Every year, i) new teachers and tenured teachers who want to change region apply to the inter-regional mobility round; ii) participants of the inter-regional mobility round, and tenured teachers who want to change school within their region, apply to the intra-regional mobility round.

Teachers' wage is set through a national wage scale based on teachers' number of years of experience and certification level (none, basic and advanced). For example, the gross wage of a teacher with the basic certification level and a year of experience is approximately 2,000 euros per month. Wages do not vary across schools and do not depend on output.

Secondary school teachers are subject-specific: each subject is taught by a different teacher. The legal working week is 15 hours for teachers with an advanced certification level and 18 hours for teachers with a basic certification level. Students are not tracked

[2] This paper focuses on mainland France and does not analyse its overseas territories.

by major nor ability. Students stay in the same class, with the same peers throughout the school year and in all subjects. For ninth graders, a typical week consists in 29 school hours, distributed across 11 teachers– subjects, among which 4 hours of French, 3.30 hours of Mathematics, and 3.30 hours of History. [3] At the end of 9th grade, students take a national and externally graded examination called *Diplôme national du Brevet* in three subjects: French, Math and History. This exam takes place in the very last days of June/early days of July.

2.2 Teacher Absence Leave Regulation

Teachers are fully paid during the first three months of their absence leave for minor illness, and during the first to third year of their leave for serious illness. After this period, they receive half of their regular pay. Teachers are fully paid during their maternity leave, which can last from 16 to 46 weeks depending on the order of the birth. Paternity leaves are also fully paid and can last from 11 to 18 days. Teacher can also take fully paid leave for professional reasons such as training, meetings, participation to an examination board *etc.*. There is no limitation in the number of days of paid absence each teacher can take per year.

2.3 Teacher Substitution Procedure

Teacher absences are not systematically replaced in France. Overall, the probability of replacement depends on the length of the absence spell and the availability of substitute teachers. Absences are handled by the regional educational authority (*rectorat*). There are no official precise criteria: regional educational authorities are simply asked to give priority to long term absences (IGEN, 2011).

In practice, when a teacher is absent, she has to notify her school principal, who then notifies the region via an online form, whatever the length of the absence spell. Regional educational authorities assign substitute teachers manually.

2.4 Substitute Teachers

Tenured Substitute Teachers. Certified teachers can ask to become substitute teachers during the intra-regional mobility round of the centralized teacher assignment

[3] The rest of the hours are distributed between Foreign Languages (5h30), Science (4h30), Sport(3h) and Art (2h), see http://www.education.gouv.fr/cid80/les-horaires-par-cycle-au-college.html

procedure but most tenured substitutes (*Titulaires sur zone de remplacement*) are teachers who participated to the inter-regional mobility round and failed to obtain one of their choices in the intra-regional mobility round (IGAENR, 2015). They are assigned to a reference school called *établissement de rattachement administratif* (RAD), and can be called to replace absent teachers in any school located in an geographical area called *zone de remplacement*. [4] There are around 250 *zones de remplacement* in France. Tenured substitute teachers' wages do not depend on the number of substitution they perform nor on the number of hours they work. Their wage is mainly fixed and equal the regular teachers' wage. As explained above, there is no clear rule for the assignment of tenured substitute teachers. Regional educational authorities, which are in charge of the assignment and do it manually, are simply given the general guideline to give priority to long absence spells (IGEN, 2011). Substitute teachers do not have the possibility to refuse any assignment. [5]

Contract Teachers. When there is a shortage of available tenured substitute teachers, regions hire contract teachers on the spot. Contract teachers are not hired via the same procedure as certified teachers. Candidates apply directly to regional educational authorities via an online platform. [6] To be eligible, they must hold a Bachelor's degree and have no criminal record. Candidates submit their resume, cover letter and, in some regions, their geographical preferences. The selection process is managed by regional professional inspectors. In general, professional inspectors are former experienced teachers. They screen candidates based on their online application and conduct interviews. Successful candidates are hired on a short term contract (*Contrat à durée déterminée*) of maximum a year. Contract teachers' wage depends on their degree (High school degree, Bachelor's, Master's or more), their professional experience, and on their region. [7] For example, the gross wage of a contract teacher in Paris, with a Bachelor's degree and a year of experience is 1699 €/ month.

3 Conceptual Framework

This section presents the main intuitions and predictions of a highly stylized conceptual framework illustrating how teacher absences can impact teacher productivity and

[4] Décret 99-823 du 17 septembre 1999

[5] This is different in other countries such as the United States, see Gershenson (2012)

[6] This online platform is called, depending on the region, either SIATEN (Système d'information des agents temporaires de l'Éducation nationale) or ACLOE (Application de gestion des candidatures en ligne)

[7] http://vocationenseignant.fr/devenir-enseignant-contractuel-ou-vacataire-mode-d-emploi

how this impact can be mitigated or aggravated by substitute teachers. This detailed conceptual framework is presented in appendix (section A).

This framework builds on the education production function framework. Teacher productivity depends on her ability, general human capital (including professional experience) and, importantly, student-specific human capital. The basic intuition of student-specific human capital is that the longer teachers spend time teaching the specific students they are assigned to, the better they are at teaching them. This may be because they get to know students and adjust to them, and also have more time to implement a long-term instructional strategy. Several suggestive empirical evidence back this intuition. Duflo, Dupas and Kremer (2011) suggest teachers adjust the level at which they teach in response to changes in class composition. Herrmann and Rockoff (2012) find daily productivity losses from absence decline with the length of an absence spell, consistent with substitute teachers learning on the job.

The main predictions of this conceptual framework are the following. Teacher absence can impact teacher productivity through different channels, depending on whether the absent teacher is replaced, and on the quality of the substitute teacher:

1. If the regular teacher is absent and no substitute teacher is assigned, teacher absence can impact productivity through the loss in instruction time and the amount of student-specific capital the regular teacher loses during her absence. The higher the regular teacher productivity, the bigger the impact of the loss in instruction time

2. If the regular teacher is absent and a substitute teacher is assigned, the main channels are:
   - the difference in ability and experience between the regular and the substitute teachers
   - how fast substitute teachers gain student-specific human capital
   - the amount of student-specific capital the regular teacher loses during her absence

4 Data and Descriptive Statistics

This section presents the administrative data on regular teachers, substitute teachers and their students. Its main advantage is the fact that it is a comprehensive panel

data matching each teacher to her students, and each absent teacher to her substitute teacher for each absence spell. The main estimation sample is composed of all ninth grade students and their Math, French and History teachers from 2007 to 2015. This corresponds to 5,233 schools, 101,479 teachers and 3,259,290 students. This section also provides the descriptive statistics necessary to understand how absence and substitution spells are distributed across teachers and schools.

4.1 Data

This paper relies on administrative data from the French ministry of Education covering the whole country and school years 2005-2006 through 2014-2015. I focus on Math, French and History teachers matched to their ninth grade students. A precise description of the data is found in appendix (section C). I exploit four main set of data:

- individual data on students including an encrypted national identification number, gender, financial aid status, parents' occupation, the identification number of their school and of their class. A separate database also includes their test scores at the end of 9th grade examination in French, Math and History, which I standardize by year and region.
- individual data on teachers including national identification number, date of birth, gender, number of year of teaching experience, teaching subject, identification number of their assignment, and the identification number of the school and of the class they teach. The two latter variables are used to match each teacher to her students. I take into account, throughout the paper, only open business days and remove holidays and weekends.
- data on teachers' absence spells: regional identification number of the absent teacher; day, month and year of the absence spells; detailed cause of absence (minor illness, maternity leave, training etc.); region identification number.
- data on teachers' assignment spells: region identification number of the substitute teacher, day, month and year of the assignment spells; identification number of their assignment; national identifying number of the school. The match between the absent and the substitute teachers is made on the identification number and dates of their respective assignment spells. As for absence spells, I take into account, throughout the paper, only open business days and remove from absence spells holidays and weekends.

4.2 Summary Statistics

Distribution of Absence Spells. Each year, 55 percent of teachers do not take any absence leave (Figure 1). Around half of teachers who are absent take only one absence spell. The majority of absence spells are health-related: 50 % for minor sickness, 10 % for long term illness, 3 % for maternity leave, 2 % for maternity leave extension (in case of a difficult pregnancy or childbirth) and 1 % for professional illness (Figure B1a).

Teachers are absent 13.14 days per year on average, which represents around 7 % of the yearly instructional time. Figure 3 shows the cumulative distribution of the number of instructional days of absence per absence spell. More than 36 % of absence spells last only one day. The distribution of absence spells is right-skewed, with 80 % of absence spells lasting less than 20 days.

Distribution of Substitution Spells. In 2015, the number of replaced days is equal to 10 days per year, which means that around 75 % of absent days are replaced (Figure 2). On average, 5 days per year are replaced by tenured substitute teachers. This means that on average in 2015, 3 % of annual instructional time is spent with tenured substitute teachers, against 6 % in 2007. Over the period, the share of replaced days by contract substitute teachers is more than four times higher in 2015 than in 2007 (from 10 % to around 45 %).

There are large variations in replacement rates by length of the absence spell (Figure 4). On average, only 0.4 % of absence spells lasting a single day and 6 % of absence spells lasting a week are replaced. The replacement rate rises quickly with the length of absence spells, and reaches 50 % for 20 days absence spells and 90 % for 100 days absence spells. Importantly, the share of replacement spells ensured by contract teachers increases with the length of the absence spells for absence spells lasting less than 20 days (which represent more than 80 % of the absence spells). The share of replacement spells done by contract substitute teachers is equal to 6 % for one day absence spells, against more than 17 % for absence spells lasting 20 days.

