Information Asymmetry and Equilibrium Monitoring in Education

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Abstract

We develop a theoretical and computational model of equilibrium school choice and achievement that embeds information asymmetries in the production of education. School effort is unobservable to households and the policymaker, leading to moral hazard. Although household monitoring of schools can mitigate this problem, some households may free-ride on the monitoring of others. Whereas the distortions related to information asymmetries affect both public and private schools, public schools are subject to an additional distortion because their funding is unrelated to their effort. Using our calibrated model we simulate two policies aimed at raising achievement: public monitoring of public schools and private school vouchers. In our simulations, public monitoring raises public school effort but can crowd out private monitoring, thus undermining its own effectiveness. Vouchers may not be able to help households in the low-income, low-ability segment because of these households' high monitoring costs; furthermore, vouchers may hurt the public school by causing the loss of high-ability households who provide monitoring. These simulations illustrate that given the complexity of the low-achievement problem, no single tool might suffice. However, they also indicate that reducing the funding distortion and monitoring costs would mitigate moral hazard. Furthermore, our simulations suggest that public schools may bias their funding and standards away from the levels preferred by households.

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1. Introduction

An educated population is a fundamental ingredient for a well-functioning democracy and a crucial driver of growth in the modern economy. Thus, education has both private returns that accrue to the individual, and public returns that accrue to society. For this reason, the policymaker often has a minimum goal of basic academic proficiency for every student in the economy. Many students, however, do not meet this goal, even after substantial public spending in the marketplace for education.

In this paper we focus on an information-based explanation for the lack of academic achievement, namely the information asymmetries among the policymaker, households, and schools. In particular, school effort (from a school's administration or its teachers) is not fully observable to parents or policymakers, and this creates a potential moral hazard problem as the school has an incentive to under-provide effort. Parental involvement in schools can function as a monitoring device that mitigates the distortion induced by information asymmetry. However, since monitoring is a public good, it may itself introduce an additional distortion as some households may free-ride on the monitoring exerted by others. This externality can in turn lead to the under-provision of monitoring relative to socially optimal levels.

Information asymmetry is at the root of other economic problems facing policymakers and market participants, such as the regulation of natural monopolies and managerial contracts in corporate settings (Laffont and Tirole 1983, Laffont and Martimort 2002). Nonetheless, to our knowledge we are the first to model the moral hazard associated with school effort in an equilibrium setting of education provision. Our analysis highlights the distortions introduced by these frictions in the equilibrium behavior of households and schools. Ignoring the effect of these frictions can lead to incorrect conclusions regarding the effectiveness of policies often proposed to address underachievement, such as public school accountability and private school vouchers. In contrast, our framework allows for more appropriate policy analysis and informs the design of more efficient mechanisms.

We develop a theoretical equilibrium model of household school and monitoring choice in the presence of information asymmetry. We calibrate the computational version of the model to 2000 data from the United States, and use it to conduct policy simulations. In our model, the production of educational achievement requires three inputs: school effort, household learning effort, and peer quality. School effort is not observable to households or the policymaker in public or private schools and is hence under-provided (as in Holmstrom 1979), which hurts achievement directly and possibly indirectly by reducing the productivity of other inputs.

Faced with moral hazard, households have the option to exert costly effort to monitor the school; monitoring mitigates but does not eliminate moral hazard. However, households vary in their costs and benefits from monitoring. In addition, they have incentives to free-ride on the monitoring of others. The underlying agency or hidden action problem, along with the concomitant free-riding associated with household monitoring, is one friction in our model.

The second friction is that while private school revenue is directly related to school effort by virtue of competition among private schools, public school revenue is not. We assume that the policymaker sets per-pupil funding in public school irrespective of actual school effort. This funding distortion can generate rents for public schools and unnecessarily raise their fiscal cost.

Furthermore, the endogenous sorting of households across schools can aggravate the effect of these frictions. For instance, high-income, high-ability households choose private schools and monitor them, hence mitigating moral hazard. In contrast, other households choose public schools. Some of these households monitor school effort, but others free-ride on monitoring. The anticipated free-riding along with the resulting low public school effort prevents the public school from attracting the high-income, high-ability households that would in turn improve peer quality and provide monitoring. Hence, public schools provide less effort than many private schools while potentially earning a rent, the size of which grows as the school exerts less effort.

Using our calibrated model, we have computed the equilibrium in a variety of scenarios. Of special importance is the comparison between the baseline, imperfect observability model, and a perfect observability model in which school effort is fully observable and monitoring unnecessary. In the baseline, most households attend public schools, though only some monitor while others free-ride on their effort. Under perfect observability, however, school effort is higher in all schools, and so is public school attendance.

One policy parameter in our model is the effort standard for the public school, from which the school may deviate when choosing its actual effort. This deviation measures the distortion caused by moral hazard. The effort standard plays an important role determining public school rent or profit, attendance, and monitoring in equilibrium. The effort standard implied by our data is quite close to that which would maximize the public school's profits given the current per-student funding. It is lower than what the majority of households would choose according to our policy analysis, perhaps indicating that public schools influence the actual standard.

