Examining the relationship between school autonomy and student performance based on PISA : implications of teacher characteristics and institutional accountability

Shin, Yura

UNIVERSITÉ DE GENÈVE
FACULTÉ DE PSYCHOLOGIE ET DES SCIENCES DE L'ÉDUCATION

EXAMINING THE RELATIONSHIP BETWEEN SCHOOL AUTONOMY AND STUDENT PERFORMANCE BASED ON PISA: IMPLICATIONS OF TEACHER CHARACTERISTICS AND INSTITUTIONAL ACCOUNTABILITY

MEMOIRE REALISÉ EN VUE DE L'OBTENTION DE LA MAÎTRISE EN SCIENCES DE L'ÉDUCATION - ORIENTATION ANALYSE ET INTERVENTION DANS LES SYSTÈMES ÉDUCATIFS

PAR

YURA SHIN

DIRECTEUR DU MEMOIRE
GEORGIES FELOUZIS

JURY
ISABEL VOIROL-RUBIDO
SAMUEL CHARMILLOT

GENÈVE DECEMBRE 2014

UNIVERSITÉ DE GENÈVE
FACULTÉ DE PSYCHOLOGIE ET DES SCIENCES DE L'ÉDUCATION
SECTION SCIENCES DE L'ÉDUCATION

Abstract

Decentralization in education systems has been a central issue in recent education reforms, but prior evidence that supports the educational benefits of decentralization remains equivocal. This study investigates how the role of school autonomy on student performance may vary by a country's development level, teacher characteristics, and accountability. It analyzes a cross-country dataset obtained from the international PISA 2012 test that encompasses 64 countries. It examines two different areas of autonomy (autonomy over curriculum and assessment, and autonomy over resource allocation) and introduces interaction terms with the variables to measure how the effect of autonomy on student performance is affected by other elements in the system. The findings of this study suggest that school autonomy over curriculum and assessment has a positive role on student performance, while autonomy over budget and personnel is not clearly related to student outcomes. The results also show that countries with higher levels of development have higher student achievement benefits in relation to autonomy. Also, the more teachers participate in professional development, the more countries gain from offering schools autonomy. Finally, the accountability settings of an education system do not significantly affect the impact autonomy has on student performance.

Table of Contents

1. Introduction

Decentralization in education systems has been a major issue in recent education reforms around the world (Bjork, 2006; Hanushek et al., 2011; Namukasa and Buye, 2007; Radó, 2010; Zajda, 2014). Many education systems have been altered from having a centralized decision-making regime to a decentralized scheme by transferring responsibilities to local authorities and individual schools in pursuit of obtaining better quality education on the premise that individual schools have better knowledge about their students' needs and effective ways to allocate resources and to elaborate the curriculum (Hanushek et al., 2011). Although some existing studies indicate that school autonomy has positive impacts on student performance, the relationships between school autonomy and student performance may vary among and within countries (OECD, 2013). Also, school autonomy interacts with other factors within systems, such as accountability arrangements and local capabilities (OECD, 2013). Indeed, in examining the relationships between school autonomy and student performance, previous studies often focus on institutional variables, such as school accountability and choice (Schuetz et al., 2007; OECD, 2013; Woessman et al., 2009), a country's GDP per capita (Hanushek, Link, and Woessmann, 2011), and the quality of the institution (Hong, 2014). However, there may be more education-specific elements that affect autonomy's impact on education outcomes such as teacher aspects and school policies on curriculum and evaluation. The expertise of school personnel especially determines local capacity for decision-making, and their competency is a crucial dimension in the success of increased local autonomy. School policies on student evaluation, curriculum and use of assessment are important as they both monitor and give incentives to local decision-makers. However, few studies have examined such education-specific variables in investigating the effects of increased autonomy on student performance.

This study focuses on the effects of school autonomy on student performance. By introducing variables of teacher characteristics and accountability arrangements, this paper investigates the heterogeneity of autonomy's impact on academic outcomes . This paper introduces the 2012 Program for International Student Achievement

(PISA) dataset – a study assessing students' competencies in reading, mathematics, and science – covering 64 economies[1]. Analysis includes the effects of autonomy in different areas of decision-making, by country's GDP per capita, by teacher characteristics and accountability. Interaction terms among these variables are introduced. The following section gives an introduction of preceding literatures about autonomy, teacher characteristics and accountability. Section 3 presents the methodology and data used in this study and develops empirical models. Section 4 describes estimation results, and Section 5 discusses the implications of the findings. Section 6 concludes this study.

2. Literature Review

2.1. School autonomy and student performance

The term "school autonomy" is understood in multiple ways (Hanushek et al., 2011). Eskeland and Filmer (2007), for example, define school autonomy as "the extent to which the school itself may choose inputs" (p. 106). Arcia et al. (2011) define it as "a form of school management in which schools are given decision-making authority over their operations, including the hiring and firing of personnel, and the assessment of teachers and pedagogical practices" (p. 2). This study uses the definition of Arcia et al. (2011) of school autonomy, and investigates schools' decision-making authority in areas of curriculum, assessment and resource allocation.

A number of factors affect student performance from the classroom settings to the national education system. For instance, many studies suggest school resources as the main determinants of student performance. They indicate that school resources such as expenditure per student (Sander, 1993; Papke, 2005), pupil-teacher ratio (Card and Krueger, 1996; Eide and Showalter, 1998; Duflo et al., 2007), and smaller

[1] Among the 65 economies that participated PISA 2012, Cyprus was excluded as sample in this study due to the lack of background data.

[2] Plausible values are multiple estimates of each individual student that allow group-level estimates of

class size (Hanushek, 1999; Hoxby, 2000) improve student performance. While it is reasonable to argue that more resources lead to better student performance, an increasing number of studies focus on the institutional settings that influence student performance such as decentralized decision-making (Woessmann, 2003; Hanushek and Woessmann, 2011), employment of external exams (Bishop and Woessmann, 2004), and parental choice of schools (Rouse, 1998). Especially, research in education governance suggests that greater autonomy can lead to better school performance (see Hoxby, 1999). Studies on recent education reforms illustrate positive impacts of school autonomy on education quality. Clark (2009), for example, examines the recent British education reform that has allowed public high schools to have greater autonomy over school operations and to receive direct funding from the government. He suggests that schools that opted out of local authority and converted to autonomy had significant gains in achievement. He points out that these schools were required to follow some instructions by the central government as a condition for being offered autonomy in the operation of schools. Woessmann (2003) examines school autonomy by looking at different areas that require decision-making such as budgeting, purchasing supplies, hiring teachers, and paying salaries. According to his regression results, school autonomy in process and personnel decisions is positively related to student performance.

The major argument favoring decentralization is that local decision-makers have better understandings of the capacities of their schools and the demands of students, which allows them to better allocate and use resources (Hanushek, Link, and Woessmann, 2011). However, some studies argue that greater local autonomy is not always positively related to better academic performance. For example, if local decision-makers have weak technical capabilities or lack the status and ability to voice their preferences, local autonomy can undermine the quality of public services including education (Galiani, Gertler, and Schargrodsky, 2008). Woessmann (2005) also points out that autonomy opens the possibility of opportunistic behaviors of agents given divergent and conflicting interests: that is, the principal and/or teachers act towards their own self-interest (e.g., corruption and misuse of funds to benefit individuals). In these cases, greater autonomy could be detrimental to students'

achievement. Therefore, the impact of giving schools discretion in their management may need to be externally audited to ensure accountability.

Many studies of cross-sectional research on international student exams analyze the relationship between school autonomy and student performance. Woessmann et al. (2003), Hanushek, Link and Woessmann (2011), and Hong (2014) examine PISA data in their studies, while Woessmann (2003) investigates Trends in International Mathematics and Science Study (TIMSS). Woessmann (2003) investigates factors that influence the difference in student performance among the 39 participating countries; he considers independent variables such as family backgrounds (e.g. education level of parents and time spent on reading books), school resources (e.g. class size and instruction time), and institutions (e.g. existence of central exams and school autonomy). The study suggests that these independent variables are strongly related to student outcomes (Woessmann, 2003).

This research looks at PISA 2012 results to examine the difference in performance of participating countries with focused attention on school autonomy as well as other relevant variables such as teacher characteristics and accountability devices. To do so, it is useful above all to identify the findings and implications of the OECD about the PISA results. OECD's analysis of PISA discusses how students' achievement on the test is linked to school autonomy. According to OECD's (2009) report, countries that provide more autonomy to schools in formulating school budgets and allocating expenditures within schools had higher student achievement, even after controlling other school factors (e.g., teacher characteristics and school locations) as well as demographic and socio-economic factors (parents' status and income). On the other hand, students in countries that grant more autonomy to schools in academic matters such as choosing textbooks and courses offered are seen to perform better than students in countries that chose centralized decision-making processes in academic areas, but the effect did not appear to be significant after accounting for other school and external factors. At the country level, education systems with a greater number of schools that have autonomy in deciding and elaborating their curricula and assessment methods tend to perform better than systems with a smaller number of schools that enjoy autonomy in such decision-making areas.

Autonomy in resource allocation did not show a clear relationship with student performance. In some countries students in schools with resource allocation autonomy performed highly while in other countries the effect was adverse. This contrasting relationship appears to be closely related to accountability arrangements. In countries where the majority of schools make their achievement data public, the relationship between student performance and school resource allocation autonomy appears to be positive. In short, both autonomy and accountability can influence student outcomes.

Other than these studies conducted by OECD, recent studies examine other variables in determining the relationship between school autonomy and student performance. Bishop and Woessmann (2004) explain the impact of school autonomy in different areas of decision-making on student performance. According to their study, the effect of school autonomy on controlling schooling quality is negative; that is, the decisions on quality standard are better made by the central authority (Bishop and Woessmann, 2004). This is because when standard and control decisions are centralized, they serve to monitor schools' actions and prevent them from misusing resources. School autonomy in other areas such as hiring teachers and selecting textbooks is favorable to academic outcomes because principals and teachers often have better understandings than the administration of the specific needs and characteristics of their students. That is, they can select teachers and textbooks that best fit with their student body.

Bishop and Woessmann (2004) also argue that teachers' control of their teaching methods, their inspection of students' performance, and competition with other schools increase academic achievement because they increase the political priority given to schooling quality and limit the scope for resource allocation. On the contrary, they suggest that teachers' decision-making power on their salaries and workload is detrimental to students' performance because it leads to lowering the priority given to learning quality in the political process. Bishop and Woessmann (2004) also suggest that external accountability is instrumental in better student achievement. They suggest this is because central examination increases the external rewards of learning and makes educational outcomes more transparent and

observable, which simplifies the monitoring of the performance of schools, teachers, and students.

Hanushek, Link, and Woessmann (2011) analyze the impact of local schools' autonomy in relation to student achievement at the level of national institutions. In their study, datasets from the four series of PISA tests, which took place in 2000, 2003, 2006, and 2009 in 42 countries, are examined with school system variables, such as school autonomy over decision-making on academic contents, budget formulation, and personal management. They also investigate how local autonomy in these areas is related to the achievement of students, depending on the level of national GDPs. Their findings suggest that local autonomy is conducive to higher student performance in high-income countries, but detrimental to student performance in countries with low levels of economic development.

Following the above-stated research, Hong (2014) investigates how institutional quality of the government (e.g., level of democracy, governance effectiveness, and control of corruption) affects student achievement. She examines these factors in relation to other school system factors including school autonomy and student achievement. She suggests that regardless of the level of institution, granting the local school system authority to make decisions on academic matters is advantageous to improve student performance. As the level of democracy and effective governance increases, giving schools autonomy over formulation and allocation of budget is more positively related to student performance.

2.2. Teachers' influence on school autonomy and student performance

Teachers are often considered one of the most important determinants of school quality (Borman and Kimball, 2005; Rivkin, Hanushek and Kain, 2005). However, existing research does not show a systematic link between teacher characteristics and student outcomes: there exist a number of factors to take into consideration in determining teacher quality (Hanushek & Rivkin, 2004, 2006). In many studies, teacher credentials, teaching experience, and salaries are often considered variables

that define teacher characteristics. In the context of the United States, Hanushek and Rivkin (2006) investigate the impacts of teacher characteristics on student achievement by examining measurable variables such as teacher education, certification, years of teaching experiences, and salaries. They point out the positive impact of teachers' professional experience on better student achievement, while having a Master's degree was not significantly related to better student performance. Akiba et al. (2007) conducted cross-national analysis on teacher quality and student performance on TIMSS and suggest that better teacher quality produced higher achievement in mathematics. They used measurable teacher characteristics such as full teaching certification, mathematics and/or education university degrees, and three or more years of teaching experience.