There are also large variations in replacement rates across regions (Figure B2). For example, in the Creteil region (disadvantaged Eastern suburb of Paris), only 6 % of absence spells are replaced whereas in the Nice region (French Riveria), almost 45 % of absence spells are replaced. The share of absence spells replaced by contract substitute teachers differs greatly between these two regions. In Creteil in 2015, 51 % of replacement spells are done by contract teachers, against 33 % of replacement spells in Nice the same year. This point is important as it shows social inequalities in students' exposition to contract teachers.

Substitute Teachers Characteristics. Table 1 shows summary statistics on

teacher characteristics. Contract teachers are on average less experienced than regular and tenured substitute teachers: they have on average 4.6 years of experience, whereas tenured substitute teachers have 10 years of experience and regular teachers 14.1 years. 32 % of contract teachers have a year or less of experience, against 13 % of tenured substitute teachers and 2 % of regular teachers. Regular teachers and tenured substitute teachers have the same distribution by certification. For both regular and tenured substitute teachers, *Agrégation* recipients represent 5 % of the population and CAPES recipients approximately 75 %. By definition, contract teachers are not certified. I then focus on the subsample of contract teachers who take the same certification examinations as regular and tenured substitute teachers (Table B1). Candidates who are contract teachers perform very badly both at *Agrégation* and CAPES. For example, only 16 % of them pass the CAPES against 33 % of candidates who are not contract teachers.

5 Empirical Strategy

This section describes the empirical strategy implemented to identify the impact of absence and substitution on student achievement. I implement a two-way fixed effect model with teacher-school and classroom fixed effects. I present the main empirical challenges and how they are addressed by this empirical strategy.

5.1 Empirical Strategy

The main empirical challenge raised by the estimation of the impact of teacher absence/substitution is the non-random teacher- student matching. As suggested by Table B2, absences and substitution can be correlated with observed and unobserved teachers' characteristics which can have a direct impact on student achievement. This table confirms results from the literature establishing the statistically significant relationship between teacher experience, her student socioeconomic background and her number of days of absence (eg. Ost and Schiman, forthcoming). Futhermore, there is a statistically significant relationship between teacher substitution and her student socioeconomic background, experience and other teacher characteristics kept equal. Low quality teachers can be systematically assigned to low achieving students.

To deal with these issues, I implement a two way fixed effect model with teacher and classroom fixed effects. First, I exploit the longititudinal dimension of the data with teacher-school fixed effects, which control for both observed and unobserved teacher

fixed characteristics (Miller et al., 2008; Herrmann and Rockoff, 2012). Therefore, I exploit within teacher, across years variations in the number of days of absence and in the number of replaced days. This source of variation has already been exploited in the previous studies on the impact of teacher absences on student achievement (Miller, 2008; Herrmann and Rockoff, 2012). However, a major concern for the validity of this strategy is unobserved variation in student ability, which can impact both teacher absences and replacement and student test scores. This is why I go a step further and take advantage of the fact that, in secondary school, teachers are subject-specific and that students stay with the same peers in the same classroom,throughout the school year and in every subject. This allows me to also exploit variation within classroom-year, across subjects. Formally, this model writes:

$$Y_{c,s,j,t} = A_{j,t}\beta + R_{j,t}\gamma + \theta_s + \theta_c + \theta_j + \theta_t + e_{c,s,j,t} \tag{1}$$

where $Y_{c,s,j,t}$ is the outcome of teacher j 's students in year t in her subject s with the students of classroom c. $A_{j,t}$ is the number of work day absences of all the absence spells taken by teacher j in year t and $R_{j,t}$ the number of replaced work days of all the absence spells taken by teacher j in year t. Finally, θ_t year fixed-effect to control for common trends across years, and θ_j is the teacher-school fixed effects to control for fixed individual characteristics. Robust standard standard errors are clustered by school, which is the most conservative level of clusturisation.

5.2 Identification Assumption and Potential Threats to Identification

The parameters of interests $A_{j,t}$ and $R_{j,t}$ are identified under the assumption that variations within teacher, across years and within classrooom, across subjects in the number of days of absence/ number of replaced days are not correlated with variations of unobserved determinants of student achievement. This would include i) within teacher variations in productivity, such as experience or motivation; ii) student ability or iii) teachers' overall working conditions. First, table B2 shows that experience is strongly correlated with the number of days of absence and replacement. We also know from the literature that experience is an observable determinant of teacher quality. That is why I add experience and the square of experience as control variables. A source of unobservable variations in within teacher quality would be teacher motivation. If, for example, a teacher were burning out, then her absences would only be a symptom of poor on-the-job productivity. This point is discussed in the robustness checks with

placebo tests in the number of days of absence and replacement. Second, low achieving students can discourage teachers and raise absences, i.e. there could be reverse causality. The classroom fixed effect addresses this issue under the assumption that, within classroom, there is no subject specific matching, i.e. that students relatively worse in one subject are not systematically assigned to relatively more absent/less replaced teachers. This issue of reverse causality is also further discussed in the robustness checks section, with a placebo test of the impact of absence/impact of a teacher in one subject on her students' test scores in another subject (i.e. with another teacher). Finally, in the heterogeneity analysis section, I distinguish between maternity leaves and other type of absences. Indeed, maternity leave is the reason of absence most likely to be unrelated to within teacher variations in motivation or burning out, student ability or working conditions.

Another type of potential threat for identification is more specific to the replacement parameters. These parameters would not be identified if the type of absence spells that are replaced were not comparable to those who are not. For example, absences planned in advance may be more likely to be replaced than absences that are unexpected. In that case, the impact of replacement may be biased. Teachers who know in advance they are going to be missing a certain period of time can prepare their absence by giving guidelines to their substitute, specific homework to their students etc. In particular, the analysis of the impact of the assignment of tenured substitute teachers or contract substitute teachers would be biased if tenured substitute teachers where assigned to different type of absence spells, e.g. of different length, period of the year or reason, than contract substitute teachers. This is all the more relevant since the summary statistics (Figure 4) shows that, for absence spells lasting less than 20 days (more than 80 % of the absence spells), the share of replacement spells done by contract teachers increases with the length of the absence spell. I tackle this issue by performing several heterogeneity analyzes, in particular by length of absence spell and reason of absence. More specifically, distinguishing between maternity leaves and other types of absence can be fruitful because maternity leaves are the absences that are the most likely to be planned long in advance.

6 Baseline Results

The main results show one additional non-replaced day of absence reduces student test scores by 0.03 % of a standard deviation. On average, substitute teachers are unable to have any statistically significant mitigating effect. This average effects masks

substantial heterogeneity: tenured substitute teachers are able to mitigate up to 25 % of this negative effect whereas contract teachers have no statistically significant mitigating effect.

6.1 Impact of the Number of Days Absence and Replacement

I begin by presenting estimates of the impact of the number of days of absence and the number of replaced days per teacher-year on their student test scores at the 9th grade examination (Table 2). Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. All regressions include year x subject fixed effects. Column 1 reports naive estimates, without teacher-school fixed effect nor control variables. With this specification, an additional non-replaced day of absence is associated with a 0.13 % of a standard deviation decrease in student test scores. An additional replaced day (as compared to missing a day of school) is associated with a 0.06 % of a standard deviation increase of student test scores. In other words, replaced days compensate more than 45 % of the negative impact of absence. I now control for teacher-school fixed effects and time-varying teacher characteristics (teacher experience and seniority). The effect of absences is divided by three but remains statistically significant (column 2). The fact that the introduction of teacher-school fixed reduces the impact of absence is consistent with a negative correlation between teacher quality and absences. Furthermore, with this specification, the effect of replaced days becomes statistically insignificant. This suggests a positive sorting between absent teachers and substitute teachers: the best absent teachers seem to get the best substitute teachers.

Finally, with the preferred specification, which includes classroom fixed effects, the marginal impact of one additional non-replaced day of absence is to reduce student achievement by 0.03 % of a standard deviation. In other words, the expected loss in daily productivity from teacher absences is on par with replacing an average teacher with one at the 30th percentile of the teacher value-added distribution.[8] This is comparable to the results of the literature. Herrmann and Rockoff (2012) for example find that the expected loss in daily productivity from teacher absences is on par with replacing an average teacher with one at the 10-20 percentile of the teacher value-added distribution. Furthermore, the coefficient associated with the number of replaced days remains statistically insignificant.

[8]For the detail of the computation, see Herrmann and Rockoff, 2012

6.2 Impact of the Number of Days of Replacement by Type of Substitute Teachers

The above results seems to suggest that substitute teachers are, on average, unable to compensate the negative impact of teacher absences. However, Table 3 shows that, in fact, the impact of replaced days largely depends on the type of substitute teachers. With the preferred specification (column 3), tenured substitute teachers are able to mitigate more than 25 % of the marginal impact of absences. On the other hand, the marginal impact of a replaced day with a contract teacher (as compared to missing a day of school) is not statistically significant.

These results suggest that substitute teacher quality plays an important role in the mitigating impact of substitution. This result is consistent with the conceptual framework showing that one of the main mechanisms underlying the impact of teacher absence is the human capital gap between the regular and the substitute teachers. .

7 Robustness Checks

This section aims at adressing the main potential threats to identification. I discuss the three main threats to identification: reverse causality, absence as a symptom of poor on-the-job teacher quality, non-comparability of replaced absences with non-replaced absences.