The frictions highlighted in our model suggest a role for policies that increase public school monitoring, connect per-pupil funding with school effort, or give households the means to switch into higher-effort schools. Hence, we have conducted two policy simulations: public monitoring of public schools, and private school vouchers. Public monitoring of public schools is inspired by actual public school accountability policies that attach consequences to performance. According to our simulations, while public monitoring can raise school effort and attract high-ability households, it can also crowd out private monitoring on the part of lower-income, lower-ability households. Private school vouchers increase private school attendance, although the lowest income and ability households do not use the voucher because of their monitoring cost. The loss of high-ability households to private schools due to vouchers lowers public school peer quality and monitoring rate, further hurting households left in public schools. Although an income-targeted voucher would mitigate these effects, the fact remains that informational frictions can render vouchers ineffective for some households. In other words, both public monitoring and vouchers may have unintended effects that limit their effectiveness, and neither tool is a complete solution for the policymaker.

The reason is the sheer complexity of the problem: school moral hazard can be mitigated by parental monitoring, but the information asymmetry between school and households is embedded in an equilibrium setting in which every school and household choice is endogenous. While this complexity defies simple tools, it suggests a role for thoughtful combinations (such as vouchers supplemented with public monitoring of public and/or private schools, provided public monitoring does not crowd out private monitoring). Moreover, our simulations indicate the importance of reducing monitoring costs (for instance, through greater provision of school-related information) to enhance private monitoring. They also point to reducing the public school funding distortion in order to mitigate the effect of the informational friction.

While we do not model the determination of policy parameters for public schools, we have analyzed the distribution of household preferences over them. This distribution is related to whether households prefer private or public schools. Households that prefer private schools prefer parameters that minimize public school attendance and hence fiscal burden. Households that prefer public schools prefer either a higher effort standard than the current one, or lower funding. Once again, these findings suggest that public schools influence the policy parameters.

Our work contributes to two distinct literatures. First, we contribute to the education literature by modeling moral hazard regarding school effort, and household monitoring as an equilibrium response. Whereas equilibrium models in education have been used to analyze policies such as private school vouchers and public school finance reform (e.g. Epple and Romano 1998, Ferreyra 2007, Nechyba 1999), using these models to frame the treatment of school effort, and household learning and monitoring efforts is novel in the literature.

While some researchers have modeled student learning effort in the production of achievement (Blankenau and Carmera 2009, De Fraja and Landeras 2006, MacLeod and Urquiola 2009), to our knowledge we are the first to model household monitoring effort. Parental monitoring of schools has been documented in the sociological literature (Hassrick and Schneider 2009) yet not in the economics literature.

Other studies have explored information-driven distortions in education provision. McMillan (2005) studies a rent-seeking public school. While we share the rent-seeking motive of the public school, McMillan assumes that school effort is observable but not contractible either by the state or the household (i.e., although the policymaker can observe school effort and sets school funding, he cannot attach any consequences to the under-provision of effort). In other words, information asymmetries are absent in his paper, as is monitoring. Chakrabarti (2008) uses a similar model to study different voucher systems. In Acemoglu et al (2006), the key issue is the multi-dimensionality of school effort (i.e., "good" effort which increases students' human capital and "bad" effort which increases outsiders' perception of the amount of good effort exerted), which leads schools to provide less good effort than is socially optimal, though the extent of the distortion depends on the institutional arrangement used to provide school effort. Household monitoring, which could presumably mitigate the misallocation of school efforts, is not present in this model, and neither is household sorting.

The second literature to which we contribute is the agency literature. We do so by embedding a micro-based bilateral agency model into an equilibrium framework for education. Well-known agency problems (such as Holmstrom 1979 and Sappington 1983) have been studied in a bilateral, partial equilibrium setting. Monitoring and its associated free-riding problems have been studied in professional partnership settings (Legros and Matthews 1992, Miller 1997, Huddart and Liang 2003, 2005) where monitoring must be performed by the very partners whose productive effort is subject to moral hazard. Our approach allows us to combine advantages of the equilibrium and agency literatures.

Since the public school in our model receives funding and policy mandates from the policymaker, our work is also related to incentive problems in government procurements (Laffont and Tirole 1993). The focus in that literature is the design of optimal procurement contracts to mitigate the rent earned by government contractors due to their information advantage. In contrast, we do not model how funding or policy mandates are established, nor do we search for the optimal contract between the public school and the policymaker (which is likely to be extremely complex and difficult to implement). Rather, our focus is on policies that, while potentially not optimal, are commonly discussed to address underachievement.

The remainder of this paper is organized as follows: section 2 presents the model, section 3 describes the computational version of the model, section 4 analyzes the equilibrium of the model, section 5 discusses policy simulations, and section 6 concludes.

2. The Model

Our model includes households who send their children to school, public and private schools who educate children, and a policymaker that funds public schools and sets policy parameters. Here we describe these elements and the model's timeline.

2.1. Households

The economy is populated by a finite number of households. Each household has one child who must go to school. Households are heterogeneous in income, y, and ability, μ. There are a finite number of income types, I, and a finite number of ability types, J. Thus, there are $H = I \times J$ household types, each representing an (income, ability) combination. In the computational version of the model we assume one household per type, in which case the total number of households in the economy equals H. The model can be extended to more than one household per type without loss of generality. Parents and students form a single decision-making unit, the household. We refer to parents, households, and students interchangeably.