Bishop and Woessmann (2004) suggest that teachers' influence on autonomy depends on their specific areas of decision-making. For instance, teachers' decision-making power in purchasing supplies or selecting textbooks has positive impacts on student performance because teachers tend to have a better understanding of their students than other stakeholders and there does not exist much leeway to make this decision in their own interest to the detriment of students (Bishop and Woessmann, 2004). On the contrary, an increase in teachers' decision-making power over their salaries and workload may be detrimental to student performance because they would be interested in increasing their salaries and decreasing their workload, which could act against student achievement (Bishop and Woessmann, 2004). Some studies suggest that teachers' decision-making power may increase when they act collectively. According to the research of Hoxby (1999) and Bishop and Woessmann (2004), teacher unions have a powerful ability to organize themselves as an interest group and become a strong bargaining power, thus they exert considerable impact on the process of political decision-making. The main interests of teacher unions are to increase their salaries and to decrease their workload, and this impacts educational resource allocation, altering the political priority from education quality to teachers' own interests. In this sense, both studies of Hoxby and Bishop and Woessmann suggest that allocating decision-making power to teacher unions will have a negative effect on education quality. On the other hand, OECD (2011) discusses the case of Finland as an example of the importance of teachers' roles in

successful national education reform. The Finnish education system requires teachers to be capable of using professional discretion and judgment to manage their classroom and grants them greater autonomy over teaching and working conditions compared to their peers elsewhere. This is an attractive factor in the teaching profession and may be closely related to school performance.

As seen in the above example of Finland, teachers' role in education operation seems to be positively associated with student performance. *Knowledge and Skills for Life: First Results from PISA 2000* (OECD, 2001) addresses the fact that students in schools where the teachers play an active role in management perform better. Specifically, teachers' participation in decision of course content appears to be positively related to students' reading literacy. In this regard, not only teachers' education level and professional development characteristics, but also their participation in school management may be closely related to the link between school autonomy and student performance.

Recent literature suggests favorable effects of increased school autonomy on student outcomes in general, but there has been little research on teachers' role in relation to school autonomy and student performance. Marks et al. (1997), for example, suggest that teacher empowerment affects student performance indirectly through school organization. Given that teachers are the main agent realizing the autonomy given to schools – by choosing courses, curriculum, and textbooks– they play an important role in utilizing autonomy to produce better student learning.

2.3. Accountability and school autonomy

As Bishop and Woessmann (2004) suggest, an increase in school autonomy may encourage principals and teachers to act opportunistically for their own benefits (e.g., increasing their salaries and/or reduce their workload), unless their decisions are fully monitored and educational goals are adequately evaluated. In this sense, accountability devices may prevent principals and teachers from acting opportunistically for their own interests. According to Arcia et al. (2011), school

accountability refers to school management accountability such as compliance with rules and regulations of school governance and reporting to those with oversight authority. Woessmann et al. (2007) use the term of accountability to refer to all devices that attach consequences to measured school achievement. They suggest three components of accountability systems: achievement standards, measurement of student achievement, and consequences of measured achievement. So these may include student evaluation by external exams, publishing achievement data, using assessment data for students' retention/promotion or comparing it with other schools in the region or the nation. Among these different devices of accountability, existing cross-national research has focused on external exams and suggests their significant interactions with autonomy (Woessmann, 2005; Fuchs and Woessmann, 2005, 2007; Hanushek, Link and Woessmann, 2011). The results from these studies suggest that school autonomy is more beneficial when the system uses external exams. External exams refer to examinations in which an authority external to the school has the exclusive responsibility, or gives final approval, over the content of examinations (Woessmann et al, 2007).

Woessmann (2005), in his cross-national research based on TIMSS, TIMSS-Repeat and PISA, identifies that introducing accountability even turns negative effects of autonomy into positive effects. For example, he points out that school autonomy over deciding teacher salaries has a negative effect on student performance when a system doesn't use external exams, but, in systems with external exams, the effect is reversed. He suggests also that in decision-making areas such as deciding course content and resource funding, external exams turn a negative effect of autonomy into a positive effect. Therefore, he argues that school autonomy is more beneficial when external exams are used.

Woessmann et al. (2007) investigate 2003 PISA data to examine whether students perform better in education systems with institutional measures such as school autonomy, accountability, and choice. They find that various forms of such institutional settings combine to improve students' academic outcomes. According to their study, "regular standardized testing is only beneficial where clear standards and goals are set by external exit exams" (p. 58). Hanushek, Link, and Woessmann's

(2011) study also suggests that the effect of introducing school autonomy is more positive in countries with an exit exam system.

At a national level, Ackeren et al. (2012) examine the impact of three state exit exam systems on student performance in Germany by comparing a state with a centralized exam regime, a state with a decentralized exam regime, and a state that has switched to a centralized exam regime. According to their study on student scores in mathematics, German, and biology, differing student performance in college-preparatory exams was only found in mathematics. Therefore, centrally designed tests and assessment criteria seem to have more positive effects on mathematics than in other subject areas. In this regard, Ackeren et al.'s (2012) study suggests that statewide exams have subject-specific rather than general effects. Some subjects with more open canons – such as German and biology– are better evaluated by locally designed exam that meet students' needs and interests.

3. Methodology

3.1. Data: PISA dataset

The 2012 PISA database contains data that allows this study to estimate the effects of autonomy in relation to teacher characteristics and accountability. The PISA study, conducted by OECD, is an international survey that tests the skills and knowledge of 15 year old students worldwide. PISA is a triennial program that has launched in 2000; the most recent assessment took place in 2012 when schools in 34 OECD countries and 31 other partner economies completed the exam. This study will rely on the database of the 2012 PISA results and analyze the international data in order to examine factors that affect the relationship between autonomy and performance level.

PISA aims to evaluate students' competencies by assessing literacy skills in reading, mathematics, and science. It is not directly linked to school curriculum but intends to

evaluate to what extent students at the end of compulsory education are prepared to meet real-life challenges and to participate in modern societies (OECD, 2013b). PISA can be used to assess the impact of educational policies and compare students' performance over time among countries that participate in the survey successively.

The PISA exam consists of a mixture of open-ended and multiple-choice questions organized into three subjects. Each subject is tested through a broad range of tasks with differing levels of difficulty. PISA tests representative samples of fifteen year old students from randomly selected schools in participating countries. Most countries implement a two-step sampling process: (1) drawing a stratified random sample of schools and (2) choosing 35 students to take the two-hour test in each school. The main focus of the 2012 PISA exam was mathematics. Approximately 70% of the testing time was assigned to this subject. Therefore, the current research uses math scores as an academic performance indicator. The test booklets given to students vary in their composition of questions and problems. PISA uses five plausible values[2] for each participating student and in each of the tested domains. In each round of surveys, PISA maps student performance in mathematics, science, and reading on a scale with an international mean score of 500 points and a standard deviation of 100 points across the OECD countries. The difference in mathematic test scores between 9th grade scores and 10th grade scores – which make up the largest share of 15-year old students – is approximately 22 test-score points, so this gives a rough idea of how much students learn during a year (Woessmann et al. 2009, p. 11).

In addition to the evaluation of the three subjects, the students and their school principals are also asked to fill out a variety of questionnaires regarding the students' backgrounds and schools' learning environments. This includes students' family backgrounds, their home environments, and school characteristics such as

[2] Plausible values are multiple estimates of each individual student that allow group-level estimates of their achievement. PISA adopts plausible values because the sample students do not take the total items but a subset of these items due to limitations in testing time and students' availability. In the case of PISA 2012, five plausible values were computed for each subject, indicating possible "true" values of the student's scores.

information about resources and teaching staff. The questionnaires about school environments provide a large part of the variables that will be used in this study, such as the level of autonomy level, teacher characteristics, and accountability arrangements at the school level. Details of these questionnaires will be introduced in the following sections.

3.2. Empirical model

In order to measure school autonomy's impact on student achievement in relation to teacher characteristics and accountability, this study will rely on variations in the school systems of 64 countries and economies. Student outcomes are, of course, affected by a number of other factors inside and outside of school, which also must be taken into account in order to determine the impact of autonomy, teacher characteristics, and accountability. For example, a school with high autonomy might have better student achievement compared to one with less autonomy, but this might be due to better material resources rather than the level of autonomy. Similarly, a school that uses standardized external evaluations might perform better than others because of the socioeconomic backgrounds of students. Therefore, this study will adopt the 'education production function' that controls differences in individual student, family, school, and country characteristics that influence student performance (Schuetz et al., 2007).

Existing studies that take an econometrical approach to education have adopted extended empirical models with different variables to examine the factors that affect student performance by applying the education production function approach. A basic educational production function represents student achievement (Edu) as a function of family inputs (F) and school inputs (S):

$$Edu = f(F,S) \quad (1)$$

In Hanushek's (1992) study, this function is formulated by taking account of family inputs including the size and structure of the family, the presence of a father, and the

amount of time that parents spend with the students; school inputs are formulated by taking account of teacher characteristics such as level of education, sex, and ethnicity. In his 2003 study, Hanushek (2003) extends this model by including the pupil-teacher ratio, academic backgrounds and experiences of teachers, and school's expenditure on education as school inputs. Woessmann's (2003) study formulates the function by considering instruction time and academic materials. Hanushek (2013) focuses on institutional factors and adds variations of school autonomy over different areas such as curriculum selection, budget formulation, and personnel hiring. Hong (2014) investigates the impact of school autonomy on student outcomes similarly to Hanushek but introduces more country-level institutional factors such as democracy, government effectiveness, and control of corruption. On the other hand, Woessmann et al. (2009) use a formula accounting for accountability, autonomy, and school choice and examine both student and country level of academic performance.

This study, using the education production function framework, takes the following equation:

$$P_c = C_c\alpha_1 + I_c\alpha_2 + T_c\alpha_3 + \mu_c + \varepsilon_c \quad (2)$$

Student performance P_c in country c represents the mathematics score in PISA 2012, which is regressed by accounting for several vectors. C_c is a vector of country factors that is determined by GDP per capita and public expenditure on education as % of GDP in this study. I_c is the vector of institutional characteristics, which is a combination of different measures of school autonomy and accountability. I use two variables to describe autonomy: "academic autonomy" that represents school's responsibility for curriculum and assessment and "resource autonomy" that represents school's responsibility for resource allocation. As for the variables of accountability, I include use of external examination, use of assessment to compare the school to district or nation schools, publishing achievement data publicly, and use of standardized mathematics curriculum. T_c represents teacher characteristics of the country, such as their overall academic level, professional development, monitoring of teachers by external authority, and the degree of teacher participation

and autonomy in their schools. Lastly, $\mu_c$represents country-specific fixed effects, and ε_c is the error term of this model.

While equation (2) investigates the direct effects of institutional and teacher characteristics on student performance, I introduce another model to examine an interaction between explanatory variables. Hanushek et al. (2011) suggests a model of estimation including an interaction term between autonomy and a country's development level and identifies that there exists a significant interaction between these two variables. In other words, autonomy plays a different role on student outcome depending on the level of a country's GDP. Therefore, this study assumes that there is an interaction between autonomy and country factors and includes another interaction term to represent this.

$$P_c = C_c\alpha_1 + I_c\alpha_2 + T_c\alpha_3 + (IAut_c \times C_c \times T_c)\alpha_4 + \mu_c + \varepsilon_c \quad (3)$$

$IAut$ denotes variables related to school autonomy among institutional variables; thus, these will be variables of academic autonomy and resource autonomy. In this model, I include an interaction term between autonomy, $IAut$, country factors, C, and teacher characteristics T, in order to allow this study to examine to what extent autonomy effects student performance interacting with the level of development of the country and with specific teacher characteristics. In other words, this model investigates autonomy's impact on math score in circumstances where country factors and teacher characteristics vary – in countrys' development levels, teachers' educational levels, degrees of participation in professional development, whether teachers are monitored by external persons and the degree of their participation and autonomy in school operations.

In addition to the above model that includes an interaction term between autonomy, country factors, and teacher characteristics, I use another equation to introduce an interaction term between different institutional variables – that is, between autonomy, country factors, and accountability settings.

$$P_c = C_c\alpha_1 + I_c\alpha_2 + T_c\alpha_3 + (IAut_c \times C_c \times IAcc_c)\alpha_5 + \mu_c + \varepsilon_c \quad (4)$$

$IAcc$ represents institutional variables that are related to accountability. It consists of the use of external examinations, the use of assessment to compare the school's performance to the level of region or nation, the use of accountability procedures by posting achievement data publicly, and the use of standardized mathematics curriculum in schools. By introducing and interaction term among autonomy($IAut$), country factors(C), and accountability($IAcc$), this model allows us to examine how autonomy impacts student performance depending on a country's development level and different accountability settings.

3.3. Measuring country factors

I include country factors in the empirical model in order to control the countries' institutional levels, especially GDP per capita and public expenditure on education, as I assume them to be determining factors of educational performance. Hanushek et al. (2011) and Hong (2014) also argue that a country's development level and quality of institutions have a significant effect on student performance when evaluating institutions' impacts on education quality. Data for 2012 GDP per capita is obtained from the World Bank in current US dollars. Data for 2012 public expenditure on education as percent of GDP is obtained from UNESCO Institute for Statistics.