7.1 Threat I: Reverse Causality

Placebo test with students' teacher in another subject. A concern for the validity of the baseline results is that the bias caused by unobserved variations in student ability, which can impact both teacher absences and replacement and student test scores. To address this concern, we test whether absences and replacements of a teacher in one subject impact her students' test scores in another subject (i.e. with another teacher). If the baseline results were driven by student ability, then the absence days and replaced days of the Math teacher of student i would be significantly correlated with student test scores in French. Table B5 reports regression estimates of the effect of absence and replaced days of the "other subject" teacher of student i on student test scores in 9th grade. Each column-panel corresponds to a single regression. This table shows that Math absence and replacement days are not significantly related to student achievement in French and in History. This is also true for French absence and replacement days on Math and History test scores; and of History absence and

replacement days on French and Math test scores. Thus, this placebo test gives strong evidence in favour of the robustness of the baseline results with respect to within teacher variations in student ability.

7.2 Threat II: Absence as a Symptom of Poor On-the-job Teacher Quality

Previous and Following Year Absences and Substitution. I also give evidence against the idea that the baseline results are driven by the fact that absences are only a symptom of poor on-the-job teacher quality. If, for example, the impact of absence were only capturing the fact that absent teacher were burning out, then previous and following absences would have a statistically significant impact. Table B6 reports a placebo test of the effect of absence and replacement of the previous year ($t-1$) and following year ($t+1$) of teacher j on student test scores in 9th grade with teacher j during the year t. Each column corresponds to a different regression. All regressions correspond to the preferred specification. This table shows absent days and replacement day of years $t-1$ and $t+1$ do not have any statistically significant impact on student achievement in year t. Therefore, it does not seem that the baseline result are biased by poor on-the-job teacher performance.

Absences During the Holidays. Teachers who fall sick or pregnant during the school holidays (days when they do not have class) or during summer time have the possibility to declare these days in order to have these absence days transferred during school time [9]. These absence spells represent around 1 % of the observations. Half of them are maternity leaves happening over the summer. Table B3 shows regression estimates of the marginal impact of one day of absence during holidays. It shows that these estimates are not statistically significant. Therefore, this suggests that the baseline estimates are not driven by that the baseline estimates are not driven by the fact that absence would be a symptom of poor on-the-job teacher quality.

7.3 Threat III: Replaced Absences are not Comparable to non-replaced Absences

Heterogeneity by Reason of Absence. Table B4 reports regression estimates by reason of absence. This table corresponds to a single regression. I make the distinction between absence spells for maternity leave and non maternity leave absence spells. As

[9] Source: https://www.service-public.fr/particuliers/vosdroits/F2481

discussed in the empirical strategy, the reason for this distinction is that maternity leave absence spells are those less likely to be determined by within teacher variations in teacher quality, student ability or working conditions. Furthermore, maternity leaves are the type of absence the most likely to be planned long in advance. We observe that the marginal impact of absence for maternity leave is to reduce student test scores by 0.05 % of a standard deviation. The impact of absence for non maternity leave absences is similar. The impact of replacement by a tenured substitute teacher, for both maternity leave and non maternity leave absences, is to mitigate 30 - 35 % of the negative impact of absence. The fact that estimates for maternity leave absence spells and non maternity absence spells are very similar gives strong support for the robustness of the baseline results.

8 Heterogeneity Analysis

Having established the impact of teacher absence and substitution affects on student achievement, I then estimate heterogeneity across teachers, absence spells and school characteristics. This heterogeneity analysis aims at shedding light on the mechanisms underlying the main results and giving suggestive evidence on the conceptual framework's predictions.

8.1 Heterogeneity by Subject

According to the conceptual framework, the main channel through which non-replaced days impact student achievement is the loss in instructional time. In this framework, the higher the regular teacher productivity, the bigger the impact of loss of instructional time and thus the bigger the impact of non-replaced days.

I investigate this mechanism by leveraging the research design to estimate heterogeneity across teaching subject. It is well established in the literature that teacher productivity varies greatly by subject. In particular Math teachers value-added is higher than in other subjects (see Chetty et al., 2014 for the latest evidence). Therefore, according to the conceptual framework, the negative impact of non-replaced days in Math should be higher than in the other two subjects.

Figure 5 reports regression estimates by teaching subject. The marginal impact of one additional day of non-replaced absence in Math is to reduce student achievement by 0.08 % of a standard deviation. In French and History, this impact is equal to 0.04 % of a standard deviation. The fact that absences have a larger impact in Math

than in other subjects is consistent with the literature (Miller et al., 2008; Herrmann and Rockoff, 2012). This result is consistent with the intuition that the higher the teacher value-added, the higher the impact of absence.

8.2 Heterogeneity by the Experience Gap between the Substitute and the Regular Teacher

Another major prediction of the conceptual framework is that the mitigating effect of substitution depends on the general human capital gap between the regular and the substitute teachers. I use teacher experience as a measure of general human capital because the link between teacher experience and teacher productivity is well established in the literature (see Koedel et al., 2015 for a review). According to the conceptual framework, the larger the experience gap between the regular and the substitute teacher, the smaller the mitigitating impact of substitution.

Table 4 reports estimates from interacting the number replaced days by each type of substitute teachers and the experience gap between the regular and the substitute teachers. It mainly shows that the mitigating effect of tenured substitution is not significantly impacted by the experience gap, suggesting the existence of other mechanisms.

8.3 Heterogeneity by Month of the School Year

The last mechanism I explore is the role of the student-specific human capital gap between the regular and the substitute teachers. According to this framework, the larger this gap, the bigger the impact of absence. I analyse the impact of non-replaced days by month of absence spell to provide suggestive evidence on this mechanism. The intuition is that the student-specific human capital gap between the regular and substitute teachers is larger in the end of the school year than in the beginning: in September, both regular and substitute teachers have limited knowledge of students and the classroom dynamics, but as the regular teacher interacts more and more with her students, she gains more and more specific human capital.

Figure 6 reports estimates of the impact of the number of days/substitution by month of the beginning of the absence spell. The three graphs correspond to a single regression with the preferred specification. The graph 6a shows the seasonality of the marginal impact of absence (controlling for the number of replaced days with tenured substitute and contract substitute). The marginal impact of absence starting in September is not statistically significant at the five percent level. Between October

and January, the marginal impact of absence on student test scores is equal to -0.06/-0.08 percent of a standard deviation and is statistically significant at the five percent level. It then drops to -0.10/ - 0.11 percent of a standard deviation in February and March. The marginal impact of absence is the most negative in June when it reaches a -0.12 percent of a standard deviation. Thus, this graph shows a trend of the impact of non-replaced days getting larger as the school year goes by. The graph 6b, which shows the marginal impact of one replaced day with a tenured substitute teacher, confirms this trend.

Overall, these results are consistent with the the existence of a student-specific human capital gap mechanism.

9 Conclusion

Using a unique French administrative dataset matching, for each absence spell, each missing secondary school teacher to her substitute teacher, this paper (a) estimates the effect of teacher absence on student test achievement; (b) studies how the effect of teacher absence can be mitigated through the assignment and quality of substitute teachers.I find that the expected loss in daily productivity from teacher absences on student test scores is on par with replacing an average teacher with one at the 30th percentile of the teacher value-added distribution. Tenured substitute teachers are able to compensate 25 % of this negative impact, while contract substitute teachers do not have a statistically significant impact. I also provide suggestive evidence on the possible channels, including the gap in general and specific human capital between the regular and the substitute teachers.

This paper has major implications for public policy. It shows that contract teachers are unable to significantly mitigate the negative impact of absence, whereas tenured substitute teachers seem to do a decent job. This is a source of inefficiency as contract teachers represent, overall, an ever growing share of the teaching workforce. It is also a source of educational inequality as substitution spells ensured by contract teachers are concentrated in disadvantaged areas.

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10 Tables and Figures

Table 1 – Substitute Teachers Characteristics

	Regular Teacher	**Tenured Sub.**	**Contract Teacher**
A. **Demographics**			
Male	0.36	0.39	0.43
	(0.48)	(0.49)	(0.50)
Age	43.8	39.0	37.9
	(10.3)	(10.5)	(8.9)
Average Experience (in years)	14.1	10.0	4.6
	(8.3)	(8.8)	(10.2)
A year or less of experience	0.02	0.13	0.32
	(0.12)	(0.34)	(0.47)
B. **Certification**			
Agrégation	0.05	0.05	–
	(0.23)	(0.22)	
CAPES	0.77	0.74	–
	(0.42)	(0.44)	
Other	0.17	0.21	–
	(0.38)	(0.41)	
C. **Evaluations**			
Classroom Observation Grade (/60)	46.82(5.99)	44.84 (6.39)	11.85 (9.59)
School Principal Grade (/100)	39.02(10.05)	39.15 (11.82)	13.86 (8.70)
Nb of teachers	193,766	67,541	23,035

Note: Standard deviation in parenthesis. On average, regular teachers have 14.1 years of experience whereas tenured substitute teachers have 10 years of experience and contract teachers only 4.6 years of experience.

Table 2 – Effect of Absence and Replaced Days on Student Test Scores in 9th Grade

in % of a SD	(1)	(2)	(3)
# days of absence	-0.130***	-0.044***	-0.028***
	(0.009)	(0.006)	(0.005)
# replaced days	0.056***	0.010*	0.010*
	(0.011)	(0.006)	(0.006)
Av. nb of days of abs.	[13.14]	[13.14]	[13.14]
Av. nb of replaced days	[10.06]	[10.06]	[10.06]
Teacher-School Fixed effect	No	Yes	Yes
Teacher experience & seniority*	No	Yes	Yes
Classroom Fixed Effects	No	No	Yes
Number of observations	32,290,084	32,290,084	32,290,084

* Quadratic function of teacher experience and of teacher seniority. Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. All regressions include year x subject fixed effects. Robust standard errors clustered by school.