Household preferences are described by the following utility function:

$$U = c^{\beta} s - \rho_a \frac{a^2}{2\mu} - \rho_m \frac{m^2}{2\mu} \qquad (1)$$

where c is numeraire consumption, s is school achievement, a is household learning effort, and m is household monitoring effort (the roles of a and m in the production of achievement are described below), $\rho_m, \rho_a > 0$, and $\beta > 0$.[2] Note that households incur disutility from exerting school and monitoring efforts, and this disutility is related to their ability, as these efforts are more costly for lower-ability households. In the computational version of the model, we assume that monitoring is a binary choice: $m \in \{0,1\}$.[3]

Households maximize utility (1) subject to the following budget constraint:

$$(1 - t)y = c + T \qquad (2)$$

where t is income tax rate and T is private school tuition (public schools charge no tuition). Although the household buys consumption and school effort in the market, learning and monitoring efforts are privately produced and have a direct utility cost. These efforts cannot be outsourced and are thus "off-budget," reflecting the assumption that education requires some inputs that only the agent can provide.[4] In equilibrium, household learning and monitoring efforts are positively related to income as well as ability because of the complementarity and normality of current consumption and achievement.

The production of child achievement, s, is as follows:

$$s = e^{\eta_1} q^{\eta_2} a \qquad (3)$$

where e is school effort, q is the school's peer quality (defined as the school's average ability), and $\eta_1, \eta_2 > 0$. Because the inputs in the production of achievement are complementary, a

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[2] We normalize the coefficient on school achievement in the utility function to one in order to facilitate the calculations. Changing this coefficient simply amounts to re-scaling the other parameters.

[3] The marginal cost of monitoring is straightforward but the marginal benefit is not, as explained later. Hence, binary monitoring greatly simplifies our computations and facilitates the interpretation of results.

[4] De Fraja and Landeras (2006) model the cost of effort in a similar fashion. It could be argued that the household might outsource its learning or monitoring effort, perhaps by hiring a party in charge of supervising children's homework or monitoring the school. However, this party's effort would also be subject to moral hazard and would hence require parental monitoring. We avoid these complications by assuming that learning and monitoring efforts cannot be outsourced. We also avoid modeling the opportunity cost of the time spent in monitoring and learning efforts. Lower-income households may face a lower opportunity cost of time, which would induce them to provide more monitoring and learning efforts holding other things constant. However, they are more likely to be single-parent households, in which parents may work multiple shifts and carry out more non-educational activities for the household, thus having less time to provide monitoring and learning efforts. A complete modeling of this problem would endogenize labor supply and income as a function of parental human capital and household type (single- v. two-parent). Our modeling choices reflect the desire to avoid these complications.

household will exert greater learning effort when attending a school where teachers work more and fellow students are more able.[5]

2.2. Private schools

School effort can be provided by private or public schools that incur a production cost equal to Ae^{λ} (with $A > 0$ and $\lambda > 1$). This can be viewed as the teaching and administrative costs of running a school – for instance, wages paid to teachers and staff who have a reservation wage for each level of effort e. We assume that private and public schools share the same production cost, as is the case if they procure school effort from the same market for teachers and staff.

We assume private schools are competitive firms that set admission criteria and cater to specific household types. While a private school would like to attract the highest possible income and ability types, free entry guarantees that these households can always find a provider that caters to them exclusively. In equilibrium, these households attend a school where all the students come from the same household type. Since the argument applies to each household type, it follows that in equilibrium, a private school formed by households of ability μ has $q = \mu$. Furthermore, we assume one household per school.[6]

In return for its services, a private school charges tuition T. If school effort were observable to the household, then perfect competition among identical private schools would lead to $T=Ae^{\lambda}$ in equilibrium. To capture the potential agency conflict due to the unobservability of e, we distinguish the private school *effort standard* (or *promised private school effort*), denoted e^{pri}, from the actual, delivered school effort e. For instance, the school may claim to offer elements such as personalized instruction, a highly stimulating learning environment,

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[5] Partly due to lack of data, very few studies estimate achievement functions incorporating *all* these inputs. Stinebrickner and Stinebrickner (2008) document that extra study time has large, positive effects on achievement. De Fraja et al (2008) develop a structural framework in which school and household efforts are determined simultaneously. They find that each of these efforts affects achievement positively, and that higher ability children exert higher effort. Parental effort is positively correlated with household income and SES. Several of these findings are echoed in Bonesrønning (2004), Datar and Mason (2008), and Houtenville and Conway (2008). Moreover, Bonesrønning (2004) and Datar and Mason (2008) find evidence that school and parent efforts are complementary. Houtenville and Conway (2008) show that school resources seem to crowd out parental effort, though the crowd-out effect is inconsequential. Complementarity of school and household effort creates a multiplier effect for policies that affect school effort by indirectly affecting household effort. Our qualitative findings hold even if these inputs are substitutes, provided their elasticity of substitution is not too high.

[6] Ferreyra (2007), McMillan (2005) and Nechyba (1999) have modeled private schools in the same way. If there is one household per type, then there is also one private school per type. If there are multiple households per type, then they are indifferent between attending a private school with one household and a private school with multiple households of the same type.

highly qualified teachers, a novel and rigorous curricula, etc., yet deliver less than it promises because these elements are not observable and/or measurable to the parents. As will be shown below, the unobservability of effort leads parents to pay a tuition higher than the effort cost.

While the school can choose a level of e different from e^{pri}, household monitoring serves to limit the extent of the effort deviation. In particular, the profit of the private school is given by

$$\pi^{pri} = T - Ae^{\lambda} - \frac{\alpha\, m}{2}(e^{pri} - e)^2 \qquad (4)$$

where α is positive and m denotes the level of monitoring provided by the household (see more on this below). Equation (4) captures the tradeoff faced by the school when choosing its effort. Since the household does not observe school effort, the school has an incentive to choose an effort below its promise in order to minimize its production cost, Ae^{λ}. In other words, the school has an incentive to exploit the information asymmetry to its advantage. Household monitoring, however, disciplines this incentive. Through the quadratic cost for the effort deviation we assume that small deviations from e^{pri} are costless to the school, so in equilibrium there will always be a (downward) effort distortion equal to ($e^{pri} - e$). Thus, monitoring raises school effort, but not up to the promised level.