3.4. Measuring school autonomy

School autonomy is the key variable in this study, which is investigated as it relates to teacher characteristics and accountability settings in order to estimate its impact on student performance. School autonomy or decentralized decision-making refers to the delegation of a task by schools. Therefore, measuring school autonomy in making decisions allows investigation of schools' independency from local or government authorities. PISA data on school backgrounds suggests two indices of school autonomy: 1) an index of school responsibility for curriculum and assessment

and 2) an index of school responsibility for resource allocation (Hanushek et al., 2011). The first category of school responsibility consists of schools' ability in establishing student disciplinary and assessment policies, approving students for admission to schools, choosing textbooks, determining course content, and deciding which courses are offered. The second covers schools' responsibilities for hiring and firing teachers, establishing and determining teachers' salaries, formulating school budgets, and deciding on budget allocations within schools. Each school principal that participated in the survey was asked to select which unit has responsibility over these types of decisions – either national or local/regional authority, the principal, teachers, or the school governing board. Responses indicating that these decisions are the responsibility of national and/or local/regional authority were recorded as 0, and responses indicating that they are the responsibility of the principal, teachers and/or the school governing board were coded as 1. Indices were created by aggregating these records in each participating country, and standardized with an average of 0 across OECD countries. Therefore, if the index is lower than 0 in a sample country, it implies that the given country gives less autonomy to its schools compared to the OECD average, and if it is higher than 0, it indicates that schools in the given country enjoy more autonomy compared to the average level of autonomy of OECD countries. The actual figures and ranges of this index are presented in the Appendix, in Table A.2, and the actual PISA questionnaire regarding school autonomy is presented in the Appendix in Figure A.1. In this study, the index of school responsibility for curriculum and assessment will be called "academic autonomy", while that of school responsibility for resource allocation is referred to as "resource autonomy".

3.5. Measuring teacher characteristics

Measuring teacher characteristics includes measurements of teachers' educational level, their professional development, whether they are monitored by external authorities, and the degree of teacher participation and autonomy in school management. Teachers' educational level and participation in professional development is obtained from PISA surveys at the school level. PISA background

questionnaires ask principals to provide information about their teaching staff, such as their qualifications, morale, and intentions. Given that PISA 2012 has a specific focus on mathematical literacy, a broad range of subjects on the schools' mathematics learning environment were investigated. This study uses mathematics teachers' education level as one of the variables to describe teacher characteristics. In the PISA survey, principals reported the proportion of mathematics teachers with an ISCED5A qualification[3] (equivalent to a bachelor's degree) with a major in mathematics in their school. The answers of the principals are aggregated at the country level to be used in cross-country analysis.

As for the professional development of teachers, in the PISA survey, principals reported the proportion of mathematics teachers who attended a formal program designed to enhance teaching skills or pedagogical practices within the past three months prior to the time the survey was completed. This is the second variable determining teacher characteristics, also computed as country averages. The PISA 2012 questionnaires regarding teacher qualifications and professional development are presented in Figure A.2 and in Figure A.3 of the Appendix.

The third variable in the category of teacher characteristics is monitoring of teachers by external authorities. To measure this variable, this study uses principals' responses to how mathematics teachers' practices are monitored in their school. Principals reported whether they used methods including tests or assessments of student achievement, teacher peer review, principal or senior staff observations of lessons, and observation of classes by inspectors or other persons external to the school. In this study, focus is on whether the schools had their mathematics classes observed by inspectors or other external persons to monitor the practice of teachers. The actual PISA 2012 questionnaire used for measuring this variable is presented in Figure A.4 in the Appendix.

[3] The new International Standard Classification of Education (ISCED) 2011 defines ISCED 5A as the tertiary-type A education, that is largely theory-based programs designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements, such as medicine, dentistry, or architecture. ISCED 5A duration is at least three years full-time, though four or more years is usual. Source: OECD, *Education at a glance 2013*, Reader's guide.

Lastly, teachers' participation and autonomy in school management represents the extent to which teachers participate in the operation of schools, in diverse areas such as teacher hiring and salaries, allocation of budget, choosing which courses to teach, and deciding which textbooks to use. Basically, the scope of these areas overlaps with those of school autonomy that were discussed earlier. Also, the degree of teacher participation and autonomy is measured in the same way as the level of school autonomy. That is, it is investigated through the data in the PISA background questionnaire about who has the main responsibility in different areas of decision-making in the school (see section 3.4). Based on the responses, those indicating that teachers have the main decision-making responsibility were coded as 1 and other responses were coded as 0, creating a specific index (Index of teacher participation and autonomy) by the OECD. This index was standardized with an average of 0 across the OECD countries to allow cross-national comparisons. Therefore, index scores above 0 indicate a relatively high degree of teacher participation and autonomy compared to the OECD average, while index scores below 0 indicate less participation and teacher autonomy in the sample country. Actual figures of this index are presented together with other variables of teacher characteristics in the Appendix in Table A.3.

3.6. Measuring accountability

Standardized examinations that have high-stakes consequences can serve as strong incentives for students to make more study efforts. For teachers, such evaluations can be used to structure their lessons and to compare the performance of their own students with those of other students. At the school level, student achievement results can be a guide for determining where to allocate resources and detecting students' needs. Also, achievement data can serve to inform the educational authorities to improve the education system and create better learning environments. However, standardized tests can yield negative effects by limiting school goals to merely passing a specific test, so called "teaching to the test" (Jensen et al., 2014). In order to avoid such adverse effects, evaluations are becoming more diverse in most OECD countries (OECD,

2013). Countries do not solely focus on student assessment but broaden the range of evaluations to schools, school leaders, and teachers. Student feedback is often used for these purposes, and all students and teaching staff are required to engage in evaluation exercises. In this regard, accountability arrangements in different education systems also vary, not only with student assessment but also with school and teacher assessment.

In this study, measurements of accountability include aspects of student evaluation, use of assessment, accountability procedures, and use of standardized curriculum. As mentioned in the previous section, Woessmann et al. (2007) suggest three components of accountability systems: achievement standards, measurement of student achievement, and consequences of measured achievement. Because the previous studies focused mostly on external exams to represent accountability, this study will examine other devices that consist of different components to investigate accountability in a broader sense. I use four variables to explain accountability: “use of external exam” to represent measurement of student achievement, “use of assessment to compare school to region/nation” and “post achievement data publicly” to represent consequences of measured achievement, and “use of standardized curriculum in math” to represent achievement standards. All of these four variables are measured from the answers to PISA background questionnaires given to participating schools.

Firstly for the use of external exams, I use the principals’ reports on which measures they use for quality assurance and improvement in their school. These include written specification of the school’s curricular profile and educational goals or that of student performance standards; systematic recording of data including teacher and student attendance and graduation rates; test results and professional development of teachers; internal or external examination, teacher mentoring, consultation with experts, and so forth. Among these measures, whether they have an external examination aimed at quality assurance will be used in this study in order to determine if the schools evaluate their students by standardized external tests.

Secondly, for the variable of use of assessment to compare school to region/nation, I use a questionnaire given to principals about various uses of assessment in their schools. Principals are requested to report on whether they use assessment in their schools for various purposes, including to inform parents about their child's progress; to make decisions about students' retention or promotion; to group students for instructional purposes; to compare their school to regional or national performance; to monitor the school's progress from year to year; to make judgments about teachers' effectiveness; to identify aspects of instruction or the curriculum that could be improved; and/or to compare the school with other schools. This study looks at the responses of principals about using student assessments to compare their school to regional or national performance and comparing their school with other schools, as these two purposes of student assessment indicate school's accountability system in light of external baselines of their students' performance.

Principals also report whether they use students' achievement data for accountability procedures, such as posting the data publicly or being tracked over time by an administrative authority. Responses indicating that they post achievement data publicly as an accountability procedure will be used as the third variable: "post achievement data publicly".

Lastly, regarding the use of standardized mathematics curriculum at the school, this study will use a background questionnaire given to the principals regarding their curricular settings concerning the subject of mathematics. In this questionnaire, principals are asked to tick the box "Yes" or "No" on three statements concerning the use of textbooks in the school, the use of computers and standardized mathematics curriculum. This study will use principals' report on whether the mathematics teachers in their school follow standardized curriculum that specifies content at least on a monthly basis. The data of accountability by country is presented in the Appendix in Table A.4, and specific PISA 2012 questionnaires for investigating the accountability settings of the participating schools are presented in Figure A.5, A.6, A.7 and A.8 of the Appendix.

3.7. Descriptive statistics

Table 1 summarizes descriptive statistics of variables used in the empirical model. It should be noted that this study is an analysis at the country level, and the PISA test scores of individual students are aggregated at the country level in order to conduct a cross-country analysis. Also note that the PISA scores of individual students are standardized with an average of 500 points and a standard deviation of 100 points across the OECD countries. However the descriptive statistics of Table 1 does not have the same figures, as this study examines other 31 economies in addition to the 34 OECD countries, and also because this study uses the country average instead of the individual students' scores.

Country factors include GDP per capita, presented in current US 1,000 dollars, and public expenditure on education as percentage of the GDP of the country.

For the two variables of autonomy, as explained in section 3.4, academic autonomy and resource autonomy are derived from two indices computed at the country level by OECD, with an average of 0 among the OECD countries. There are two indices of school responsibility that are used in the empirical model: "index of school responsibility for curriculum and assessment" for academic autonomy, which relates to decision-making areas such as disciplinary policies, assessment policies, textbook selection, course content, and courses offered in the school; and "index of school responsibility for resource allocation" for resource autonomy, which represents the degree of school autonomy over hiring and firing of teachers, teachers' starting salaries, salary increases, and budget formulation and allocation. [4] Since the index of school responsibility is standardized with an average of 0 among OECD countries, a negative sign in an index of school responsibility indicates that the given country has rather centralized policies in operation of schools compared to the OECD average, and a positive sign implies that the given country offers more autonomy to its schools than the OECD average.

[4] Besides these two indices, OECD also provides an index of school responsibility, which implies the degree of school responsibility in overall decision-making areas. Specific data of this index is presented in Table A.2 in the Appendix.

As for teacher characteristics, there are four variables that are used in the empirical models. First, “Teacher education level” represents a measurement of the proportion of math teachers in schools with ISCED5A math majors. The figures at the country level are the mean of school-level responses for the entire country. Second, “Professional development” is measured by the percentage of math teachers who attended a formal program aimed at professional development for teaching mathematics, also aggregated at the country level from school-level responses. Next, “Teacher monitoring” regards the methods of teacher monitoring in schools, and affirmative answers about whether the teachers are monitored by external authorities. Therefore, the three above-mentioned variables’ scores range from 0 to 1. Lastly, “Teacher participation/autonomy” represents the index of teacher participation and autonomy computed by OECD, as explained in section 3.5. This ranges from negative signs to positive signs, as the index is computed by standardization with an average of 0 among all OECD countries.

For the variables that describe accountability, all four variables are computed by recoding principals’ responses about schools’ accountability settings, as explained in section 3.6. In these questionnaires, principals reported “Yes” or “No” regarding various ways of quality assurance, use of assessment, accountability procedures, and use of standardized curriculum in mathematics. I take the percentage of schools whose principal responded “Yes” about the related questionnaires in the total number of participating schools in the country. For example, in Switzerland, regarding a question about whether schools use a standardized mathematics curriculum, 226 schools ticked “Yes” out of 384 schools, so the value of this variable is 0.698, which represent the proportion of schools that gave an affirmative answer about that question among the whole participating schools. In this sense, the four variables for accountability range from 0 to 1; the higher the number is, the more schools there are in the country that use specific accountability devices.

Table 1 Descriptive statistics of the international dataset

	Mean	Std. Dev.	Min	Max
Student performance				
PISA 2012 mathematics score	473.853	55.730	368.103	612.676
Country Factors				
GDP per capita ($ 1.000)	31.732	27.981	1.755	134.617
Public expenditure on education (% of GDP)	4.976	1.450	1.907	8.740
Autonomy				
Academic autonomy	-0.153	0.599	-1.151	1.139
Resource autonomy	-0.023	0.523	-0.719	1.579
Teacher characteristics				
Teacher education level	0.585	0.250	0.012	0.982
Professional development	0.418	0.157	0.167	0.882
Teacher monitoring by external authority	0.394	0.253	0.018	0.969
Teacher participation/autonomy	-0.082	0.665	-1.644	1.973
Accountability				
External exam	0.681	0.202	0.060	0.975
Assessment used to compare school to region/nation	0.635	0.217	0.154	0.958
Achievement data published publicly	0.398	0.252	0.032	0.889
Standardized curriculum	0.840	0.156	0.303	0.988

Notes:

Samples: 64 countries. Among the 65 countries and economies that participated in PISA 2012, Cyprus was excluded due to lack of background data.

Table 2 shows the correlation between all the variables that were used in the empirical models. “Math score” means PISA 2012 mathematics score; “Expenditure on education” is public expenditure on education as a percentage of GDP per capita of the country; “Academic autonomy” stands for the PISA Index of school responsibility for curriculum and assessment; “Resource autonomy” represents the PISA index of school responsibility for resource allocation. In the same way as in Table 1, “Teacher education level” means the proportion of teachers with ISCED5A math majors; “Professional development” stands for the proportion of math teachers

who attended a formal program designed to enhance teaching skills or pedagogical practices during the three months before the PISA test; “Teacher monitoring” is calculated by the proportion of positive responses to whether teachers are monitored by external authorities; and “Teacher participation/autonomy” means the PISA Index of teacher participation and autonomy. “External exam” represents the proportion of schools that use external exams for quality assurance in the country; “Compare school to region/nation” is calculated by the positive responses to whether schools use assessment data to compare their school’s achievement to that of the regional and/or national level; “Post achievement data” is the proportion of schools that post achievement data publicly as an accountability procedure in the country; and “Standardized curriculum” means the proportion of schools that use a standardized curriculum in mathematics within the country.