Note: With teacher-school fixed effects, teacher experience and seniority and student background as controls (column 3), the marginal impact of one day of absence is to reduce student test score by 0.04 % of a standard deviation. The coefficient is statistically significant at the 1 % level. The number of replaced days does not have any statistically significant impact on student test scores.

Table 3 – Effect of Absence and Replaced Days on Student Test Scores in 9th Grade by Type of Substitute Teacher

in % of a SD	(1)	(2)	(3)
# days of absence	-0.132***	-0.046***	-0.027***
	(0.010)	(0.005)	(0.005)
# replaced days x tenured sub.	0.072***	0.017***	0.007***
	(0.011)	(0.006)	(0.005)
# replaced days x contract sub.	0.024**	-0.010	-0.006
	(0.012)	(0.007)	(0.007)
Average # days of abs.	[13.14]	[13.14]	[13.14]
Average # replaced days tenured sub.	[7.73]	[7.73]	[7.73]
Average # replaced days contract sub.	[2.22]	[2.22]	[2.22]
Teacher - school fixed effect	No	Yes	Yes
Teacher experience & seniority*	No	Yes	Yes
Classroom Fixed Effect	No	No	Yes
Number of observations	32,290,084	32,290,084	32,290,084

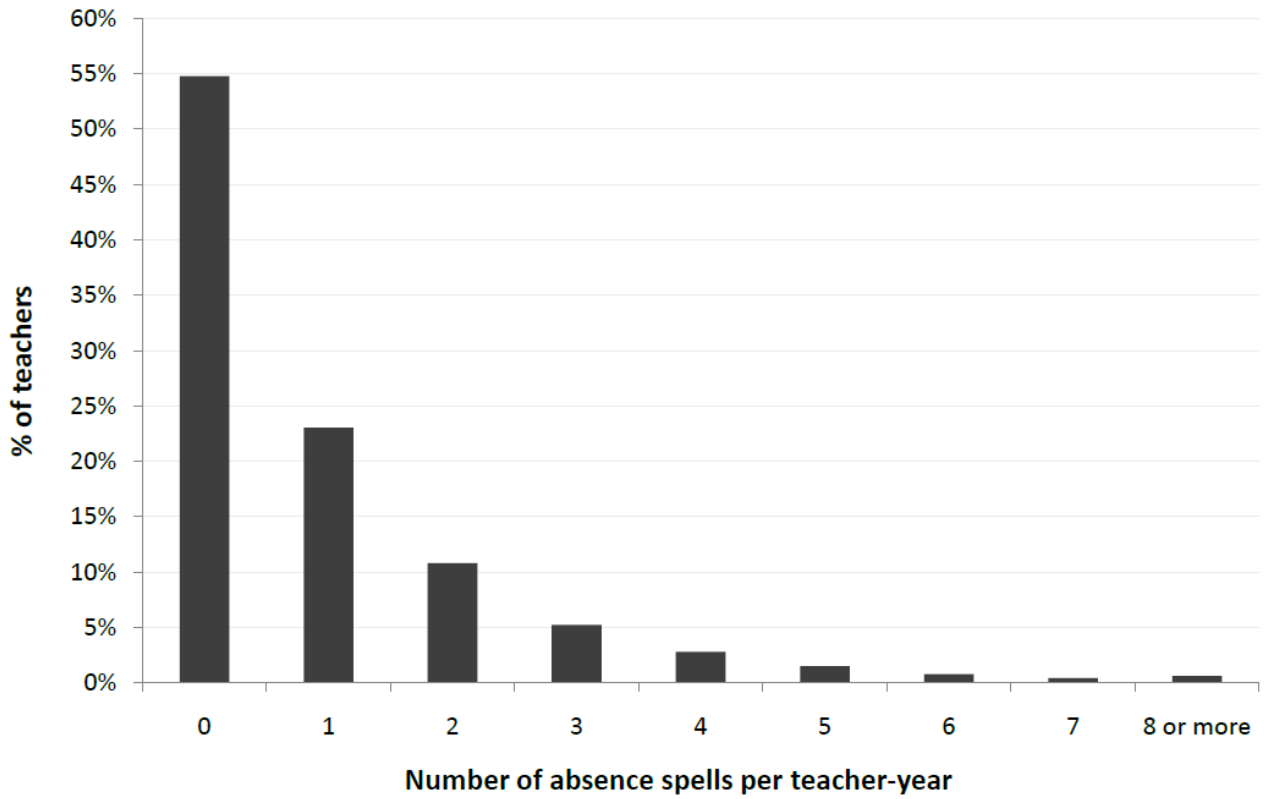
* Quadratic function of teacher experience and of teacher seniority. Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. Robust standard errors clustered by school.
Note: With teacher fixed effects and teacher experience and seniority as controls (column 3), the marginal impact of one replaced day with a tenured substitute teacher is to increase student achievement by 0.016 % of a standard deviation. It corresponds to 30 % of the impact of teacher absence. The marginal impact of one replaced day with a contract substitute teacher is to decrease student achievement by 0.009 % of a standard deviation. It corresponds to 17 % of the impact of teacher absence.

Table 4 – Impact of days of absence/replacement in 9th Grade by Experience Gap between Regular and Substitute Teacher

in % of a SD of student test scores	
# days of absence	-0.039***
	(0.005)
# replaced days x tenured sub.	0.015**
	(0.008)
# replaced days x tenured sub. x exp. gap regular-tenured sub.	-0.000
	(0.000)
# replaced days x contract sub.	0.014
	(0.013)
# replaced days x contract sub. x exp. gap regular-contract sub.	- 0.001**
	(0.000)
Average # days of abs.	[13.14]
Average # replaced days tenured sub.	[7.73]
Average # replaced days contract sub.	[2.22]
Teacher - school and classroom fixed effect	Yes
Teacher experience & seniority	Yes
Student background	Yes
Number of observations	32,290,084

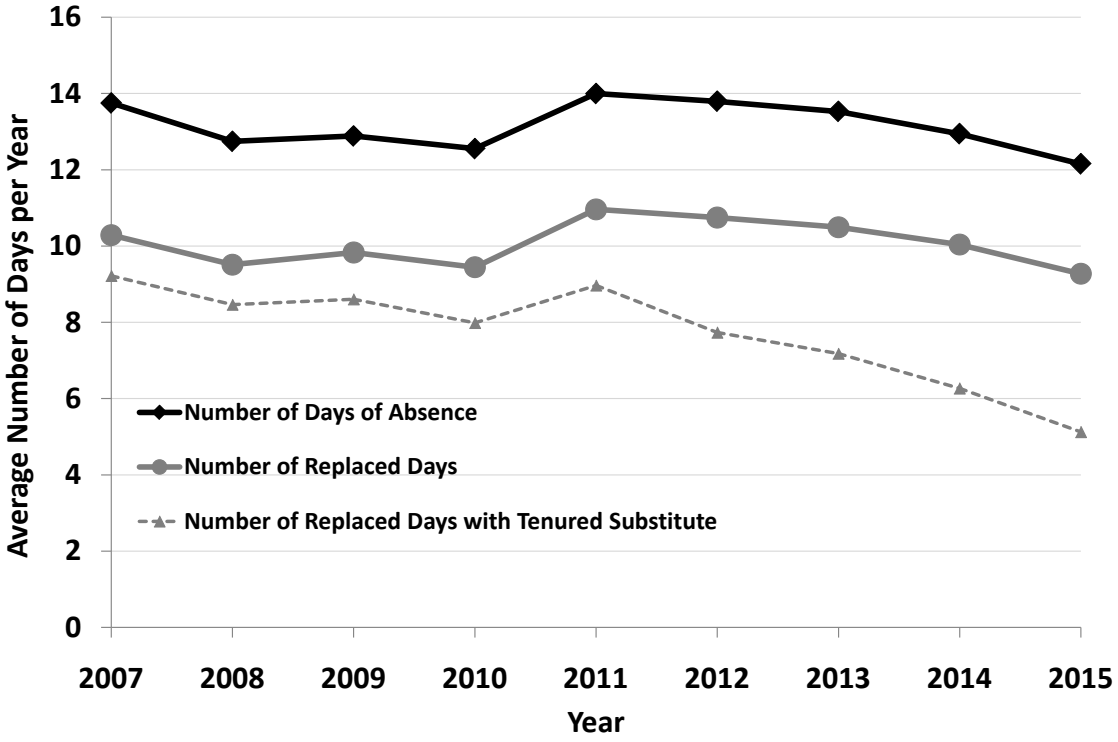
Robust standard errors clustered by school.