As (4) shows, household monitoring is critical to the effort provided by the school in equilibrium, since higher monitoring reduces the effort (input) distortion directly.[7] In contrast, in a fully specified agency model, monitoring reduces the input distortion indirectly. It produces output measures which contain imperfect information about the agent's effort and are used explicitly in an optimal pay-for-performance contract. This contract, in turn, affects the input provision. However, as long as monitoring and the optimal contract do not completely solve the agency problem, there will be some input distortion in equilibrium. Our model captures this key agency feature in a reduced-form fashion. It does not capture, however, other insights from the fully specified agency model, such as the use of performance metrics in contract design. In Appendix A we provide a model extension which incorporates output measures omitted from the reduced form model presented here.[8]

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[7] Duflo et al (2009) provide evidence that parental involvement in school management (a proxy for parental monitoring) improves teacher effort and achievement and thus affects school effort as implied by equation (4).

[8] Input-based monitoring also has empirical support. Based on randomized evaluations in the Third World, Banerjee and Duflo (2006) conclude that if the goal of an intervention is to boost the provision of an input (such as teacher attendance), then the incentives must target the input rather than the output. In our model, the financial incentives (represented by the quadratic term in equation 4) are indeed related to the input. Input-based monitoring, in turn,

Assuming the school is price-taker with respect to T, then for any given e^{pri} the school chooses e to maximize π^{pri} :

$$e^* = f(e^{pri}) \in argmax\ \left[T - Ae^{\lambda} - \frac{\alpha\, m}{2}(e^{pri} - e)^2\right] \tag{5}$$

This, in turn, yields $e^{pri}=f^{-1}(e)$. In other words, for each standard e^{pri} set by the school (or requested by the consumers) there is an effort level e effectively provided by the school (and purchased by the consumers). Competition drives each private school's equilibrium profit to zero: $\pi^{pri}=0$. Thus, after substituting the first-order condition from equation (5), the equilibrium tuition T^* for each e^{pri} (and the corresponding actual e) becomes:

$$T^*(e) = A[f(e^{pri})]^{\lambda} + \frac{\alpha\, m}{2}(e^{pri} - f(e^{pri}))^2 = Ae^{\lambda} + \frac{A^2\lambda^2}{2\alpha\, m}e^{2(\lambda-1)} \tag{6}$$

As a result, the equilibrium tuition covers the production cost of effort *as well as* the agency cost (first and second term of the last equality in equation 6, respectively), even though the private school market is competitive.[9] This is consistent with the standard intuition of agency theory (Holmstrom 1979) by which the price of any given effort is higher than its actual production cost, with less effort being provided than under perfect observability.

Importantly, the agency cost is partially mitigated by monitoring, as higher monitoring leads to higher school effort and lower agency costs. As will be discussed below, a household attending a private school always chooses a positive level of monitoring. Moreover, the assumption of one household per school implies that monitoring in private schools is a private good. This allows us to focus on the monitoring *gap* between public and private schools rather than the absolute level of monitoring in each school.[10]

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does boost output (Duflo et al 2007). In the developed world, the Ofsted Reports in England exemplify a public monitoring of schools that evaluates inputs and outputs. See http://www.ofsted.gov.uk/oxedu_reports/download/%28id%29/116266/%28as%29/134943_345339.pdf for an example of the evaluator's attention to inputs such as teaching quality and practices in this particular school.

[9] The reason is that agency cost is systematic, as effort is not observable in any school. For instance, suppose a competing school wished to undercut the incumbent by lowering the tuition from $T^*(e')$ to $T=A(e')^{\lambda}$ for a customer interested in purchasing e' with an associated $e^{pri}=f^{-1}(e')$. Since $T=A(e')^{\lambda}$ does not cover the agency cost, the undercutting school would incur a loss. If the undercutting school promises the household e' (i.e., $e^{pri}=e'$) and contemplates delivering e', the school and the household would quickly realize that the optimal choice of e is $e''=f(e')$, not e'.

[10] With multiple households in the same private school, a household's monitoring effort may depend on the monitoring of the other households. We assume that households of a given type behave symmetrically given that they are identical. Under this assumption, if monitoring is binary then two pure-strategy equilibria on monitoring are possible: no-monitoring and full-monitoring, in which either no household monitors or all households monitor, respectively. If the monitoring cost is too low (high), the no-monitoring (full-monitoring) equilibrium may not exist. The full-monitoring equilibrium, if it exists, is the same as the equilibrium which results from assuming one

2.3. Public school

In addition to private schools, a public school exists in this economy.[11] All households are eligible to attend public school. This school derives its public character from its funding through tax revenues, the absence of tuition, and the fact that households in the school are not allowed to supplement school effort. We assume that the policymaker exogenously sets an *effort standard* for the public school (or *promised public school effort*), denoted by e^{pub}. Private schools, in contrast, set their own standards.