Table 2 Correlation between explanatory variables

	Math score	GDP per capita	Expenditure on education	Academic autonomy	Resource autonomy	Teacher education level	Professional development
Math score	1						
GDP per capita	0.433***	1					
Expenditure on education	0.016	-0.028	1				
Academic autonomy	0.369***	0.11	0.098	1			
Resource autonomy	0.138	0.126	0.018	0.599**	1		
Teacher education level	0.17	-0.148	-0.012	0.027	0.034	1	
Professional development	0.102	0.053	0.061	-0.006	-0.03	0.205	1
Teacher monitoring	-0.254**	-0.165	-0.270**	-.169	-0.056	0.067	0.182
Teacher participation/ autonomy	0.363***	0.252	0.109	0.669	0.505	0.08	0.18

External exam	0.087	-0.051	-0.133	0.192	0.165	0.082	0.269**
Compare school to region/nation	-0.153	-0.144	0.142	-0.080	0.075	0.200	0.231*
Post achievement data	-0.038	-0.169	0.171	0.090	0.216*	0.188	0.076
Standardized curriculum	-0.179	-0.406***	-0.274**	-0.046	-0.062	-0.128	0.113

	Teacher monitoring by external authority	Teacher participation/ autonomy	External exam	Compare school to region/nation	Post achievement data	Standardized curriculum
Teacher monitoring by external authority	1					
Teacher participation/ autonomy	-0.325***	1				
External exam	0.291**	0.087	1			
Compare school to region/nation	0.188	0.073	0.557***	1		
Post achievement data	0.027	0.051	0.347	0.645***	1	
Standardized curriculum	0.120	-0.211*	0.289	0.191	0.15	1

Notes:

"Math score": PISA 2012 mathematics score, aggregated at the country level; "Expenditure on education": Public expenditure on education as percentage of GDP per capita of the country; "Academic autonomy": PISA Index of school responsibility for curriculum and assessment, aggregated at the country level; "Resource autonomy": PISA index of school responsibility for resource allocation, aggregated at the country level; "Teacher education level": Proportion of teachers with ISCED5A with math major in the school, aggregated at the country level; "Professional development": Proportion of math teachers who attended a formal program designed to enhance teaching skills or pedagogical practices during the past three months before the PISA test, aggregated at the country level; "Teacher monitoring by external authority": Proportions of schools that responded their mathematics teachers' practice is observed by inspectors or other persons external to the school; "Teacher participation/autonomy": PISA Index of teacher participation and autonomy; "External exam": Proportion of schools that use external exam for quality assurance in the country; "Compare school to region/nation": Proportion of schools that responded they use assessment to compare the school to the district or the nation; "Post achievement data": Proportion of schools that post achievement data publicly as an accountability procedure in the country; "Standardized curriculum": Proportion of schools that use a standardized curriculum in mathematics. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

4. Results

4.1. Estimation results of the basic model

First, I investigate how school autonomy affects student performance both when considered alone and when country factors are added to the estimation. Table 3 shows the effect of academic autonomy on student achievement in mathematics. Column 1 represents estimation results without controlling for country factors, while column (2) reports the results when autonomy, GDP per capita, and expenditure on education were included. Academic autonomy appears to have a significantly positive association with math performance both in column (1) and (2). Therefore, schools' higher responsibility for making academic decisions leads to better student performance in mathematics. Table 2 supports this fact by showing a significant correlation between math scores and academic autonomy.

On the other hand, Table 4 shows the effect of resource autonomy on student achievement in mathematics. Column (3) reports regression results of resource autonomy alone, and column (4) shows those of resource autonomy when country factors were controlled. Resource autonomy also has a positive sign, but its coefficient is not significant. Therefore, the tables identify that academic autonomy has positive effects on math scores, while resource autonomy does not.

As for the country factors, GDP per capita and expenditure on education were examined. As explained in section 3.3, I include the country factors in the empirical models in order to take account of a country's level of development in estimating the effects of institutional settings and teacher characteristics on the country's academic performance. GDP per capita is positively significant both when estimated with academic autonomy and with resource autonomy. This is also supported by Table 2, as the correlation between GDP per capita and math performance is positive and significant. On the other hand, public expenditure on education does not show a significant effect on education performance in the estimation results.

Although the effect of GDP per capita has a correlation with math scores, a country's development level does not solely determine the quality of education systems in the country. The characteristics of educational institutions, school operation, and teacher-related matters also have a great impact on the quality of the educational environment in each country. That is why this study aims to examine teacher characteristics and accountability settings together with school autonomy while controlling for development level and budget on education of sample countries.

Table 3 Effect of academic autonomy on student performance

	Country factors non-included (1)	Country factors included (2)
Academic autonomy	20.558** (6.579)	18.244** (6.281)
GDP per capita		22.144*** (6.253)
Expenditure on Education		-0.231 (6.246)
R^2	0.136	0.292

Notes:

Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

Table 4 Effect of resource autonomy on student performance

	Country factors non-included (3)	Country factors included (4)
Resource autonomy	7.823	4.812
	(7.065)	(6.734)
GDP per capita		23.582***
		(6.735)
Expenditure on Education		1.571
		(6.682)
R^2	0.020	0.196
Countries	64	64

Notes:

Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

Table 5 reports how teacher characteristics affect student performance in math. The four columns report estimation results of teacher characteristics: teachers' education level; their participation in professional development; monitoring of teachers by external authorities; and teacher participation in school operation, with and without other variables controlled. In column (1), when other variables are not controlled for, most teacher characteristics show positive signs except teacher monitoring. Teacher participation/autonomy has a positive and significant effect on math score in this column. That is, when teachers have a higher degree of autonomy in school operation and participate more in the school's decision-making processes, it has a positive effect on student performance. It is also seen in Table 2 that the correlation between teacher autonomy and math score is significant and positive. However, column (1) does not include country factors or autonomy variables, and the effect becomes insignificant when country factor and autonomy are introduced.

Column (2) includes GDP per capita and expenditure on education in the estimation, and teacher education level has a positive and significant coefficient. That is, the higher overall education level of math teachers, the better students perform in mathematics. This is constant when taking academic autonomy into account in the estimation. Column (3) reports the results when academic autonomy is included in

the model. The effect of academic autonomy on student performance in math is positively significant together with teacher education level. That is, this model explains, students perform better in mathematics where schools have more autonomy in academic decisions and where teachers have higher academic qualifications. Column (4) on the other hand represents results when resource autonomy is estimated with teacher characteristics. Teacher education level, which is significant and a positive variable in column (2) and (3), is insignificant in this model. Resource autonomy, unlike academic autonomy in column (3), does not have significant effects on student performance.

It is noticeable that monitoring of teachers has negative sign in all columns of Table 5. It is assumed that student performance in math decreases with the frequency of monitoring of math teachers by external authorities during class. Although the coefficient is not statistically significant, Table 2 supports the negative effect of teacher monitoring, where it shows a negative and significant correlation between teacher monitoring and math scores. Teacher participation and autonomy also shows a positive and strong effect on student performance, although insignificant. Teacher professional development has a minor and insignificant effect, especially compared to their academic level. This implies that a teacher's academic level plays a much more important role in student outcomes than attending professional development programs.

Table 5 Effect of teacher characteristics on student performance

	Country factors and autonomy non-included (1)	Country factors included (2)	Academic autonomy included (3)	Resource autonomy included (4)
Teacher education level	7.859	11.576*	12.547*	0.670
	(6.672)	(6.500)	(6.400)	(6.805)
Professional development	4.415	2.700	4.754	3.470
	(6.940)	(6.698)	(6.673)	(6.946)
Teacher monitoring by external authority	-9.520	-6.270	-8.919	-6.911
	(7.117)	(7.256)	(7.274)	(7.423)
Teacher participation/autonomy	17.757**	11.298	-3.963	10.960
	(7.203)	(7.128)	(11.145)	(8.610)
GDP per capita		20.719***	22.783***	19.858***
		(6.598)	(6.577)	(6.705)
Expenditure on education		-0.553	-2.229	0.015
		(6.628)	(6.570)	(6.707)
Academic autonomy			18.061*	
			(10.270)	
Resource autonomy				-0.260
				(7.636)
R^2	0.205	0.298	0.338	0.284
Countries	64	64	64	64

Notes:

Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Control variables include GDP per capita and public expenditure on education. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

Table 6 shows effects of accountability on math score. This estimation aims to examine the effect of different accountability devices on student performance. The four columns represent regressions results of accountability: use of external exam for quality assurance; use of assessment data to compare school's performance to the regional and/or the national level; publishing achievement data publicly as a procedure of accountability; and use of standardized curriculum in mathematics, with and without controlling for other variables.

In column (1), when no country factors or autonomy variables are included, the effect of external exams on math scores is positively significant. The coefficient slightly decreases in other columns but is still significant in columns (2) and (4) when country factors and resource autonomy are controlled. This identifies that using externally standardized examination for assuring education quality has a positive effect on student performance when country's development level and resource academy are considered to take roles together on math score. On the other hand, column (1) reports that standardized math curriculum has a negative and significant effect on student performance. However, this effect becomes insignificant when other variables are introduced.

Column (2) reports the effects of accountability when country factors are controlled. Using assessment to compare schools to the region/nation has significance with a negative sign. This implies that using assessment to compare the school to the regional and/or national achievement level decreases student performance in mathematics. This result contradicts the case of external exams, and it might imply that using student assessment for the purpose of comparing school performance to the regional or national average degrades academic outcomes by neglecting specific needs and learning processes of students in the school, while using external exam helps the school focus on specific learning goals.

In column (3), when accountability variables are estimated with academic autonomy, none of the variables of accountability show significant effects. However, academic autonomy appears to be positively associated with math scores in this model, as it was in Table 3.

Publishing achievement data publicly shows a positive sign in column (1), although it is not significant. Moreover in other columns, when taking account of autonomy variables, the coefficient greatly decreases, even turning negative when included with academic autonomy in column (2).

Table 6 Effect of accountability on student performance

	Country factors and autonomy non-included (1)	Country factors included (2)	Academic autonomy included (3)	Resource autonomy included (4)
External exam	17.290**	15.797*	10.035	14.714*
	(8.426)	(8.287)	(8.659)	(8.368)
Assessment used to compare school to region/nation	-20.168	-18.861*	-12.378	-20.623*
	(10.072)	(9.709)	(10.095)	(9.869)
Achievement data published publicly	6.686	10.245	-6.513	0.348
	(8.927)	(8.499)	(8.539)	(7.599)
Standardized curriculum	-12.124*	-0.583	-0.335	2.212
	(7.134)	(7.598)	(7.427)	(6.817)
GDP per capita		22.696***	21.604***	21.597***
		(7.134)	(6.997)	(7.159)
Expenditure on education		4.496	2.162	1.955
		(7.135)	(7. 082)	(6.743)
Academic autonomy			13.043*	
			(6.934)	
Resource autonomy				2.212
				(6.817)
R^2	0.117	0.256	0.302	0.260
Countries	64	64	64	64

Notes:

Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

Table 7 identifies the effects of all explanatory variables of autonomy, teacher characteristics, and accountability before and after taking account of a country's GDP per capita and expenditure on education. The levels of association differ from the previously presented results, in which categories of variables were examined separately. The basic model of this study presumes that education achievement is a function of country factors, institutions, and teacher characteristics; therefore putting all explanatory variables together in a single estimation permits identifying the result of the basic model.

The table identifies that the two autonomy variables have contradicting effects on math score. Academic autonomy has a significantly positive association with student performance in math when taking country factors into consideration. On the other hand, resource autonomy exhibits a negative association, although it is not statistically significant. Therefore, the basic model explains that where schools have more responsibility in areas of curriculum and assessment, students tend to perform better. However, higher responsibility in allocating school resources does not lead to a significant change in student achievement in mathematics.

Of all the teacher characteristics, only teacher education level has a significant coefficient in this estimation and only when country factors are included. The proportion of mathematics teachers with ISCED5A seems to have a strong effect on students' math scores when considered with the country's GDP per capita and public education expenditure. On the other hand, the variable of teachers' participation in professional development programs exhibits a positive correlation but is not significant. Therefore, it can be derived that education level of teachers has a stronger effect on student performance in math than teachers' professional development.

As for the variables of accountability, using assessment data to compare a school to the regional/national level has a negative effect on student achievement in math. The coefficient is significant when included with country factors in column (2). As previously discussed, it might be that using assessment for the sake of comparing

school performance to the national level does not contribute to student learning. The effect of external exams is also high and positive but is not significant.

Lastly, among the two country factors in column (2), GDP per capita appears to be highly and positively associated with student math scores. On the contrary, the effect of expenditure on education is minor and not statistically significant.