Figure 1 – Distribution of Absence Spells by Teacher-Year



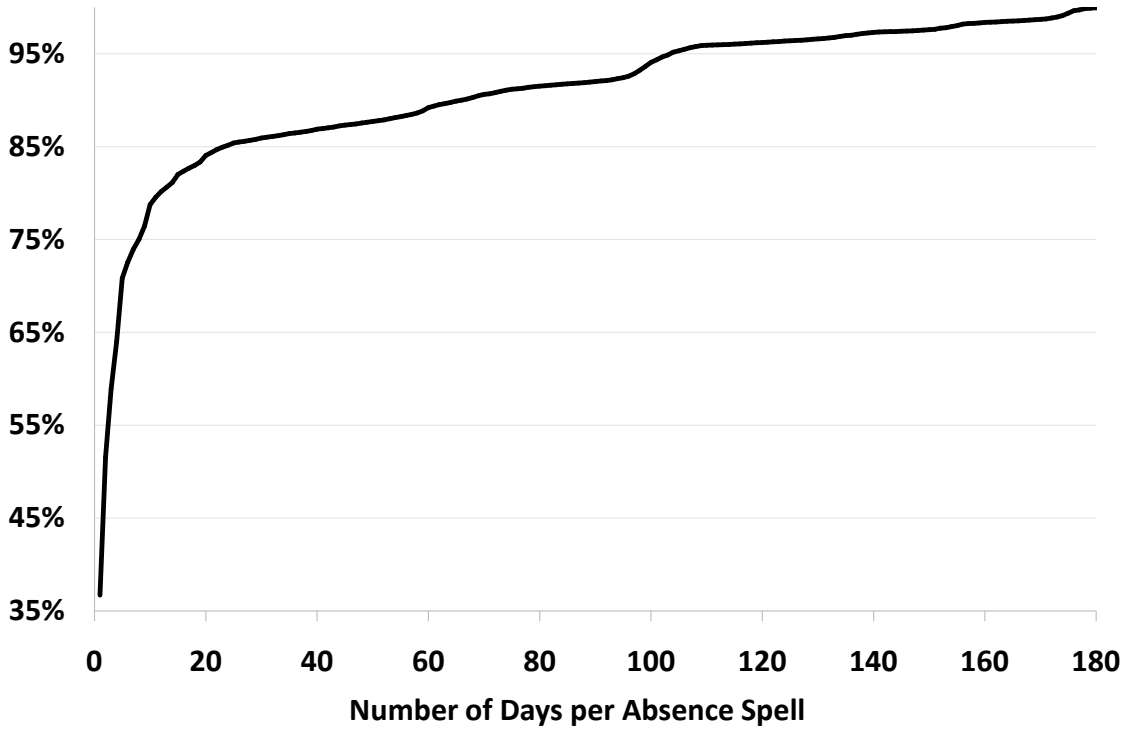
Note: 55 % of secondary teachers do not take any absence spell per year.

Figure 2 – Number of Days of Absence and Replacement per Year



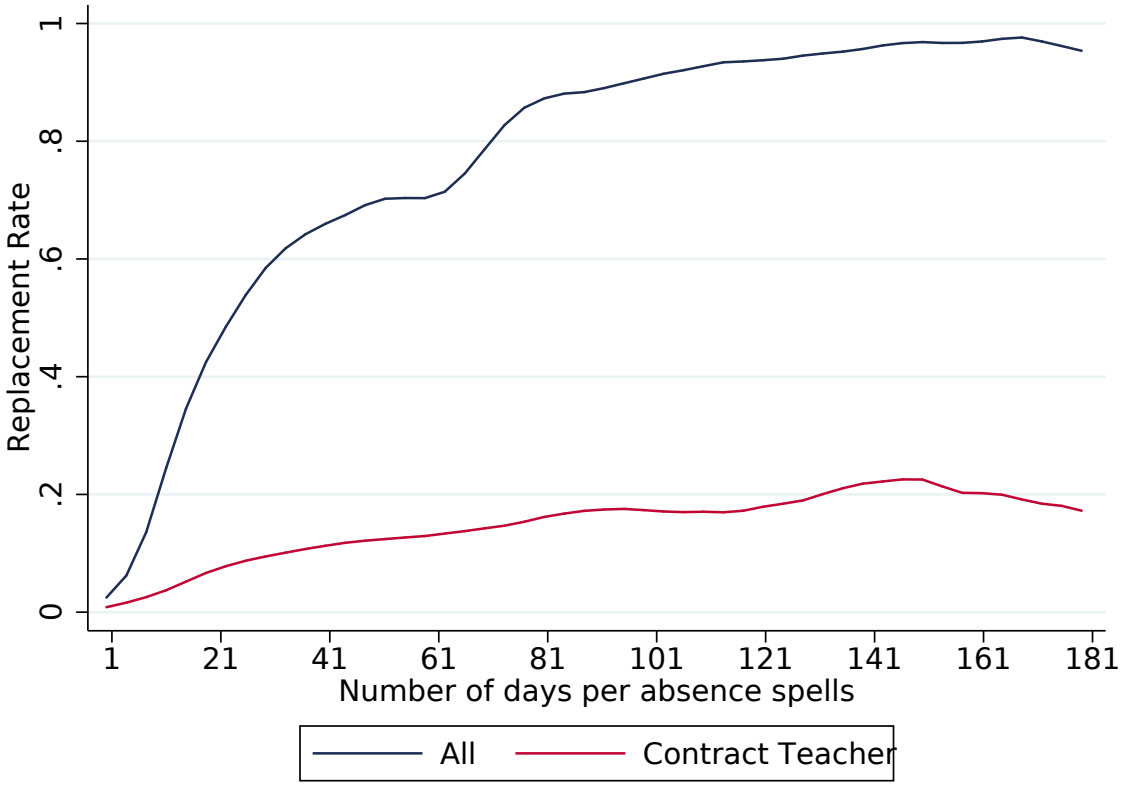
Notes: In 2015, middle school teachers were on average absent 12 days. On average, the number of replaced days in 2015 is 10 days, which means that 78 % of absent days are replaced. The average number of replaced days with a tenured substitute teacher is 5.55 days in 2015, which means that 55 % of replaced days are done by tenured substitute teachers.

Figure 3 – Cumulative Distribution of Absence Spells per Length



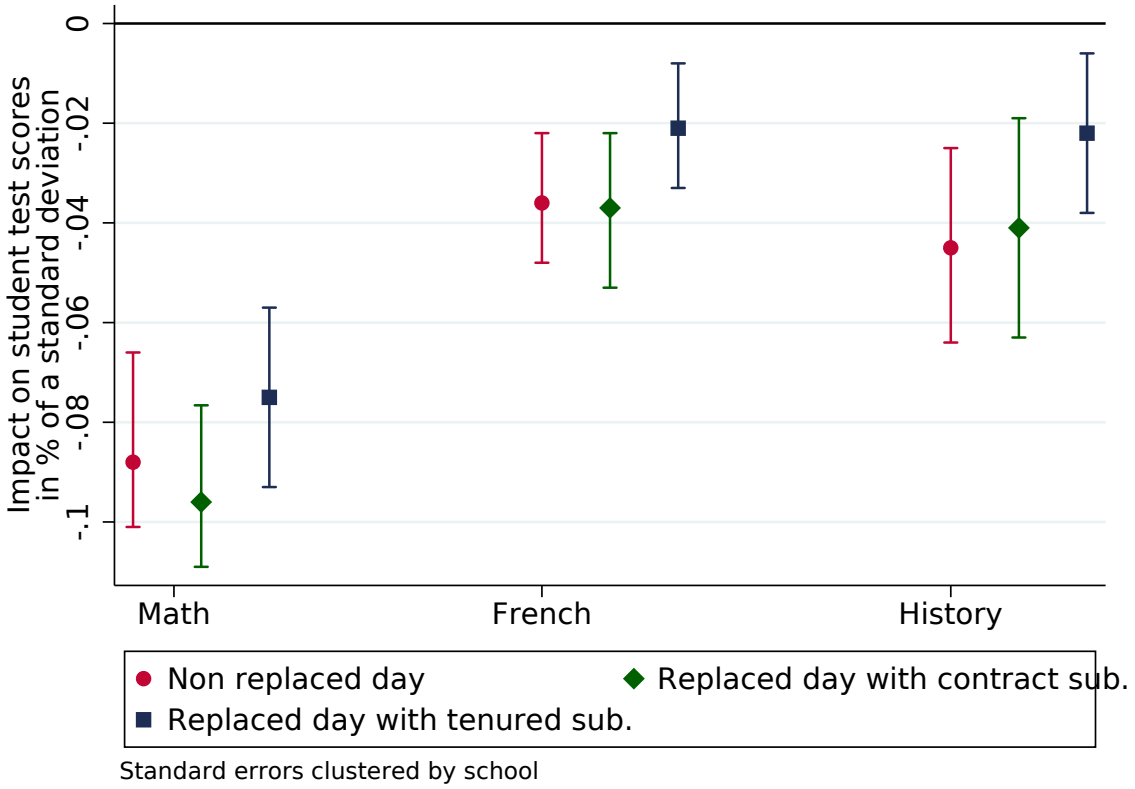
Notes: 36 % of absence spells taken by middle school teachers last only one day. 90 % of absence spells last less than 40 days.

Figure 4 – Replacement Rate per Length of Absence Spell



Notes: 70 % of absence spells lasting 40 days are replaced (black line). 10 % of absence spells lasting 40 days are replaced by a contract substitute teacher. This implies that 60 % of 40 days absence spells are replaced by a tenured substitute teacher.