The public school is also subject to an agency problem because neither the households nor the policy maker observe its actual effort. The policymaker procures services from the school and pays X per student regardless of the school's effort (as in McMillan 2005 and Chakrabarti 2008). The implicit assumption is that the policymaker can easily verify public school enrollment but not public school effort. The public school's profit is then

$$\pi^{pub} = \left(X - Ae^{\lambda}\right)N - \frac{\alpha\, M}{2}\left(e^{pub} - e\right)^2 \qquad (7)$$

where N is total enrollment, and M is the sum of monitoring efforts from households attending public school. The second term of the objective function captures the agency cost. In contrast with private schools, monitoring at the public school is a public good. As long as some households provide monitoring effort, it may be optimal for another household to free-ride on others' effort and not provide its own. For a given N, the returns to monitoring for a given household are lower the higher the M (i.e., there are decreasing returns to monitoring), and the lower the e^{pub} and α. The potential free-riding in monitoring introduces an additional distortion relative to private schools, as it leads to the under-provision of monitoring in public schools.[12]

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household per private school. The same thing is true for the no-monitoring equilibrium. If both equilibria exist, full-monitoring dominates no-monitoring because it yields a positive school effort. Hence, in the paper we focus on the more interesting full-monitoring equilibrium. If monitoring is a continuous choice and multiple households of the same type attend the same private school and behave symmetrically, then free-riding may arise in private schools. In this case, some households may leave their current private school and start a new, smaller private school to reduce free-riding. Without fixed costs, this leads to one household per private school in the limit.

[11] Assuming one public school is equivalent to assuming one public school district with multiple public schools and open enrollment. The Chicago Public Schools district, with its extensive public school choice program (Cullen et al 2006), is a good example of this setting. A multi-district setting would be an interesting extension yet one outside the scope of this paper, as it would necessitate the treatment of housing markets and voting over policy parameters.

[12] The model entails the possibility that a given household might monitor in private school but free-ride in public school. We do not know of any evidence comparing the monitoring behavior of the same households in public and private schools. However, for the Milwaukee voucher program, Witte et al (2008) provide evidence that voucher-

Public school funding is another source of friction. Competition among private schools ensures that each private school's tuition T is tied to the school's effort standard e^{pri} and hence actual effort e, and is exactly enough to cover the school's cost (or $\pi^{pri} = 0$). In contrast, public school funding per student X is determined exogenously by the policymaker and is not necessarily tied to the public school effort standard e^{pub} or actual effort e. Moreover, X may be such that the school earns a rent equal to $\pi^{pub} > 0$ in equilibrium.[13] This additional friction further raises the fiscal cost of the public school.

2.4. Model summary, timeline and equilibrium

The timeline of events in this one-period model[14] is as follows:

1. Funding level X and public school effort standard e^{pub} are established;
2. Households simultaneously choose school, monitoring effort, learning effort, and consumption;
3. Schools choose school efforts.[15]

We now elaborate on this sequence. First, X and e^{pub} are exogenously determined. In reality, many forces can affect these policy parameters, including the potentially conflicting influence of policymakers, households and schools, social norms, etc. While the actual determination of these parameters is an interesting political economy problem, here we focus on information asymmetry and equilibrium monitoring taking e^{pub} and X as given. Second, given that the school chooses

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using parents have higher levels of involvement than comparable parents with children in public schools. For the privately funded DC voucher program, Wolf et al (2001) conclude that voucher-using parents are more likely to monitor the school than public school parents. This greater monitoring is facilitated, in part, by the fact that private schools provide more information to parents (i.e., monitoring costs are lower at private than public schools).

[13] Although we model a competitive teacher market, we can interpret the rents as being re-distributed among public school teachers, such that a public school teacher's total compensation exceeds that of a private school teacher for a given effort. Naturally this creates incentives for teachers to select public over private schools. Since we do not model how teachers are assigned to public or private schools, we can think of this assignment as random. Endogenizing teacher sorting is an interesting yet complex extension of this model, beyond the scope of this paper.

[14] In reality, education occurs over an extended period of time, only at the end of which may achievement be measured perfectly. We equate this period to our model's one period. Hence, our model does not capture the many interim actions that in reality take place over that period. For instance, schools deliver effort each year, and households make enrollment and monitoring choices partly based on schools' past efforts. Thus, households could plausibly collude in order to discipline schools. A static model does not allow the parties to use future actions in order to affect each others' current actions – a device that would help mitigate the agency problem. This interesting extension is beyond the scope of our paper.

[15] This timing is critical to the model. For household monitoring to have an impact on public school effort, the threat induced by monitoring must be credible. If monitoring is chosen last, then the household has no incentive to choose a non-zero monitoring effort. Anticipating the zero monitoring, the public school would disregard the agency cost unless there were monitoring from a non-household source such as the state.

actual effort last, the household can anticipate the school effort it will receive conditional on its own choices. If attending a private school, the household chooses c, e^{pri}, a, m to maximize

$$U = c^{\beta} s(e, a, \mu) - \rho_a \frac{a^2}{2\mu} - \rho_m \frac{m^2}{2\mu}$$

subject to

$$(1-t)y = c + T$$

$$e \in argmax\ \ \pi^{pri} = \left(T - Ae^{\lambda}\right) - \frac{\alpha\, m}{2}(e^{pri} - e)^2$$

$$T = Ae^{\lambda} + \frac{\alpha\, m}{2}(e^{pri} - e)^2$$

Notice that zero monitoring leads to a degenerate outcome because in the absence of monitoring, the private school rationally provides e=0, which leads to zero achievement s and thus zero household utility. Hence, a household that attends a private school always chooses a positive level of monitoring (in the case of binary monitoring, the household chooses m=1).