Table 7 Effect of all explanatory variables in the same estimation

		Country factors non-included (1)	Country factors included (2)
Autonomy	Academic autonomy	15.600	20.445*
		(11.879)	(11.620)
	Resource autonomy	-4.432	-6.507
		(8.690)	(8.500)
Teacher characteristics	Teacher education level	6.737	13.564*
		(7.084)	(7.226)
	Professional development	8.289	4.588
		(7.459)	(7.322)
	Teacher monitoring by external	-14.948	-10.977
		(7.692)	(7.749)
	Teacher participation/autonomy	-.081	-7.714
		(12.005)	(11.736)
Accountability	External exam	13.593	13.696
		(9.120)	(9.138)
	Assessment used to compare school to region/nation	-17.037	-18.712*
		(10.673)	(10.716)
	Achievement data published	1.740	5.110
		(8.762)	(8.588)
	Standardized curriculum	-8.726	1.927
		(7.108)	(7.991)
Country factors	GDP per capita		23.734***
			(7.623)

	Expenditure on education		1.865 (7.489)
R^2		0.287	0.381
Countries		64	64

Notes:
Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

4.2. Estimation results of the extended models with interaction terms

In this section, I use extended models that include interaction terms between the explanatory variables. While the basic model identified direct effects of variables in each category, the extended models examine how different variables interact with each other and contribute to indirect effects on student performance in math. The main purpose of using extended models is to investigate how a country's level of development and education-specific factors – such as teachers and institutions in this study – influence the degree of school autonomy's impact on student performance. As explained in section 3.2, the extended models examine interactions between 1) autonomy, country factors, and teacher characteristics; and 2) autonomy, country factors, and accountability. Among the two country factors (GDP per capita and expenditure on education), I use only the variable of GDP per capita in the extended model, as the variable of expenditure on education was proved to have no significant effect in the basic model.

4.2.1. Interaction between autonomy, GDP per capita and teacher characteristics

Table 8 represents regression results of the relationship between academic autonomy and teacher characteristic, including an interaction term between autonomy, GDP per capita, and four teacher characteristics. The interaction between academic autonomy and GDP per capita is significant and positive. That is, the

higher a country's GDP level is, the higher and more positive the impact of autonomy is on education performance. Professional development of teachers also has a significant and positive interaction with academic autonomy and GDP per capita. This explains that teachers' participation in professional development contributes to increasing the positive effect of academic autonomy on student performance, together with country's GDP.

Table 8 Interaction between academic autonomy, GDP per capita and teacher characteristics

Academic autonomy	9.914
	(9.829)
Academic autonomy x GDP per capita	14.385**
	(6.808)
Teacher education level	10.366
	(10.385)
Academic autonomy x GDP per capita x Teacher education level	-2.461
	(6.670)
Professional development	8.168
	(6.204)
Academic autonomy x GDP per capita x Professional development	16.721**
	(8.094)
Teacher monitoring by external authority	-9.455
	(6.668)
Academic autonomy x GDP per capita x Teacher monitoring by external authority	2.197
	(7.673)
Teacher participation/autonomy	10.366
	(10.385)
Academic autonomy x GDP per capita x Teacher participation/autonomy	-8.942
	(9.268)
R^2	0.510
Countries	64

Notes:

Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Control variables include GDP per capita. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

Table 9 identifies the effects of resource autonomy on math performance in interaction with GDP per capita and teacher characteristics. In the first row, resource autonomy shows a negative sign, unlike academic autonomy in Table 8, although the effect is insignificant. Resource autonomy does not show a significant relationship with math scores in the correlation matrix, Table 2, and has a negative sign in Table 5, when included with teacher characteristics. Therefore, in contradiction to academic autonomy, resource autonomy does not contribute to higher academic performance and even has a negative sign in certain estimations. Interaction of resource academy with GDP per capita has a positive sign but is insignificant.

Professional development of teachers is positively and significantly associated with student math scores in this model. Therefore, math teachers participation in programs designed to develop professional skills improves students' performance in math. Its effect is also positive and significant in interaction with resource autonomy and GDP per capita. That is, as in Table 8, professional development increases the positive effect of academic autonomy on student performance together with GDP per capita. The difference between the effect of professional development in Table 8 and that of Table 9 is that: in Table 8, the effect of professional development is significant in interaction with academic autonomy and GDP per capita, so its impact on student performance is indirect; in Table 9, professional development is positively associated with student performance both directly and indirectly by taking channels of resource autonomy and GDP per capita.

Teacher participation and autonomy has a coefficient that is positive and significant. That is, the more teachers participate in the school's operations and the more autonomy they have in decision-making processes of their schools, the better the students tend to perform in math. This is also seen in the correlation matrix, Table 2, and regression analysis between teacher characteristics with math scores, Table 5. However, in Table 9, the positive effect of teacher participation/autonomy becomes insignificant when it interacts with resource autonomy and GDP per capita.

Table 9 Interaction between resource autonomy, GDP per capita and teacher characteristics

Resource autonomy	-10.655
	(7.931)
Resource autonomy x GDP per capita	3.305
	(9.361)
Teacher education level	7.869
	(6.533)
Resource autonomy x GDP per capita x Teacher education level	-7.830
	(7.245)
Professional development	11.775*
	(6.904)
Resource autonomy x GDP per capita x Professional development	17.356*
	(9.432)
Teacher monitoring by external authority	-9.046
	(6.801)
Resource autonomy x GDP per capita x Teacher monitoring by external authority	12.428
	(7.589)
Teacher participation/autonomy	20.084**
	(8.005)
Resource autonomy x GDP per capita x Teacher participation/autonomy	-6.469
	(11.888)
R^2	0.448
Countries	64

Notes:

Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Control variables include GDP per capita. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

4.2.2. Interaction between autonomy, GDP per capita and accountability

Table 10 reports the regression results of academic autonomy and accountability in interaction with GDP per capita and with a dependent variable of math score. Academic autonomy has a strong and positive impact on student math performance in this model. When introducing an interaction term with GDP per capita, it is still significant and positive, although the effect is not as large as the direct effect of academic autonomy. This explains that, with other variables of interaction terms controlled, academic autonomy positively relates to student scores in math, but this association is stronger in countries with higher GDP than in those with lower GDP levels. The interactions between academic autonomy, GDP per capita, and accountability are not significant though, which contrasts to the case of teacher characteristics.

Table 11 identifies the effects of resource autonomy and accountability on student performance by introducing interaction terms between those two variables and and GDP per capita. External exams have a positive and significant effect on math scores in this model, while the effect of using assessment to compare a school to regional/national averages is negatively significant. However, when entered with interaction terms for resource autonomy and GDP per capita, it has no significant effect on student performance. This explains that external have a direct effect on math scores, but this effect does not combine with autonomy and GDP per capita and gives an indirect effect on math score. As for the variable of using assessment to compare a school to the regional/national average, it has a negative and direct effect on student performance when controlled for other variables, but likewise, its effect does not significantly meet with variables of resource autonomy and GDP per capita and gives an indirect effect on math achievement.

Table 10 Interaction between academic autonomy, GDP per capita and accountability

Academic autonomy	21.638***
	(7.079)
Academic autonomy x GDP per capita	13.345*
	(7.569)
External exam	7.847
	(8.362)
External exam x Academic autonomy x GDP per capita	1.545
	(8.473)
Assessment used to compare school to region/nation	-14.409
	(10.843)
Assessment used to compare school to region/nation x Academic autonomy x GDP per capita	13.840
	(9.963)
Achievement data published publicly	5.515
	(8.353)
Achievement data published publicly x Academic autonomy x GDP per capita	-2.976
	(8.829)
Standardized curriculum	-0.940
	(7.049)
Standardized curriculum x Academic autonomy x GDP per capita	5.641
	(8.566)
R^2	0.405
Countries	64

Notes:
Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Control variables include GDP per capita. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

Table 11 Interaction between resource autonomy, GDP per capita and accountability

Resource autonomy	2.347
	(8.916)
Resource autonomy x GDP per capita	2.347
	(8.916)
External exam	14.933*
	(8.772)
External exam x Resource autonomy x GDP per capita	10.259
	(9.141)
Compare school to region/nation	-18.786*
	(10.097)
Compare school to region/nation x Resource autonomy x GDP per capita	-17.112
	(16.515)
Publish achievement data	6.558
	(9.091)
Publish achievement data x Resource autonomy x GDP per capita	11.025
	(11.411)
Standardized curriculum	-3.230
	(7.974)
Standardized curriculum x Resource autonomy x GDP per capita	5.409
	(13.551)
R^2	0.285
Countries	64

Notes:
Dependent variable: PISA 2012 mathematics score. Least-square regressions. Robust standard errors in parentheses. Control variables include GDP per capita. Significance level: *** 1 per cent, ** 5 per cent, * 10 per cent.

5. Discussion

5.1. Basic findings

The estimation results in the previous section identified the complex relationship between explanatory variables and student performance in math. Country's development level, school autonomy, teacher characteristics, and accountability settings are associated with student outcomes to different degrees, and some of them interact with each other creating indirect effects on student math scores. Among the various variables, some that I assumed would affect students' math achievement had insignificant effects, while interaction terms that I supposed would be significant had minor effects or were insignificant. Nevertheless, the results from the empirical models in this study support the assumption that the effects of autonomy on student performance depend on several factors.

The results of this study imply that a country's GDP per capita has a strong and positive impact on student math scores. This effect remained constant when autonomy, teacher characteristics, and accountability were controlled. Countries with higher level of development are more likely to have better educational infrastructures and resources, so this is understandable. On the other hand, public expenditure on education as per GDP per capita does not have a significant effect on student performance. This might be because resources invested in education go through many channels that are country specific and also depend on the quality of educational institutions and policies.

The findings about the direct effects of autonomy on student performance appear differently in the two categories of school autonomy. Between academic autonomy and resource autonomy, only the former shows a significant relationship with student performance in math. That is, the more schools have responsibility for deciding academic matters, the higher the students tend to perform in math. This is found in the positive and significant correlation between math scores and academic autonomy and in the regression results when country factors, teacher

characteristics, and accountability variables are controlled for. On the other hand, the effect of resource autonomy on math scores is not found to be significant. The primary logic favoring autonomy is that local decision-makers have better understandings of the capacities and the demands of students and that this knowledge permits them to better allocate the resources and improve productivity (Hanushek, Link, and Woessmann, 2011). In this regard, it makes sense that having higher autonomy in deciding curricula and assessment leads to better student performance. Teachers know the specific needs and characters of their students, which is likely to help students learn better. However, in the area of resource allocation, higher autonomy can open a leeway for principals and teachers to act in their own interest, for example by focusing on raising their salaries or reducing their workload (Bishop and Woessmann, 2004). This helps explain the mixed results in the relationship between the two areas of autonomy and student performance. However, the heterogeneous effects of autonomy are also due to other factors that affect student performance. The PISA 2012 report identifies that the effect of autonomy in resource allocation is less clear than autonomy over academic decisions and that the exact effect depends on the accountability settings of the country (OECD, 2012). On the other hand, Hanushek, Link and Woessmann (2011) suggest that autonomy's impact on student performance varies depending on the development level of a country. The results of this study also identify the positive interaction between autonomy and GDP per capita but only in autonomy over academic decisions.

In short, school autonomy over course contents, textbook, and assessment benefits student performance in math. But this effect varies depending on the level of GDP of a country; countries with higher level of development benefit more from school autonomy than countries with lower development level. However, autonomy over personnel and budget allocation is not significantly related to student performance, nor does it have a significant interaction with GDP per capita.

5.2. Implications of teacher characteristics

As previously noted, the heterogeneous effect of school autonomy is partly due to the involvement of other factors such as the development level or institutional quality of a country. With this in mind, this study aimed to find out other factors than those relating to a country's economic and social institutions that interact with school autonomy, which are more education-specific. In this regard, introducing teacher characteristics to the education production model added a new angle to existing research.

The results of this study identified a positive link between teacher education level and student performance when controlled for country factors and for academic autonomy. That is, the higher the proportion of math teachers with ISCED5A certification and/or math majors in the country, the better the students perform in math. This is in line with the findings of Akiba et al. (2007), who suggest that teachers' education level, major in math and teaching experience are positively related to student score in TIMSS. However, the interaction of teacher education level with autonomy and GDP per capita was not significant. So, having more teachers with higher academic training influences student performance in a positive way but does not significantly change the relationship between autonomy and academic results.

Professional development of teachers has a significant interaction with autonomy. While professional development has an insignificant effect on student math scores by itself, its interaction with both academic and resource autonomy appears to be positive and significant. The results also imply that the more teachers participate in professional development and the higher the level of country income is, the more benefits the schools can get from autonomy. The importance of teacher professional development on student learning has been argued in previous studies (Jackson and Bruegmann, 2009; Avalos, 2011; and Schleicher, 2012), but the interaction between teachers' professional development and school autonomy has not yet been investigated. The positive interaction between these two might be due to the efforts by schools or policies of the central authority to keep teachers competent enough to

make important decisions in school as a condition for giving them more autonomy and discretion in school management. For teachers to be capable to decide academic matters, design assessment tools, and engage in allocating school resources, they should regularly evaluate their professional competency and knowledge in these areas. In this sense, teachers' professional development can have a significant effect on the impact of school autonomy on student performance. The data used in this study only measures the mathematics teachers' attendance in professional development programs with a focus on mathematics, but OECD is expanding its measurement in this area (e.g. *OECD Teaching and Learning International Survey*). When more data on teacher development – rate of participation, types of development programs, whether it is a requirement for teachers and whether they are free or charge, etc. – from more countries is collected and available, it will allow a closer look at the relationship between teacher development and autonomy.

It was identified that teacher monitoring has a negative and significant effect on student achievement. This might be because when teachers are observed by inspectors or persons external to their school, they focus on other administrative routines than the lesson itself. For example, if an inspector visits a school on a regular basis to monitor the school's teaching practices, the teachers are often required to prepare reports on their school activities, submit lesson plans, make sure that the school is clean, and organize the visit of the inspector. Also, teachers might try to show selective aspects that are beneficial to their evaluation during observation of their class – by encouraging good students to answer and discouraging unexpected behaviors from students. Therefore, these might explain the negative relationship between teacher monitoring by external authorities and academic achievement.