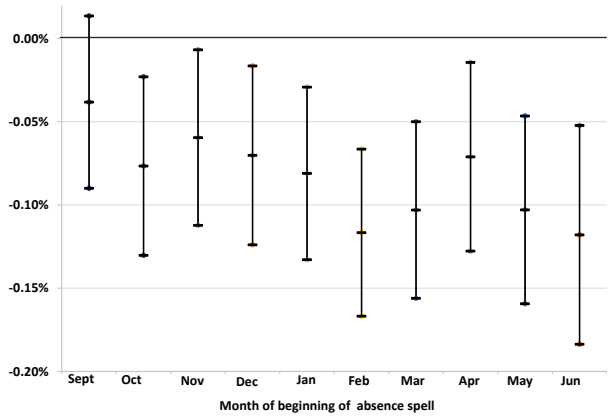
Figure 5 – Impact of Absence/Replacement by Teaching subject



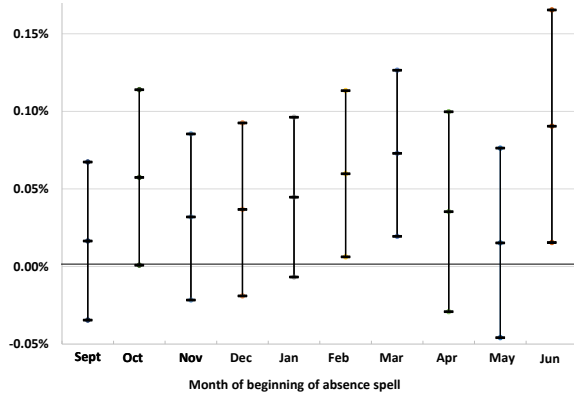
Notes: Estimates by subject are estimated through interaction terms. For each subject, the first reported estimates corresponds to the number of days of non-replaced absence, the second to the number of days with a contract teacher and the third to the number of days with a tenured substitute teacher. The marginal impact of one day of non-replaced absence of the Math teacher is to reduce student test scores by 0.86 % of a standard deviation. This impact is statistically significant at the five percent level.

Figure 6 – Impact of Absence/Replacement on 9th Grade Student Test Scores per Month of the Year

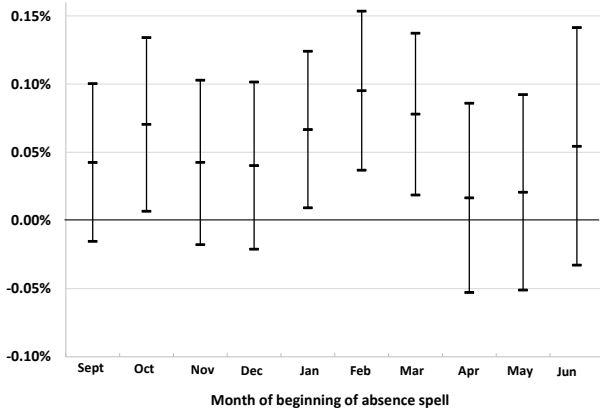
(a) Impact of absence



(b) Impact of tenured substitute



(c) Impact of contract teacher



Notes: These figures corresponds to a single regression, with the preferred specification. It reports the marginal impact of one day of absence/replacement with a tenured substitute/replacement with a contract teacher on 9th grade student test scores by month of beginning of the absence spell.

Appendix

A Detailed Conceptual Framework

I present a highly stylized conceptual framework aimed at understanding the intuitions of my empirical analysis. I essentially build on Herrmann and Rockoff (2012) and add to their framework the potential underlying mechanisms of the effect of absence and substitution on productivity.

Consider $q_{j,i,t}$ the productivity of a representative teacher j during a specific hour of teaching t with student i. The average hourly productivity of teacher j over her hours of teaching with student i, indexed from 1 to $T_{j,i}$ writes:

$$q_{j,i} = \frac{1}{T_{j,i}} \sum_{t=1}^{T_{j,i}} q_{j,i,t} \tag{2}$$

Crucially, I assume the average hourly productivity to be strictly increasing in the number of hours T_j teacher j spends instructing her student i :

$$q_{j,i} = q_j(T_{j,i}), \text{ with } \frac{\delta q_{j,i}(T_{j,i})}{\delta T_{j,i}} > 0 \tag{3}$$

The intuition is that teachers acquire, over their hours of teaching, student-specific human capital which contributes positively to their average productivity. Several suggestive empirical evidence back this intuition. Duflo, Dupas and Kremer (2011) suggest teachers adjust the level at which they teach in response to changes in class composition. Herrmann and Rockoff (2012) find daily productivity losses from absence decline with the length of an absence spell, consistent with substitute teachers learning on the job. Therefore, I assume the longer teachers teach the student they are assigned to, the better they are at teaching them. This may be because they get to know and adjust to their students, and also have more time to implement a long-term instructional strategy.

I write total productivity $Q_{T_{j,i}}$ over hours of teaching indexed from 1 to $T_{j,i}$ as a function of hourly productivity:

$$Q_{T_{j,i}} = f_{T_{j,i}}(q_{j,i,1}, q_{j,i,2}, ..., q_{j,i,T_{j,i}}), \text{ where } j = \begin{cases} r \text{ if the regular teacher is teaching} \\ s \text{ if the substitute teacher } s \text{ is teaching} \end{cases} \tag{4}$$

From the student i perspective, the total number of planned hours of instruction

T_i writes:

$$T_i = T_{i,r} + T_{i,s} + T_{i,a} \tag{5}$$

where $T_{i,a}$ is the number of instruction hours lost by student i when her regular teacher is absent and no substitute teacher is assigned. I write $Y_{i,T}$, student i output over T, as a function g_T of the sum of regular teacher r and potential substitute teacher s respective productivity, lost instruction time $T_{i,a}$ and an idiosyncratic error ϵ_{i,T_i} (other inputs):

$$Y_{i,T_i} = g_T(f_{T_{i,r}} + f_{T_{i,s}}, T_{i,a}, \epsilon_{i,T_i}) \tag{6}$$

Following the standard education production function framework (Todd and Wolpin, 2003), I assume $f_{T_{i,j}}$ and g_T to be additive and separable:

$$Y_{i,T_i} = T_{i,r} q_r(T_{i,r}).\alpha + T_{i,s} q_s(T_{i,s}).\beta + T_{i,a}.\gamma + \epsilon_{i,T_i} \tag{7}$$

Empirically, we observe two main different cases: 1) The regular teacher is absent and no substitute teacher is assigned; 2) The regular teacher is absent and a substitute teacher is assigned.

Case 1. It corresponds to $T_{i,s} = 0$, $T_{i,a} > 0$ and $T_{i,r} = T_i - T_{i,a}$. The marginal effect of teacher absence writes:

$$\frac{\delta Y_{i,T_i}}{\delta T_{i,a}} = -\alpha[\underbrace{q_r(T_i - T_{i,a})}_{(a)} + \underbrace{\frac{\delta q_r(T_i - T_{i,a})}{\delta T_{i,a}}(T_i - T_{i,a})}_{(b)}] + \underbrace{\gamma}_{(c)} \tag{8}$$

Each term of this equation can be interpreted as follows:

- Term (a): The more productive the regular teacher is, the greater the output loss from her absence
- Term (b): It can be interpreted as the disruptive effect of the regular teacher absence. It is the additional student-specific human capital that teacher r would have acquired during her absence. Intuitively, teacher r absence give her less time to know her students and also creates discontinuities in her long-term instructional strategy.
- Term (c): This is the variation in student output caused directly by the fact that students do not have class during teacher r absence. Its sign can depend on the quality of the regular teacher and on whether the absence was expected. For ex-

ample, if the absence was expected and the regular teacher is forward-looking, she can give them extra homework: they have material to study during her absence, which can mitigate the negative impact of her absence. The sign of this term can also depend on the quality of the school environment outside the classroom. More precisely, it can depend on the amount and the quality of adult supervision outside the classroom, in the school and its premises. For example, if students are left without sufficient adult supervision during the hours teacher r is absent, they can adopt negative non-cognitive behavior (bullying, fighting, smoking drugs etc.), which can exacerbate the negative impact of teacher absence (Burdick-Will, 2013; Lacoe, 2013). The quality of the school environment depends on the quality of the school principal, and on the number and quality of hall monitors.

Overall, in case 1, the marginal effect of teacher absence will be negative unless $\gamma > \alpha[q_r(T_i - T_{i,a}) + \frac{\delta q_r(T_i - T_{i,a})}{\delta T_{i,a}}(T_i - T_{i,a})]$, i.e. unless students use their lost instruction hours so efficiently that these hours are more productive than the instruction hours they would have had with their missing regular teacher.

Case 2. It corresponds to $T_{i,s} > 0$, $T_{i,a} = 0$ and $T_{i,r} = T_i - T_{i,s}$. The marginal effect of teacher absence writes:

$$\frac{\delta Y_{i,T_i}}{\delta T_{i,s}} = -\alpha[\underbrace{q_r(T_i - T_{i,s})}_{(d)} + \underbrace{\frac{\delta q_r(T_i - T_{i,s})}{\delta T_{i,s}}(T_i - T_{i,s})}_{(e)}] + \beta[\underbrace{q_s(T_{i,s})}_{(f)} + \underbrace{T_{i,s}\frac{\delta q_s(T_{i,s})}{\delta T_{i,s}}}_{(g)}] \quad (9)$$

The terms (d) and (e) have similar interpretations as (a) and (b) in case 1, the other terms can be interpreted as follows:

- Term (f): The more productive the substitute teacher, the smaller the negative effect of teacher r absence
- Term (g): This is the additional student-specific human capital acquired by the substitute teacher.

Overall, in case 2, the marginal effect of teacher absence will be negative if and only if:

$$\alpha[q_r(T_i - T_{i,s}) + \frac{\delta q_r(T_i - T_{i,s})}{\delta T_{i,s}}(T_i - T_{i,s})] > \beta[q_s(T_{i,s}) + T_{i,s}\frac{\delta q_s(T_{i,s})}{\delta T_{i,s}}] \quad (10)$$

In particular, equation (10) will be verified when the regular teacher is of higher quality than the substitute teacher ($q_r > q_s$) and/or when the regular teacher acquire student-specific human capital faster than the substitute teacher ($\delta q_r/\delta T_{i,r} > \delta q_s/\delta T_{i,s}$).