If attending the public school, each household chooses c, a, m to maximize

$$U = c^{\beta} s(e, a, q) - \rho_a \frac{a^2}{2\mu} - \rho_m \frac{m^2}{2\mu}$$

subject to

$$(1-t)y = c$$

$$e \in argmax\ \ \pi^{pub} = \left(X - Ae^{\lambda}\right)N - \frac{\alpha\, M}{2}(e^{pub} - e)^2$$

When making these choices, the household takes the tax rate, public school per quality and other households' school and monitoring choices as given. After comparing the equilibrium values of the two school choices, the household chooses the school that provides the higher utility (in case of a tie, we assume that the household attends public school). Importantly, the household "sees through" the schools' optimization problem and hence anticipates their optimal effort choices – namely, the household correctly anticipates the school effort distortion for each level of parental monitoring and chooses a and m accordingly.

An equilibrium consists of a set of household and school choices that satisfy the following:

- Household rationality: conditional on other households' choices, no household has an incentive to deviate from its own optimal choices.

- School rationality: each school chooses school effort to maximize its own profit, and the school is open only if its profits are non-negative.
- Market clearing: each household attends one and only one school and total tax revenue equals total public school funding: $t\sum_{i}^{H} y_i = XN$.

If an equilibrium exists, it satisfies the following properties:[16]

1. Income and ability stratification over school choice. If a household attends a private (public) school in equilibrium, any household with the same ability but higher (lower) income will also attend a private (public) school. Similarly, if a household attends a private (public) school in equilibrium, any household with the same income but higher (lower) ability will also attend a private (public) school.
2. Income and ability stratification over parental monitoring in public school. If a household monitors the public school in equilibrium, any public school household with the same ability but higher income (or with the same income but higher ability) will also monitor it. Similarly, if a household does not monitor the public school in equilibrium, any public school household with the same ability but lower income (or with the same income but lower ability) will not monitor it either.
3. Greater effort distortion in public school for a given school effort standard. The school effort distortion is larger in public than private schools as long as not all public school households monitor.

Formal proof of these properties is in Appendix B; here we offer some basic intuition. First, stratification over school choice is common to other models as well (Epple and Romano 1998); as in those models, it follows from properties of household preferences.[17] Second, stratification over monitoring follows from the variation of monitoring costs and benefits across households. Recall that monitoring costs are inversely related to household ability. Since school and household learning effort are complements, monitoring benefits a household because it raises achievement directly (by raising school effort) and indirectly (by leading to an increase in learning effort); these benefits are highly nonlinear and do not have a closed-form solution. The

[16] We assume binary monitoring when proving these properties. We cannot characterize the equilibrium analytically if monitoring is continuous.
[17] For instance, household preferences in our model satisfy single-crossing by income as in Epple and Romano (1998). See Appendix B for further details on the preference conditions that deliver the stratification results.

increase in learning effort is higher for higher ability households, for whom the cost of learning effort is lower. Since achievement and consumption are normal goods, the demands for school and student effort are also normal. Hence, the increase in learning effort is higher for higher income households. Third, if a private and public schools promise the same effort but monitoring is higher at the private school, then actual school effort is also higher there because for a given promise, actual effort is increasing in parental monitoring.

Though we do not have a formal proof for the existence of equilibrium, we have established conditions sufficient to determine whether an allocation is an equilibrium and have developed an algorithm that relies on them in order to compute the equilibrium.[18]

2.5. Policymaker and policy alternatives

In addition to the policy parameters X and e^{pub}, the policymaker may choose values for other policy parameters as well. For instance, he may implement public monitoring of public schools, or private school vouchers, the parameters of which we also view as exogenous. Public monitoring is inspired by public school accountability programs that provide incentives for public schools to raise achievement while attaching consequences to school outcomes. We operationalize this alternative by introducing a public monitoring effort, M_0, which changes the public school profit function as follows:

$$\pi^{pub} = \left(X - Ae^{\lambda}\right)N - \frac{\alpha\,(M + M_0)}{2}\left(e^{pub} - e\right)^2 \tag{8}$$

Since we assume that public monitoring is costly, the state budget constraint changes to:

$$t\sum_{i}^{H} y_i = XN + \kappa M_0 \tag{9}$$

where κ is the unit cost of public monitoring.[19]

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[18] We conjecture that our equilibrium is unique, and this conjecture is supported by the fact that we have never found multiple equilibria in our computational application although our algorithm can find all equilibria for a given parameter point. Multiple equilibria could arise if the model were able to deliver both an equilibrium in which the public school offers high effort and all households monitor, and an equilibrium in which the public school offers low effort and no household monitors (a "good" and "bad" equilibrium, respectively). For both equilibria to be possible, the public school must include a variety of households – some for which monitoring has high cost and low payoff, and others for which monitoring has high payoff and low cost. Assuming the public school includes such household variety, consider the bad equilibrium. A household with low-cost, high-payoff monitoring is better off monitoring than not because of the greater school effort it can induce, even if other households free-ride on its monitoring. Hence, the bad equilibrium is not sustainable. Alternatively, such a household could switch into a private school, in which case the good equilibrium would not be sustainable.