Lastly, the degree of teacher participation and autonomy in school operations appears to be positively related to student performance when country factors and resource autonomy are controlled for. As introduced with the example from Finland in Section 2.2, teachers' discretion in managing classroom and autonomy over their working and teaching conditions has a positive impact on student performance

(OECD, 2011). Marks et al. (1997) also suggest that teacher empowerment affects student performance indirectly through school organization. Bishop and Woessmann (2004) on the other hand, argue that teachers' decision-making power can have different influences on student performance depending the areas of decision-making. The data I use to describe teacher participation and autonomy does not imply specific areas of decision-making unlike school autonomy indices, so it would be useful for future research to focus on this to more closely investigate the relationship between teachers' decision-making power in different areas and student achievement.

In short, among the four variables of teacher characteristics, education level of teachers has a positive effect, but does not influence autonomy's effects on student performance. Teacher monitoring by external authorities is detrimental to student performance, while teachers' participation and degree of autonomy in their schools management is beneficial to better student outcomes. Lastly, teachers' participation in professional development has a significant and positive interaction with autonomy and GDP per capita and increases the benefits of autonomy on student performance.

5.3. Implications of accountability

Prior research has addressed a positive link between school autonomy and accountability (Bishop and Woessmann, 2004; Woessmann 2005, Fuchs and Woessmann 2007; Woessmann et al. 2007; Hanushek, Link and Woessmann, 2011). While these studies mainly focused on the use of external exams among various accountability devices, this study introduced other accountability devices in addition to external exams – using assessment to compare a school to regional/national averages, posting achievement data publicly, and using standardized curriculum in math – to find out other factors that play a role in the effects of autonomy on student performance.

The estimation results identify a positive effect of external exams on student performance. Its effect is significant when country factors and resource autonomy are controlled for. Theoretically, setting clear standards and providing information regarding the results can give incentives to students and inspire superior performance (Woessmann et al, 2007), so higher student achievement in systems with external exams makes sense. Although in the extended models, the interaction of external exams with autonomy and GDP was not significant. Therefore, this study did not demonstrate that school autonomy is beneficial in systems with external exams, unlike previous studies. It is noticeable though that using external exams has positive and significant correlations with the variables using assessment to compare a school to regional/national average, teacher professional development, and teacher monitoring by external authorities. Therefore, it seems that systems with external exams are more likely to use other accountability devices and assure teacher quality through professional development and monitoring.

Using assessment data to compare a school to the region and/or the nation average is negatively associated with student performance. Its interaction with autonomy and GDP per capita was not significant but had a negative sign. This contradicts the findings of Woessmann et al. (2007) that this specific form of accountability has a positive interaction with school autonomy, especially in the areas of formulating budget and hiring teachers. The conflicting findings might be explained by evolving education policies in many countries, especially with decentralization in education systems and hiring of new accountability devices. In addition, given that decentralization in education is based on the logic that local decision makers, teachers, and principals better know the specific needs of students, using assessment for comparing school's average score to the national level does not cater for individual learning needs, nor does it provide great incentives to the student to put more effort into performing better. However, further studies are needed to better investigate the effect of using assessment data to compare a school to the regional/national average and its relationship to autonomy and student performance.

Posting achievement data publicly has a positive sign, but its effect were insignificant on student performance. In the case of using standardized mathematics curriculum,

it had a negatively significant effect on student achievement in math when no other variables were controlled for and had a negative relationship with GDP per capita and public expenditure on education. Neither of these two accountability variables showed a significant interaction with autonomy. Similarly to the use of assessment to compare a school to the regional/national average, using a standardized curriculum in math might not contribute to individuals learning better when people have different needs and abilities. However, further research would be helpful to understand this relationship better.

In summary, the results of the estimations including accountability variables identify that external exams have a positive link with student performance in math, but no significant interaction was found with autonomy. Comparing schools' achievement data to regional and/or national averages seems to be detrimental to student outcomes and so does using standardized curriculum in math, while the effect of publishing achievement data publicly is minor. All in all, there is little support for accountability's positive interaction with autonomy in this study, contrarily to the case of teacher characteristics.

5.4. Limitations and possible implications of equity

The goal of school education is not only to attain high level of student achievement, but also to give the equal opportunity to the students, regardless of their socioeconomic status (Woessmann et al. 2007). If the educational opportunity is distributed to the students equally, the difference in achievement among students should be independent of family socioeconomic background (Roemer, 1998). According to Roemer, the inequality in educational achievement should only be tolerated when the difference comes from the students' effort, not from the socioeconomic circumstances that are beyond their control. Equity in education is one of the foremost goals of education systems, and ensuring equal opportunity of learning to all students regardless of their family background is often the focus of many education policies.

This study analyzes the PISA dataset in which the variables are aggregated to the country average, so does not capture whether the impact of these variables may be different on individual students. In other words, the results of the country-level analysis in this study find the overall effects of different variables on student performance in general, but they do not imply how these effects may affect the equity inside the country. School autonomy in academic decisions, for example, has been proved to have a positive link with higher student performance, but will it have an adverse impact on equity in achievement? Higher teacher education level and using external exams lead to better student outcomes, but will they also contribute to the equality of learning opportunity? Examining these aspects is important to determine whether a given education policy are successful, and whether they do not undermine equality of learning opportunity while encouraging schools to treat well-performing students better. Certain types of autonomy expectedly provide a form of differentiation for schools, which may give different effects on students depending on their socioeconomic backgrounds (Woessmann et al., 2007). However, there is little research on possible effects of autonomy on equity, not to mention its relationship with teacher characteristics and use of accountability devices. Ammermüller (2005), argues that the school autonomy may increase the parents' commitment to the educational success of their children, and this may increase their influence on teachers, schools, and their children's educational performance. Using the data from the PISA 2000, he finds out that parents' commitment to schools increases with school autonomy, which may trigger inequity, but he does not suggest whether autonomy may give different effects on students with different socioeconomic backgrounds.

Woessmann et al. (2007) provides more evidence on the aspects that autonomy, teacher characteristics and accountability are associated with equality of educational opportunity. Their study examines how strongly the scores in PISA 2003 depend on the socioeconomic background of students' families, and measures the effects of autonomy, accountability and school choice on student outcomes both at the student and at the country level. In this respect, addressing some of their findings in school autonomy, teacher characteristics, accountability and equity would be useful to compliment the limited findings of this study. Woessmann et al. (2007) measures

how the national features of autonomy, accountability and school choice are linked to the equality of opportunity achieved by a school system. To do so, they include students' socioeconomic status in their estimation, by using the Index of Economic, Social and Cultural Status (ESCS) provided by the PISA background questionnaires. They introduce an interaction term between the institutional features of education systems and the students' socioeconomic status to their education production function models. From the results, they find that the relationship between school autonomy and equity are sensitive to the areas of autonomy. They suggest that countries where more schools have autonomy in hiring teachers have lower equity, although there is an opposing effect when it comes to more general decisions regarding the personnel. They find that school autonomy over determining course contents are beneficial for equality of opportunity. Autonomy in budget formulation and salary determination on the other hand, are unrelated to the equity of student achievement. With respect of accountability settings, Woessmann et al. (2007) do not find a significant link between accountability devices and equality of opportunity. The effects of external exams are slightly smaller for students with lower socioeconomic status than for the students with higher socioeconomic status, but still have a strong and positive effect in their performance. Using assessment data to compare the school to region or nation performance, according to them, does not differ significantly for students with different socioeconomic status. As for monitoring of teachers by external inspectors, which was defined as one of the teacher characteristic in this study, is found to have no significant effect on equity in student performance.

Despite of the findings above, there is little evidence that the features of autonomy, teacher characteristics and accountability may be associated with the (in)equity in student achievement. Woessmann et al. (2007) suggest meaningful findings, but many of the variables that were examined in this study remain uncertain. Given more autonomy, schools might prioritize different aspects in their operation. For example, some schools might focus on allocating their resource on well-performing students and aspire to have higher school outcomes in general, while others might aim to focus on students who do not meet the standards and exert more efforts in assisting them. Accountability devices also can monitor the school performance by measuring

overall student performance as the school average, which will not greatly contribute to equity. But they can also monitor school systems by examining how the student achievement is distributed within a school by students' backgrounds, and within the region and country according the location. Whether teachers' characteristics are linked to equality in opportunity may also largely depend on other factors. Results of regressions in this study suggest that teachers' participation in professional development interacts with school autonomy, and gives positive effect on student performance. That being said, if a system focuses on equality in education opportunities and provide more in-service training programs for teachers in this area, it might contribute to offering equity in education. However, more investigation is necessary to prove the possible link between them.

6. Conclusions

School autonomy has been a policy intensively discussed in the education field. In the contempt of its uncertainty, many systems have shifted the locus of decision-making within their education systems over the past decade (Hanushek, Link and Woessmann, 2011). Despite favorable voices towards the decentralization in education, recent studies suggest that autonomy's effects on education outcomes vary depending on other elements in the system.

This study investigates the heterogeneous effects of school autonomy on student performance in different areas of decision-making. It also looks at the interactions with various other factors in education systems. Using the PISA 2012 dataset, I introduce a cross-country analysis on different variables of autonomy, teacher characteristics, and accountability and their relationship with student performance in mathematics. Interaction terms with the GDP per capita of these variables are included to examine how their effects vary depending on the level of development of a country.

The central findings of this study are that autonomy's effects on student achievement vary according to the area of decision-making and interact with a country's development level and with teacher characteristics. Autonomy over decisions on academic areas such as course content, assessment style, and textbooks has a positive effect on student performance, while autonomy over budget and personnel is not clearly related to student outcomes. The level of development of a country affects the relationship between autonomy and student performance. Countries with higher income level benefit more from autonomy than countries with lower development levels in terms of their academic outcomes. Also, the effects of autonomy are positively associated with teachers' participation in professional development. That is, when more teachers attend programs aimed at developing their professional competencies, it increases the positive effect of autonomy on student achievement, both in academic and managerial autonomy. On the other hand, accountability doesn't show any clear interaction with school autonomy. External exams are closely linked to higher student performance, but they do not provide a noticeable effect on the relationship between autonomy and student achievement.

Although this study gives meaningful implications to existing studies that adopt education production functions as their methodology, it also has limitations. The PISA 2012 math score is used to represent student performance, due to the limitation of background data in other subject areas. Because the PISA 2012 survey has a specific focus on mathematics, the background data I used to explain teacher characteristics and accountability are largely related to math. For example, the variables of teachers' education level; their participation in professional development; and use of a standardized curriculum are obtained from PISA background questionnaires on mathematics. In this sense, the findings of this study on the features of autonomy, teacher characteristics and accountability might differ in other subject areas. Also, this study uses country-level averages to represent different indices of student performance, autonomy, teacher characteristics, and accountability, but education policies and school settings may vary greatly within a country. In the same way, education policies may have different effects on individuals according to their different demographic and socioeconomic

backgrounds. Since this study uses country means, it cannot capture specific local differences. Also, as mentioned in the prior section, this study does go further to examine how the education system features may contribute to the equity of achievement.

Future research may compensate the limitations mentioned above and include a closer examination of the teacher characteristics and accountability devices with effects that were not clearly linked to autonomy. Additional studies may also include grouping sample countries by region, level of development, or other system-specific criteria to investigate how autonomy's effects may vary by these elements.

The results of this study indicate that autonomy's impact on student performance is highly dependent on decision-making, development levels, and teacher characteristics across a country. There may be other implications with accountability settings in some systems. It suggests that popular education policies may not produce expected effects in different education systems due to the complexity of variables interacting in the system.

References

Akiba, M. & Liang, G. (2014). Teacher qualification and the achievement gap: A cross-national analysis of 50 countries, In J.V. Clark (ed.), *Closing the Achievement gap from an international perspective: Transforming STEM for effective education*. Springer: New York.

Arcia, G., Macdonald, K., Patrinos, H. A. & Porta, E. (2011). School autonomy and accountability. Washington DC: World Bank.

Bishop, J. H. (1997). The effect of national standards and curriculum-based exams on achievement. *American Economic Review, Papers and Proceedings*, 87, 260-264.

Bishop, J. H. (1999). Are national exit examinations important for educational efficiency? *Swedish Economic Policy Review*, 6, 349-398.

Bishop, J. H. & Wößmann, L. (2004). Institutional effects in a simple model of educational production. *Education Economics*, 12(1), 17-38.

Bjork, C. (2014). Education decentralization: Asian experiences and conceptual contributions. New York: Springer.

Clark, D. (2009). The performance and competitive effects of school autonomy. *Journal of Political Economy*, 117(4), 745-783.

Eide, E. & Showalter, M. H. (1998). The effect of school quality on student performance: A quintile regression approach. *Economics Letters,* 58(3), 345-350.

Eskeland, G. & Filmer, D. (2007). Autonomy, participation and learning: Findings from Argentine schools, and implications for decentralization. *Education Economics*, 15(1), 103-127.

Felouzis, G. &. Charmillot, S. (2012). *Les enquêtes PISA*, *Que sais-je?* Paris: Puf.

Fuchs, T. & Woessmann, L. 2007. What accounts for international differences in student performance? A re-examination using PISA data. *Empirical Economics*, 32(2), 433-464.