B Additional Tables and Figures

Table B1 – Performance at the Certification Exam of the Contract Teachers who take it

	Contract Teachers Candidates		**Other Candidates**	
	Agreg.	CAPES	Agreg.	CAPES
A. Demographics				
Age (in years)	37.72	35.17	31.05	28.18
	(7.75)	(7.68)	(8.32)	(6.65)
Male	0.53	0.39	0.46	0.35
	(0.50)	(0.48)	(0.49)	(0.48)
B. Performance				
Passing Rate	0.03	0.16	0.15	0.33
	(0.18)	(0.37)	(0.36)	(0.47)
Written Part Grade (/20)	3.91	5.67	6.25	7.30
	(2.52)	(3.14)	(3.61)	(3.69)
Oral Part Grade (/20)	7.00	7.30	8.09	8.50
	(3.78)	(4.17)	(3.83)	(4.58)
Nb of obs	286	1,232	8,037	11,779

Note: Standard deviation in parenthesis. On average, the passing rate of contract teachers at the CAPES examination is 16 %. The average passing rate of other candidates is 33 %.

Table B2 – Regression Estimates of the Relationship between Absence/Replacement and Teacher Characteristics

	# Abs. Days		Share Replaced Days		Share Replaced x Contr.		Share Replaced x Tenured Sub.	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Experience (Ref: 6 + years)								
One year or less of experience	-4.976***	-4.099	-0.043***	-0.056***	-0.012**	-0.014	-0.031***	-0.045***
	(1.255)	(2.479)	(0.008)	(0.016)	(0.005)	(0.009)	(0.006)	(0.011)
Two years of experience	-4.854***	-5.415***	-0.026***	-0.0382***	-0.008**	-0.017***	-0.018***	-0.020**
	(0.613)	(1.061)	(0.005)	(0.008)	(0.002)	(0.005)	(0.004)	(0.007)
Three years of experience	-3.475***	-4.059***	-0.019***	-0.025***	-0.005*	-0.011***	-0.013***	-0.0138**
	(0.455)	(0.658)	(0.004)	(0.006)	(0.002)	(0.003)	(0.003)	(0.005)
Four years of experience	-1.706***	-2.711***	-0.006*	-0.012**	-0.000	-0.006*	-0.006*	-0.007
	(0.377)	(0.532)	(0.003)	(0.004)	(0.002)	(0.003)	(0.002)	(0.004)
Five years of experience	0.637	-0.681	0.008**	0.000	0.007***	0.000	0.001	0.000
	(0.350)	(0.449)	(0.002)	(0.003)	(0.001)	(0.002)	(0.002)	(0.003)
Seniority (Ref.: 6 + years)								
One year of seniority	5.320	22.930	0.498**	0.649**	0.332	0.294	0.167	0.356
	(10.26)	(13.150)	(0.210)	(0.257)	(0.200)	(0.263)	(0.177)	(0.319)
Two years of seniority	3.084***	0.004	0.018***	0.004	0.007***	-0.002	0.012***	0.006*
	(0.268)	(0.437)	(0.001)	(0.003)	(0.001)	(0.002)	(0.001)	(0.003)
Three years of seniority	1.545***	1.001**	0.012***	0.0111***	0.005***	0.002	0.008***	0.009***
	(0.223)	(0.365)	(0.00171)	(0.002)	(0.000)	(0.001)	(0.001)	(0.002)
Four years of seniority	1.368***	1.112***	0.011***	0.0101***	0.005***	0.002	0.006***	0.007***
	(0.222)	(0.315)	(0.001)	(0.002)	(0.000)	(0.001)	(0.001)	(0.002)
Five years of seniority	0.695***	0.374	0.007***	0.004**	0.004***	0.001	0.003***	0.003
	(0.205)	(0.275)	(0.001)	(0.002)	(0.000)	(0.001)	(0.001)	(0.001)
Evaluations								
Classrom Obs. Eval.	-0.266***	0.0115	-0.001***	0.000	-0.000	-0.000	-0.000	0.000
	(0.0170)	(0.0371)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
School Principal Eval.	-0.532***	-0.222***	-0.004***	-0.002***	-0.001***	-0.000	-0.003***	-0.002**
	(0.065)	(0.075)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Student Composition								
Prop. of financial aid students	-0.492*	0.901*	-0.007***	0.002	0.003***	0.001	-0.009***	0.001
	(0.339)	(0.530)	(0.002)	(0.006)	(0.001)	(0.002)	(0.001)	(0.005)
Gender								
Male	-4.688***		-0.029***		-0.013***		-0.017***	
	(0.124)		(0.000)		(0.000)		(0.000)	
Certification Level (Ref: Capes)								
Agrégation	0.383		0.003		0.002*		0.001	
	(0.219)		(0.002)		(0.000)		(0.001)	
Teaching subject (Ref.: History)								
French	0.855***		-0.002*		0.002***		-0.003***	
	(0.158)		(0.001)		(0.0005)		(0.002)	
Math	-0.851***		-0.002**		0.007***		-0.010***	
	(0.144)		(0.001)		(0.000)		(0.000)	
Teacher - school fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Nb. of obs.	282,001	282,001	282,001	282,001	282,001	282,001	282,001	282,001

* Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. All regressions include year fixed effects. Robust standard errors clustered by teacher-school.

Note: With teacher-school fixed effects, the relationship between the share of financial aid students assigned to a teacher and her share of replaced absent days is negative and statistically significant at the 1 % level.

Table B4 – Impact of Absence and Replacement by Type of Absence (Maternity leave vs. others) on Student Test Scores

N = 32,290,084	# Days of Abs.	# Replaced Days x Tenured Sub.	# Replaced Days x Contract. Sub.
in % of a SD	(1)	(2)	(3)
Maternity Leave	-0.036***	0.015***	0.002
	(0.007)	(0.008)	(0.009)
	[53.67]	[21.67]	[12.14]
Non Maternity Leave	-0.056***	0.021***	-0.060*
(same length)	(0.007)	(0.008)	(0.030)
	[49.30]	[16.69]	[8.42]

Note: Estimates corresponds to a single regression with the preferred specification. Results are reported in percentage of a standard deviation of student test scores.

Table B3 – Robustness Effect of Teacher Absence Spells During Holidays on Student Test Scores in 9th Grade

in % of a SD	(1)	(2)
# days of holiday absence	0.029	0.027
	(0.035)	(0.024)
Teacher-School Fixed effect	No	Yes
Teacher experience & seniority*	No	Yes
Student background**	No	Yes
Number of observations	32,290,084	32,290,084

* Quadratic function of teacher experience and of teacher seniority. ** Student background: parents' occupation and financial aid status. Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. All regressions include year x subject fixed effects. Robust standard errors clustered by school.

Table B5 – Robustness Check: Placebo Test of the Effect of Absence and Replaced Days of "Other subject" Teacher on Student Test Scores in 9th Grade

	Math Exam		French Exam		History Exam	
	(1)	(2)	(3)	(4)	(5)	(6)
A. Math Teacher						
# Days of Absence	-0.081***	-0.078***	-0.00	0.004	-0.009	-0.002
	(0.009)	(0.009)	(0.00)	(0.009)	(0.010)	(0.010)
# Replaced Days	0.001		-0.00		0.000	
	(0.001)		(0.00)		(0.000)	
# Replaced Days x Tenured Sub.		0.007		-0.007		-0.002
		(0.011)		(0.010)		(0.011)
# Replaced Days x Contract Sub.		-0.012		-0.004		0.003
		(0.011)		(0.010)		(0.011)
Math Teacher - School Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
B. French Teacher						
(with French Teacher -school fixed effects)						
# Days of Absence	-0.011	-0.007	-0.044***	-0.035***	-0.020	-0.016
	(0.007)	(0.007)	(0.007)	(0.005)	(0.013)	(0.10)
# Replaced Days	-0.002		0.013		0.013	
	(0.009)		(0.009)		(0.009)	
# Replaced Days x Tenured Sub.		0.004		0.016**		0.017
		(0.008)		(0.008)		(0.010)
# Replaced Days x Contract Sub.		-0.012		-0.005		0.007
		(0.010)		(0.010)		(0.010
French Teacher - School Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
C.History Teacher						
# Days of Absence	-0.004	-0.000	-0.005	-.001	-0.038***	- 0.035***
	(0.099)	(0.010)	(0.009)	(0.010)	(0.010)	(0.011)
# Replaced Days	-0.013		-0.003		0.013	
	(0.011)		(0.011)		(0.012)	
# Replaced Days x Tenured Sub.		-0.014		-0.001		0.013
		(0.011)		(0.011)		(0.013)
# Replaced Days x Contract Sub.		-0.025		-0.013		-0.002
		(0.020)		(0.011)		(0.014)
History Teacher - School Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Each column corresponds to a single regression. The dependent variable is student test scores in 9th grade. All regressions include subject fixed effects, year fixed effects, subject x year fixed effects. Robust standard errors clustered by school.
Notes: With the Math exam test scores as the dependent variable (panel A, columns 1 to 6)

Table B6 – Robustness Check: Placebo Test of the Effect of Absence and Replaced Days of Previous and Following Year on Student Test Scores in 9th Grade