Vouchers are tuition subsidies for private schools. We consider both universal and income-targeted vouchers. We assume that they are funded by the state through income taxes, and that the voucher dollar amount can depend on household income as denoted by the voucher function $v(y)$. With universal vouchers, $v(y)=v$ for all y. A household may supplement the voucher with additional payments toward tuition but cannot retain the difference when the tuition is lower than the voucher level. Hence, the tuition is never set below the voucher level. Under vouchers, the household attending a private school faces the following budget constraint:

$$(1-t)y = c + \max(T - v(y), 0) \quad (10)$$

To summarize, in this section we have described our theoretical model and stated properties of the equilibrium. Since the model does not have a closed-form solution, we compute the equilibrium numerically. Thus, the next section provides some computational details.

3. Computational Version of the Model

To analyze the model, we must first choose adequate values for the parameter vector $\theta=(\beta, \eta_1, \eta_2, \lambda, A, e^{pub}, \alpha, \rho_a, \rho_m)$. Hence, we calibrate our model to 2000 data for the United States K-12 educational system. The calibration strategy is to compute the equilibrium at alternative parameter points in order to find the point that minimizes a well-defined distance between the predicted equilibrium and the observed data. Since the equilibrium does not have a closed-form solution, we solve for it through a numerical algorithm for a tractable representation of the economy. Hence, in this section we describe this representation, our calibration strategy, and the fit of our model to the data.

Our computational representation of the economy includes five income types, whose incomes equal the 10^{th}, 30^{th}, 50^{th}, 70^{th} and 90^{th} percentile of the 2000 national income distribution for households with children in grades K through 12. This distribution comes from

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[19] Modeling M_0 as an additive term is more general than it might seem. The key issue is that public monitoring changes the marginal benefit of private monitoring – which, in turn, differs among households. Hence, aggregate private monitoring M can go up or down in response to M_0 depending on its level before the introduction of public monitoring, the cost of public monitoring, and other parameters of the problem. The simulations presented in Section 5 illustrate this point. Thus, our formulation allows for public monitoring to behave either as a substitute or as a complement of aggregate private monitoring. Hassrick and Schneider (2009) report that parents who face barriers to private monitoring (less access to school staff and other parents, difficulties getting to the school, etc.) rely more on formal lines of accountability and authority. This is in line with the evidence from Figlio and Kenny (2009) cited below. In other words, some parents seem to view public and private monitoring as substitutes.

the 2000 School District Data Book. All dollar amounts are expressed in dollars of 2000. We include five ability levels, equal to the 10^{th}, 30^{th}, 50^{th}, 70^{th} and 90^{th} percentile of the IQ distribution (a normal distribution with a mean of 100 and a standard deviation of 15). In the absence of direct evidence on the joint distribution of income and ability, we assume that they are independently distributed. Our setting of income and ability types yields twenty-five household types, with one household per type. Since sensitivity analyses conducted for larger numbers of household types have shown the robustness of the equilibrium at the calibrated parameter values, we simplify our computations by working with twenty-five household types. We set per-pupil spending in public schools, X, equal to the observed national average of $7,000. Since we assume for computational purposes that monitoring effort, m, is binary, total monitoring in public school, M, equals the number of public school households who monitor.

To calibrate the model, we choose the parameter point that best matches the observed values of nine variables of interest. Appendix C offers further details on the construction of these variables. The first is fraction of households with children in private schools (equal to 0.16 according to the 2000 School District Data Book). The second is average income for households with children in private schools (equal to $82,800 according to the 2000 School District Data Book). The third is average private school tuition (equal to $5,000 according to US Department of Education 2002). The fourth is proportional difference between average public and private school teacher salaries (equal to 0.44 according to the 1999-2000 Schools and Staffing Survey). When we compute predicted salaries we work with teacher compensation rather than salaries, as we assume that public school profits are re-distributed among teachers.

The fifth variable is difference between average effort among private v. public school teachers (equal to zero standard deviations according to the 1999-2000 Schools and Staffing Survey). In our model, effort is a productive input – the more of it that is used, the higher the achievement. In the absence of perfect measures for this input, we use number of hours worked by teachers. The sixth variable is difference in average achievement between private and public school students (equal to 0.45 standard deviations according to the 2000 National Assessment for Educational Progress). The seventh variable is difference in average ability between private and public school students (equal to 0.76 standard deviations according to Epple et al (2004)'s calculations based on the National Education Longitudinal Survey).

The eighth variable is difference in average student effort between private and public schools (equal to 0.5 standard deviations according to the 2004 Digest of Education Statistics). In the absence of good empirical measures for student effort, we use average number of hours spent doing homework per week among high school students in 2004. The ninth variable is the fraction of households who monitor in public schools. Normalizing the private school average to 1 since our model views private schools as a benchmark of full parental monitoring, we arrive at a public school monitoring rate of 0.76 based on the 1999 Digest of Education Statistics.

We use y_j to denote the observed values of the variables we are matching, j=1….9. As we search over the parameter space, for each value of the parameter point θ we compute the equilibrium, from which we extract the predicted values $\hat{y}_j(\theta)$, j=1….9, for the variables listed above (see Appendix C for a description of the equilibrium computation). Thus, we choose the value for θ that minimizes the following distance between the data and the model's predictions:

$$L(\theta) = \sum_{j=1}^{9} w_j (y_j - \hat{y}_j(\theta))^2 \quad (11)$$

where the distance for variable j is weighed by a factor which is inversely related to the precision in the variable's measurement. In particular, the first four variables are measured with greater precision than the others in the sense that their empirical counterparts are more adequate, and for the fifth through eighth variable we are likely to observe a lower bound for the actual construct of interest (see Appendix C for further details). Note both the non-linearity of the model and the coarseness of our household representation prevent us from matching the data exactly.