Galiani, S., Gertler, P. & Schargrodsky, E. (2008). School decentralization: helping the good get better, but leaving the poor behind. *Journal of Public Economics*, 92(10-11), 2106-2120.

Hanushek, E. A. (1992). The trade-off between child quantity and quality. *Journal of Political Economy*, 100, 84-117.

Hanushek, E. A. (2006). School resources, In E. A. Hanushek & F. Welch (Eds.), *Handbook of Economics of Education*, 2, 866-908.

Hanushek, E. A., Link, S. & Woessmann, L. (2011). Does school autonomy make sense everywhere? Panel estimates from PISA. *Journal of Development Economics,* 104, 212-232.

Hanushek, E. A., Raymond. M. E. (2006). School accountability and student performance. *Regional Economic Development,* Federal Reserve Bank of St. Louis, 2(1), 51-61.

Hanushek, E. A. & Rivkin, S. G. (2004). How to improve the supply of high-quality teachers. *Brookings Papers on Education Policy*, 7, 7-25.

Hanushek, E. A & Rivkin, S. G. (2006). Teacher quality. In E. A. Hanushek & F. Welch (Eds.), *Handbook of Economics of Education,* 2, 1052-1075.

Hanushek, E. A & Rivkin, S. G. (2010). Generalizations about using value-added measures of teacher quality. *American Economic Review*, 267–271.

Hanushek, E. A. & Rivkin, S. G. (2012). The distribution of teacher quality and implications for policy. *The Annual Review of Economics*, 4, 131–157.

Harris, D. N. and Sass, T. R. (2011). Teacher training, teacher quality and student achievement. *Journal of Public Economics*, 95, 798-812.

Hong, J. (2014). *Institutions and the quality of education*, A thesis submitted as a

partial fulfillment of a master's degree to the Department of Economics, Seoul: Seoul National University.

Hoxby, C. M. (1996). How teachers' unions affect education production. *The Quarterly Journal of Economics,* 111(3), 671-718.

Hoxby, C. M. (1999). The productivity of schools and other local public goods producers. *Journal of Public Economics*, 74(1), 1-30.

Hoxby, C. M. (2000). The effects of class size on student achievement: New evidence from population variation. The quarterly journal of economics, 115(4), 1239-1285.

Jackson, K. (2009). Student demographics, teacher sorting, and teacher quality: Evidence from the end of school desegregation. *Journal of Labor Economics*, 27, 213-256.

Jensen, J., McDaniel, M., Woodard, S. & Kummer, T. (2014). Teaching to the test…or testing to teach: Exams requiring higher order thinking skills encourage greater conceptual understanding. *Educational Psychology Review*, 26(2), 307-329.

Lee, J. W. & Barro, R. J. (2001). Schooling quality in a cross–section of countries. *Economica*, 68(272), 465-488.

Marks, H. M & Louis, K. S. (1997). Does teacher empowerment affect the classroom? The implications of teacher empowerment for instructional practice and student academic performance. *Educational Evaluation and Policy Analysis*, 19 (3), 245-275.

Mourshed, M., Chijioke, C. & Barber, M. (2010). *How the world's most improved school systems keep getting better*. McKinsey and Company.

Namukasa, I. & Buye, R. (2007). Decentralization and education in Uganda. *Canadian International Education*, 36(1), 93-116.

OECD, (2001). *Knowledge and skills for life: First results from PISA 2000*. Paris: OECD Publishing.

OECD, (2009). *PISA data analysis manual: SPSS second edition.* Paris: OECD Publishing.

OECD, (2011). *School autonomy and accountability: Are they related to student performance?* PISA in Focus, 9. Paris: OECD Publishing.

OECD (2011). *Teachers matter: attracting, developing and retaining effective teachers – Pointers for policy development*. Paris: OECD Publishing.

OECD (2013). *Education at a glance*. Paris: OECD Publishing.

OECD (2013). *PISA 2012 Results: What makes schools successful? Resources, policies and practices*, 4. Paris: OECD Publishing.

OECD (2014). *TALIS 2013 Results: An international perspective on teaching and learning*, Paris: OECD Publishing.

Radó, P. (2010). *Governing decentralized education systems: Systematic change in South Eastern Europe*. Local Government and Public Service Reform Initiatives/Open Society Foundation.

Schleicher, A. (Ed.) (2011). *Building a high-quality teaching profession: lessons from around the world*. Paris: OECD Publishing.

Schleicher, A. (Ed.) (2012). *Preparing teachers and developing school leaders for the 21st century: lessons from around the world*. Paris: OECD Publishing.

Rivkin, S., Hanushek, E. & Kain, J. (2005). Teachers, schools, and academic achievement. *Econometrica*, 73(2), 417-458.

Rockoff, J. E. (2004). The impact of individual teachers on students' achievement: Evidence from panel data. *American Economic Review*, 94(2), 247-252.

Ronfeldt, M. and Reininger, M. (2012). More of better student teaching? *Teaching and Teacher Education*, 28, 1091-1106.

Schuetz, G., West, M. R., & Woessmann, L. (2007). School accountability, autonomy, choice, and the equity of student achievement: International

evidence from PISA 2003. *OECD Education Working Paper, 14*. Paris: OECD.

UNESCO Institute for Statistics (2006). *Teachers and educational quality: monitoring global needs for 2015*. Montreal: UNESCO Institute for Statistics.

Vegas, E. (1999). *School choice, Student Performance, and Teacher and School Characteristics: The Chilean Case*. World Bank Policy Research Working Paper, 2833. Washington D. C : World Bank.

Woessmann, L. (2001). Why Students in Some Countries Do Better: International Evidence on the Importance of Education Policy. *Education Matters*, 1, 67-74.

Woessmann, L. (2003). Schooling Resources, Educational Institutions, and Student Performance: The International Evidence. *Oxford Bulletin of Economics and Statistics* 65, (2), 117-170.

Woessmann, L. (2005). The Effect Heterogeneity of Central Exams: Evidence from TIMSS, TIMSS-Repeat and PISA. *Education Economics,* 13(2), 143-169.

Woessmann, L. et al. (2007). School accountability, autonomy, choice, and the level of student achievement: International Evidence from PISA 2003, *OECD Education Working Paper*, 13. Paris: OECD Publishing.

Woessmann, L. et al. (2009). *School accountability, autonomy and choice around the world*. IFO Economic Policy. Cheltenham: Edward Elgar Publishing.

Zajda, J. (2014). *Second international handbook on globalization, education and policy research*. New York: Springer.

Appendix

A. Background Questionnaires of PISA 2012

A.1. School autonomy

Figure A.1 Questionnaire about school autonomy

Q Regarding your school, who has a considerable responsibility for the following tasks?

(Please tick as many boxes as appropriate in each row.)

	Principals	*Teachers*	*<School governing board>*	*<Regional or local education authority>*	*National education authority*
a) Selecting teachers for hire	□	□	□	□	□
b) Firing teachers	□	□	□	□	□
c) Establishing teachers' starting salaries	□	□	□	□	□
d) Determining teachers' salary increases	□	□	□	□	□
e) Formulating the school budget	□	□	□	□	□
f) Deciding on budget allocations within the school	□	□	□	□	□
g) Establishing student disciplinary policies	□	□	□	□	□

h) Establishing student assessment policies	□	□	□	□	□
i) Approving students for admission to the school	□	□	□	□	□
j) Choosing which textbooks are used	□	□	□	□	□
k) Determining course content	□	□	□	□	□
l) Deciding which courses are offered	□	□	□	□	□

A.2. Teacher characteristics

Figure A.2 Questionnaire about teachers' educational level

Q How many of the following are on the <mathematics staff> of your school?

Include both full-time and part-time teachers. *A full-time teacher is employed at least 90% of the time as a teacher for the full school year. All other teachers should be considered part-time.*

Please count only those teachers who have taught or will teach mathematics during the current school year.

(Please write a number in each space provided. Write 0 (zero) if there are none.)

	Full-time	*Part-time*
a) Teachers of mathematics in TOTAL	____	____
b) Teachers of mathematics with an <ISCED5A> qualification	____	____

c) Teachers of mathematics with an <ISCED5A> qualification <with a major> in mathematics ____ ____

d) Teachers of mathematics with an <ISCED5A> qualification in <pedagogy> ____ ____

e) Teachers of mathematics with an <ISCED5B> but not an <ISCED 5A> qualification ____ ____

Figure A.3 Questionnaire about teachers' professional development in mathematics

Q During the last three months, what percentage of teaching staff in your school has attended a programme of professional development with a focus on mathematics?
A programme of professional development here is a formal programme designed to enhance teaching skills or pedagogical practices. It may or may not lead to a recognised qualification. The programme must last for at least one day in total and have a focus on mathematics teaching and education.

a) All staff at your school _____ %

b) Staff who teach mathematics at your school _____ %

Figure A.4 Questionnaire about teacher monitoring

Q During the last year, have any of the following methods been used to monitor the practice of mathematics teachers at your school?
(Please tick one box in each row.)

	Yes	*No*
a) Tests or assessments of student achievement	□	□

b) Teacher peer review (of lesson plans, assessment instruments, lessons)	□	□
c) Principal or senior staff observations of lessons	□	□
d) Observation of classes by inspectors or other persons external to the school	□	□

A.3. Accountability

Figure A.5 Questionnaire about student assessment method

Q Which of the following measures aimed at quality assurance and improvement do you have in your school?

	Yes	*No*
a) Written specification of the school's curricular profile and educational goals	□	□
b) Written specification of student performance standards	□	□
c) Systematic recording of data including teacher and student attendance and graduation rates, test results and professional development of teachers	□	□
d) Internal evaluation/self-evaluation	□	□
e) External evaluation	□	□
f) Seeking written feed-back from students (e.g. regarding lessons, teachers or resources)	□	□
g) Teacher mentoring	□	□

h) Regular consultation aimed at school improvement with one or more experts over a period of at least six months	□	□
i) Implementation of a standardised policy for mathematics (i.e. school curriculum with shared instructional materials accompanied by staff development and training)	□	□

Figure A.6 Questionnaire about use of student assessment

Q In your school, are assessments of students in <national modal grade for 15-year-olds> used for any of the following purposes?
(Please tick only one box in each row.)

	Yes	*No*
a) To inform parents about their child's progress	□	□
b) To make decisions about students' retention or promotion	□	□
c) To group students for instructional purposes	□	□
d) To compare the school to <district or national> performance	□	□
e) To monitor the school's progress from year to year	□	□
f) To make judgements about teachers' effectiveness	□	□
g) To identify aspects of instruction or the curriculum that could be improved	□	□
h) To compare the school with other schools	□	□

Figure A.7 Questionnaire about accountability procedures

Q In your school, are achievement data used in any of the following <accountability procedures>?

*Achievement data include **aggregated** school or grade-level test scores or grades, or graduation rates.*

(Please tick one box in each row.)

	Yes	*No*
a) Achievement data are posted publicly (e.g. in the media)	□	□
b) Achievement data are tracked over time by an administrative authority	□	□

Figure A.8 Questionnaire about using standardized mathematics curriculum

Q Which of the following statements apply in your school?

A policy refers to written rules known to those concerned with the policy.

(Please tick one box in each row.)

	Yes	*No*
a) The school has a policy on how to use computers in mathematics instruction (e.g. amount of computer use in mathematics lessons, use of specific mathematics computer programs).	□	□
b) All <national modal grade for 15-year-olds> mathematics classes in the school use the same textbook.	□	□
c) Mathematics teachers in the school follow a standardised curriculum that specifies content at least on a monthly basis.	□	□

B. Tables of Data

Table A.1 PISA 2012 Mathematics score by country and country factors included in the empirical model

Country	Mathematics score PISA 2012	GDP per capita (1,000 USD)	Public expenditure on education as % of GDP
Albania	394.329	4.406	3.268
Argentina	388.432	14.680	6.259
Australia	504.151	67.436	5.121
Austria	505.541	46.792	5.796
Belgium	514.529	43.396	6.549
Brazil	391.460	11.320	5.822
Bulgaria	438.738	7.022	4.097
Canada	518.070	52.409	5.396
Chile	422.632	15.245	4.522
Chinese Taipei	559.825	48.400	N/A
Colombia	376.489	7.763	4.384
Costa Rica	407.000	9.443	6.282
Croatia	471.131	13.159	4.308
Czech Republic	498.958	18.690	4.507
Denmark	500.027	56.364	8.740
Estonia	520.546	16.887	5.152
Finland	518.750	45.649	6.763
France	494.985	39.759	5.675
Germany	513.525	42.598	5.081
Greece	452.973	22.395	4.091
Hong Kong, China	561.241	36.708	3.507
Hungary	477.044	12.560	4.712
Iceland	492.796	42.362	7.600
Indonesia	375.114	3.551	3.562