	Previous year		Following year	
	(1)	(2)	(3)	(4)
# Days of Absence	0.004	0.003	0.002	0.000
	(0.019)	(0.020)	(0.013)	(0.013)
# Replaced Days	0.015		0.004	
	(0.023)		(0.018)	
# Replaced Days x Tenured Sub.		0.023		0.003
		(0.027)		(0.020)
# Replaced Days x Contract Sub.		0.008		0.018
		(0.029)		(0.027)
Teacher - school fixed effect	No	No	Yes	Yes
Teacher experience & seniority*	Yes	Yes	Yes	Yes
Classroom Fixed Effect	Yes	Yes	Yes	Yes
Number of observations	31,643,528	31,643,528	31,643,528	31,643,528

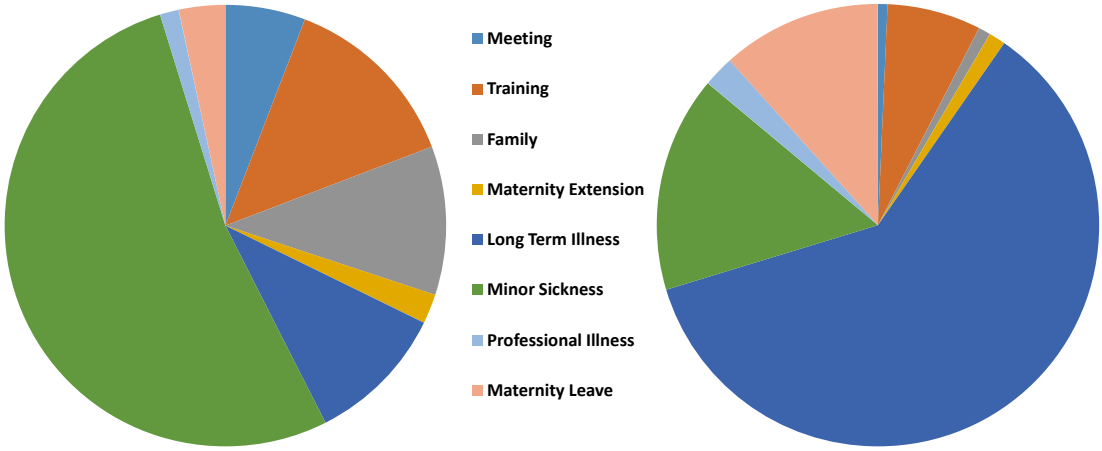
* Quadratic function of teacher experience and of teacher seniority. ** Student background: parents' occupation and financial aid status. Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. The level of observation is teacher/topic x student x year. All regressions include year x subject fixed effects. Robust standard errors clustered by teacher-school. Robust standard errors clustered by school.

Notes: In columns 1 and 2, the number of days of absence, number of replaced days and number of replaced days with the two types of substitute teachers of the previous year are used as independent variables. Column 1 shows that the marginal impact of one additional day of absence and replacement of the teacher in the year $n-1$ does not have any statistically significant impact on her student test scores, assigned to her during the year n.

Figure B1 – Distribution of Absence Spells and Days per Type of Absence

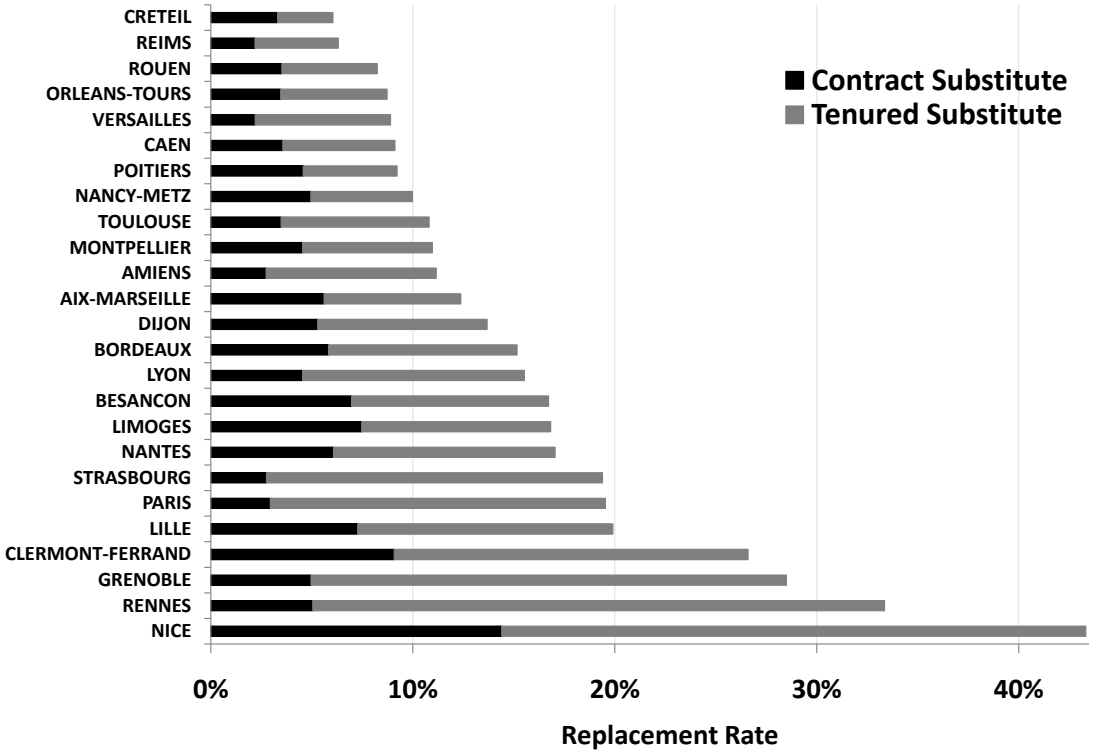
(a) Distribution of the Number of Absence Spells per Type of Absence

(b) Distribution of the Number of Absence Days per Type of Absence



Notes: Figure B1a plots the distribution of the number of absence spells (2006-2015) per type of absence. Absence spells for minor sickness account for 50 % of absence spells. Maternity leaves account for 3 % of absence spells. Figure B1b plots the distribution of the number of absence days per type of absence. Absences for minor sickness account for 16 % of the total of absence days per year. Maternity leaves account for 12 % of the total of absence days per year.

Figure B2 – Replacement Rate per Region



Notes: In the Creteil region (Eastern Parisian suburb), 6% of absence spells are replaced in 2015. 45 % of replacement spells are made by tenured substitute teachers in the Creteil region in 2015. In the Nice region (French Riviera), 44 % of absence spells are replaced in 2015. 70 % of replacement spells are made by tenured substitute teachers in the Nice region.

C Data Construction

Table C7 – Main Datasets

Name	Observation level	Period covered
OCC	teacher x assignment spell	2001 - 2015
CONG	teacher x absence spell	2001 - 2015
RELAIS	teacher x class x year	2004-2015
FAERE	student x year	2006-2015

The OCC and CONG datasets are raw administrative datasets which are not previously cleaned by the Statistical Department of the Ministry of Education. I do not use the cleaned version of these datasets because they are not exhaustive:

1. The cleaned version of the OCC datasets does not include all teacher assignment spells but only the assignment spells which are ongoing at the time of the extraction by the Statistical Department (in December of each year). This is highly problematic for the purpose of this study because I need to observe all teacher assignments through the school year in order to know, for each absence spell, whether a substitute teacher has been assigned, and the identity of this substitute teacher.

2. The cleaned version of the CONG datasets does not include all teacher absence spells but only absence for heath reasons: minor sickness, maternity leave, long term illness and professional illness. This is highly problematic because, as shown in figure B1b, non health related absences (meetings, training, family) represent around 30 % of absence spells.

C.1 Merging Procedures

1. Merge between data on absence spells (CONG) and data on teacher assignment spells (OCC). Matching variables: dates of assignment spells, dates of absence

spells, regional teacher identification number, regional identification number. The dates variables give the exact day, month and year.

Table C8 – Description of the Merge between the Dataset on Teacher Assignments and the Dataset on Absence Spells

School Year	Nb of obs – OCC	Nb of obs – CONG	Matching Rate
2001	1,138,588	2,642,820	100 %
2002	1,208,334	2,752,949	100 %
2003	1,249,347	2,678,823	100 %
2004	1,237,848	2,827,934	100 %
2005	1,295,957	2,858,053	100 %
2006	1,961,504	2,778,671	100 %
2007	1,194,925	2,806,209	100 %
2008	1,376,532	1,376,532	100 %
2009	1,405,110	2,607,199	100 %
2010	1,387,348	2,667,126	100 %
2011	1,390,155	2,617,673	100 %
2012	1,343,316	2,481,001	100 %
2013	1,331,228	2,444,893	100 %
2014	1,324,245	2,418,418	100 %
2015	1,307,329	2,445,823	100 %

2. Merge between the obtained dataset and the dataset on teacher assignment spells (OCC) to match each teacher absence spells to its substitute teacher. Matching variables: dates of the assignment spells, dates of the absence spells, assignment identification number, school identification number:

   - match on the dates: the assignment spell of the substitute teacher must be included in the absence spell of the absence teacher

     match on the assignment identification number and school identification number: each position held by a teacher has an identification number, the assignment number. For example, "Math teacher #4 " is an assignment. It is not school-specific and must be combined with the school identification number to identify a single assignment, e.g. "Math teacher #4 in school #154 ". When a substitute teacher is assigned, she is given the same assignment number/school identification number as the absent teacher. Therefore, substitution spells are assignment spells which are included in the absent teacher assignment spell.