Ireland	501.497	45.922	6.155
Israel	466.481	32.567	5.637
Italy	485.321	33.814	4.294
Japan	536.407	46.548	3.855
Jordan	385.596	4.909	4.945
Kazakhstan	431.798	12.120	3.061
Korea	553.767	24.454	5.246
Latvia	490.571	13.947	4.935
Liechtenstein	534.965	134.617	2.112
Lithuania	478.823	14.172	5.198
Luxembourg	489.845	103.859	3.745
Macao, China	538.134	77.196	2.679
Malaysia	420.513	10.432	5.941
Mexico	413.281	9.818	5.191
Montenegro	409.627	6.514	N/A
Netherlands	522.972	45.961	5.928
New Zealand	499.750	38.680	7.385
Norway	489.373	99.636	6.872
Peru	368.103	6.424	2.760
Poland	517.501	12.721	5.171
Portugal	487.063	20.175	5.624
Qatar	376.448	92.633	2.453
Romania	444.554	8.437	3.073
Russian Federation	482.169	14.091	4.102
Serbia	448.859	5.294	4.822
Shanghai-China	612.676	12.784	1.907
Singapore	573.468	54.007	3.230
Slovak Republic	481.645	16.893	4.057
Slovenia	501.127	22.059	5.681
Spain	484.319	28.282	4.982

Sweden	478.261	55.039	6.984
Switzerland	530.931	78.929	5.277
Thailand	426.737	5.480	7.569
Tunisia	387.825	4.197	6.166
Turkey	447.984	10.661	2.862
United Arab Emirates	434.007	41.692	N/A
United Kingdom	493.934	38.649	6.227
United States	481.367	51.755	5.420
Uruguay	409.292	14.728	4.499
Vietnam	511.338	1.755	6.285
Mean	473.853	31.732	4.976

Table A.2 School autonomy index by country

Country	Index of school reasonability	Index of school responsibility for curriculum and assessment	Index of school responsibility for resource allocation
Albania	-0.621	-0.243	-0.591
Argentina	-0.657	-0.483	N/A
Australia	0.025	0.077	0.060
Austria	-0.664	-0.193	-0.435
Belgium	-0.025	-0.056	-0.277
Brazil	-0.685	-0.436	-0.459
Bulgaria	0.407	-0.834	0.790
Canada	-0.247	-0.594	-0.377
Chile	0.559	0.232	0.750
Chinese Taipei	0.003	0.262	0.181
Colombia	-0.238	-0.080	-0.135
Costa Rica	-0.677	-0.667	-0.374
Croatia	-0.426	-0.848	-0.315
Czech Republic	1.238	0.704	1.209
Denmark	0.173	-0.116	0.141
Estonia	0.429	0.484	0.177

Finland	-0.064	-0.043	-0.173
France	-0.479	-0.086	-0.518
Germany	-0.397	-0.197	-0.577
Greece	-1.298	-1.151	-0.708
Hong Kong, China	0.783	0.952	0.399
Hungary	0.474	0.012	0.442
Iceland	0.125	0.201	0.025
Indonesia	0.486	0.771	0.357
Ireland	-0.142	0.122	-0.422
Israel	-0.097	-0.029	-0.246
Italy	-0.567	0.316	-0.588
Japan	0.043	1.139	-0.281
Jordan	-1.315	-1.077	-0.563
Kazakhstan	-0.486	-0.788	-0.333
Korea	-0.362	0.716	-0.445
Latvia	0.566	-0.169	0.588
Liechtenstein	0.557	0.047	0.306
Lithuania	1.022	0.670	0.780
Luxembourg	-0.172	-0.776	-0.082
Macao, China	1.446	0.794	1.579
Malaysia	-1.089	-0.882	-0.500
Mexico	-0.737	-0.817	-0.231
Montenegro	-0.829	-0.775	-0.260
Netherlands	1.373	1.002	1.331
New Zealand	0.558	0.487	0.141
Norway	-0.401	-0.549	-0.187
Peru	-0.105	-0.043	0.147
Poland	0.222	0.402	-0.106
Portugal	-0.457	-0.627	-0.463
Qatar	-0.065	-0.856	-0.321
Romania	-0.500	-0.493	-0.577
Russian Federation	0.383	-0.211	0.014
Serbia	-0.449	-0.868	-0.370
Shanghai-China	-0.052	-0.577	-0.295

Singapore	-0.164	-0.227	-0.368
Slovak Republic	0.930	0.481	0.808
Slovenia	0.206	-0.350	-0.143
Spain	-0.522	-0.397	-0.386
Sweden	0.615	-0.190	0.735
Switzerland	-0.286	-0.667	-0.259
Thailand	0.854	0.962	0.613
Tunisia	-0.861	-0.577	-0.167
Turkey	-1.353	-1.077	-0.719
United Arab Emirates	0.004	-0.223	0.524
United Kingdom	0.815	0.794	0.474
United States	0.401	-0.343	0.165
Uruguay	-0.933	-0.831	-0.485
Vietnam	-1.069	-0.987	-0.467
Mean	-0.075	-0.153	-0.023

Notes:

Values on the index represent difference from the OECD average. Positive values indicate that schools have more responsibility than local, regional or national education authorities compared with the OECD average. Negative values indicate that local, regional or national education authorities have more responsibility than individual schools, compared with the OECD average. Range of values: -2.87 ~ 1.60 (school autonomy) ; -1.26 ~ 1.44 (index of school responsibility for curriculum and assessment) ; -0.80 ~ 2.71 (Index of school responsibility for resource allocation). 'Index of responsibility for curriculum and assessment' was calculated by principals' responses to who has the responsibility in disciplinary policies, assessment policies, textbook selection and course content and course offered in their school. 'Index of school responsibility for resource allocation' represents autonomy over hiring and firing of teachers, teacher start salaries, salary increase and budget formulation and allocation.

Table A.3 Data of teacher characteristics by country

Country	Education level of teachers	Teacher professional development	Teacher monitoring	Teacher participation /autonomy
Albania	0.171	0.457	0.621	-0.382
Argentina	0.108	0.453	0.234	-0.419
Australia	0.583	0.523	0.113	0.329
Austria	0.385	0.494	0.290	-0.064
Belgium	0.226	0.358	0.447	0.314

Brazil	0.701	0.357	0.242	-0.401
Bulgaria	0.860	0.337	0.473	-0.227
Canada	0.582	0.594	0.196	-0.085
Chile	0.544	0.305	0.244	-0.129
Chinese Taipei	0.740	0.560	0.086	0.807
Colombia	0.189	0.255	0.113	-0.718
Costa Rica	0.683	0.453	0.443	-0.338
Croatia	0.804	0.678	0.315	0.019
Czech Republic	0.828	0.221	0.308	0.209
Denmark	0.731	0.270	0.178	0.040
Estonia	0.725	0.609	0.078	0.159
Finland	0.604	0.319	0.033	0.176
France	0.838	0.337	0.706	0.208
Germany	0.598	0.225	0.234	0.247
Greece	0.982	0.254	0.229	-0.846
Hong Kong, China	0.563	0.336	0.408	1.973
Hungary	0.848	0.216	0.152	0.204
Iceland	0.069	0.272	0.184	0.119
Indonesia	0.764	0.411	0.778	0.441
Ireland	0.665	0.882	0.479	0.078
Israel	0.622	0.615	0.367	-0.081
Italy	0.603	0.273	0.018	0.345
Japan	N/A	0.222	0.262	-1.026
Jordan	0.894	0.294	0.969	-1.583
Kazakhstan	0.854	0.336	0.803	-0.984
Korea	0.735	0.318	0.677	0.046
Latvia	0.384	0.361	0.367	0.599
Liechtenstein	0.240	0.256	0.750	0.399
Lithuania	0.774	0.468	0.343	0.601
Luxembourg	0.770	0.447	0.050	-0.089
Macao, China	0.587	0.511	0.444	0.659
Malaysia	0.237	0.411	0.689	-1.125
Mexico	0.250	0.441	0.385	-0.927

Montenegro	0.504	0.427	0.609	-0.883
Netherlands	0.156	0.289	0.429	0.042
New Zealand	0.577	0.617	0.314	0.654
Norway	0.546	0.245	0.120	-0.286
Peru	0.234	0.319	0.510	0.104
Poland	0.867	0.451	0.151	0.538
Portugal	0.728	0.344	0.027	-0.519
Qatar	0.364	0.724	0.778	-0.045
Romania	0.903	0.441	0.582	-0.216
Russian Federation	0.865	0.247	0.438	-0.212
Serbia	0.825	0.472	0.343	0.160
Shanghai-China	0.848	0.721	0.903	-0.664
Singapore	0.671	0.664	0.242	-0.172
Slovak Republic	0.411	0.218	0.260	0.526
Slovenia	0.652	0.535	0.050	0.462
Spain	0.421	0.279	0.100	-0.212
Sweden	0.616	0.435	0.262	0.448
Switzerland	0.361	0.280	0.393	-0.257
Thailand	0.737	0.719	0.485	1.643
Tunisia	0.866	0.396	0.853	-1.211
Turkey	0.124	0.167	0.257	-1.325
United Arab Emirates	0.802	0.565	0.857	-0.699
United Kingdom	0.774	0.554	0.586	0.619
United States	0.662	0.623	0.443	-0.078
Uruguay	0.012	0.332	0.650	-0.540
Vietnam	0.587	0.528	0.877	-1.644
Mean	0.585	0.418	0.394	-0.082

Notes:

"Education level of teachers" represents the proportion of teachers of mathematics with an ISCED5A qualification with a major in mathematics in the school measured as country average; "Teacher professional development" denotes the proportion of math teachers who have attended a program of professional development with a focus on mathematics in the school measured as country average; "Teacher participation /autonomy" is the OECD index of teacher participation/autonomy that represents the degree of teachers' participation in school operation in the school, measured as country average. Data source: PISA 2012, OECD.

Table A.4 Data of accountability by country

Country	External examination	Compare school to region/nation	Achievement data posted publicly	Standardized mathematics curriculum
Albania	0.660	0.766	0.267	0.979
Argentina	0.370	0.251	0.099	0.836
Australia	0.697	0.537	0.648	0.908
Austria	0.230	0.242	0.048	0.742
Belgium	0.675	0.227	0.036	0.707
Brazil	0.731	0.830	0.347	0.955
Bulgaria	0.946	0.860	0.505	0.984
Canada	0.630	0.756	0.488	0.850
Chile	0.534	0.500	0.575	0.982
Chinese Taipei	0.765	0.370	0.153	0.809
Colombia	0.798	0.718	0.484	0.956
Costa Rica	0.503	0.608	0.120	0.959
Croatia	0.798	0.685	0.258	0.907
Czech Republic	0.606	0.584	0.419	0.971
Denmark	0.591	0.557	0.401	0.303
Estonia	0.775	0.649	0.340	0.892
Finland	0.550	0.493	0.033	0.672
France	0.517	0.633	0.448	0.526
Germany	0.598	0.432	0.096	0.750
Greece	0.060	0.173	0.257	0.861
Hong Kong, China	0.905	0.419	0.331	0.903
Hungary	0.574	0.808	0.477	0.864
Iceland	0.754	0.748	0.271	0.780
Indonesia	0.870	0.713	0.198	0.933
Ireland	0.828	0.770	0.206	0.902
Israel	0.611	0.657	0.461	0.899
Italy	0.308	0.598	0.343	0.624
Japan	0.784	0.168	0.058	0.937
Jordan	0.686	0.677	0.208	0.898

Kazakhstan	0.936	0.900	0.780	0.798
Korea	0.788	0.692	0.697	0.852
Latvia	0.845	0.923	0.316	0.946
Liechtenstein	0.833	0.600	0.083	0.750
Lithuania	0.550	0.590	0.305	0.815
Luxembourg	0.421	0.619	0.143	0.436
Macao, China	0.644	0.222	0.111	0.533
Malaysia	0.823	0.815	0.356	0.933
Mexico	0.736	0.748	0.376	0.970
Montenegro	0.939	0.765	0.765	0.941
Netherlands	0.813	0.673	0.888	0.924
New Zealand	0.885	0.930	0.764	0.810
Norway	0.517	0.670	0.530	0.836
Peru	0.415	0.423	0.102	0.895
Poland	0.767	0.605	0.475	0.915
Portugal	0.862	0.866	0.527	0.984
Qatar	0.840	0.757	0.406	0.955
Romania	0.831	0.674	0.669	0.667
Russian Federation	0.951	0.916	0.737	0.929
Serbia	0.533	0.333	0.571	0.803
Shanghai-China	0.896	0.497	0.032	0.935
Singapore	0.921	0.945	0.485	0.988
Slovak Republic	0.381	0.665	0.743	0.965
Slovenia	0.346	0.597	0.550	0.978
Spain	0.760	0.421	0.132	0.928
Sweden	0.654	0.889	0.758	0.333
Switzerland	0.454	0.407	0.034	0.698
Thailand	0.975	0.858	0.756	0.736
Tunisia	0.474	0.705	0.162	0.627
Turkey	0.810	0.755	0.641	0.874
United Arab Emirates	0.923	0.803	0.437	0.951
United Kingdom	0.906	0.958	0.822	0.932

United States	0.860	0.948	0.889	0.948
Uruguay	0.453	0.154	0.089	0.922
Vietnam	0.509	0.883	0.735	0.951
Mean	0.681	0.635	0.398	0.840

Notes:

“External examination” is a measurement of the proportion of schools that use external evaluation as a measure of quality assurance; “Achievement data posted publicly” represents the proportion of schools that post achievement data publicly as an accountability procedure; and “standardized mathematics curriculum” denotes the proportion of schools in which the mathematics teachers follow a standardized curriculum that specifies content at least on a monthly basis. Data source: PISA 2012, OECD.