Table 1 shows the parameter values delivered by our calibration. Table 2 lists the observed and predicted values for the matched variables. As one would expect given their measurement, the first four variables are matched better than the following four, and the fifth through eight variables are over predicted. Overall, however, we are encouraged by the model's fit to the data.

In an equilibrium model such as ours, changes in one parameter trigger changes in several endogenous variables. However, it is still possible to identify computationally the first-order effects of parameter changes on the variables that are matched in the calibration, and Appendix C describes these effects.

4. Analyzing the equilibrium

In this section we first analyze the computational equilibrium of our model (henceforth called “benchmark” or “baseline” equilibrium). A central contribution of our paper is modeling informational frictions in education. To highlight their role, we also analyze the equilibrium that would prevail if there were perfect observability in the economy – namely, if school effort were perfectly observable (if $e^{pub}=e$ and $e^{pri}=e$ in public and private schools, respectively), thus rendering household monitoring unnecessary. In this case, tuition at private schools would be equal to the cost of teacher effort, and profits for the public school would be equal to $B^{pub}=(X-Ae^{\lambda})N$. In addition, we investigate the equilibrium response to changes in the public school effort standard, and the distribution of household preferences over public school policy parameters.

4.1. Benchmark Equilibrium

Column 1 of Table 3 displays the model’s equilibrium computed at our parameter values. In the baseline, 84 percent of households attend public school. As the top panel of Figure 3 shows, high-ability, high-income households attend private schools, which is consistent with the first equilibrium property. All private school households monitor, yet the lowest-income households in public school do not monitor – which is consistent with the second equilibrium property. On average across schools, the model predicts greater monitoring among higher income households. This prediction has empirical support (see US Department of Education 2002, Table 25), which lends further validity to our model since the positive correlation between monitoring and income was not used in the calibration.

Spending per student is higher in public than private schools. However, private schools promise and deliver higher effort. This is because private schools attract higher income households, whose demand for school effort is higher. This higher income, coupled with higher ability, leads to higher monitoring in private schools. This ensures higher school effort, which is consistent with De Fraja et al (2008)’s finding that schools larger proportions of high SES students exert more effort.

Although the cost of effort is higher for private schools given their higher teacher effort, teacher compensation is higher for public school teachers because of the public school profit, redistributed among teachers. Of its total revenue, the public school spends 59 percent to cover its cost (44 percent pays for teacher effort, and 15 percent pays for agency costs), and captures the remaining 41 percent as a rent. Private schools, in contrast, enjoy zero profits and spend almost 80 percent of their revenue in teacher effort. In other words, private schools use funding more efficiently than public schools.

Since students in private schools have higher ability and income and enjoy higher teacher effort and peer quality, they produce higher learning effort. As a result of having more of each input, private schools deliver higher achievement.

Column 2 of Table 3 describes the equilibrium under perfect observability. As standard agency intuition would indicate, school effort is higher than in the presence of moral hazard. In particular, average school effort is approximately 30 percent higher in each type of school. Although eliminating the need to monitor makes private schools more attractive, the higher effort exerted by public schools raises public school attendance. As the top panel of Figure 5 shows, only the highest-income, highest-ability type remains in private school. Hence, greater observability reduces the stratification of students across schools and promotes greater mixing in the public school. Household learning effort rises across the board in response to higher school effort. This, in turn, boosts average achievement.

Note, however, that perfect observability does not eliminate public school rents because public school funding is fixed regardless of school effort. Since more students attend public schools, the tax rate is higher. However, overall welfare is also higher due to the higher achievement and the elimination of costly monitoring.

4.2. The Role of Effort Standard in Equilibrium Choices

Although we assume that public school funding is relatively inflexible, perhaps due to institutional rigidities in the educational budget allocation process, the public school effort standard (e^{pub}) is likely more flexible. As is clear from (7), a change in the effort standard will alter public school profits. Furthermore, it may also alter public school effort and household choices. Hence, the top panel of Figure 1 depicts the equilibrium value of public school profit for alternative values of the effort standard (recall that at our parameter values, e^{pub}=0.66). The bottom panel depicts the equilibrium actual public school effort, fraction of households attending public schools, and public school monitoring rate as a function of the effort standard.

For low values of effort standard, profits are positive but flat. Since the actual effort is lower than the effort standard, only 20 percent of households (at the bottom of the income distribution) attend public schools. These households derive negative payoffs from monitoring, so they choose to attend public school and not monitor. This, in turn, allows the school to deliver zero effort and enjoy a rent of $7,000 per student.

As the value of the effort standard rises, profits first rise and then fall. However, public school attendance, effort and monitoring rate rise steadily. This is because a higher effort standard attracts higher-income, higher-ability households. As these households join the school they also monitor it, which in turn forces the school to offer a positive (and increasing) effort. While higher attendance increases revenue and rents for a given effort, higher effort and monitoring reduces profits. As long as the first effect dominates, profit is increasing in effort standard; the reverse happens when the second effect dominates, eventually leading to negative profits (a situation not displayed in Figure 1, as it is not an equilibrium).

The top panel of Figure 1 also suggests that in an environment where funding is not flexible, the policymaker can eliminate or at least minimize rents by choosing the appropriate effort standard, equal to 0.85 in this case (a higher effort standard would yield negative profits to the public school). As we will see later, this is the same standard that households would choose if they were able to do so. This standard is certainly higher than that implied by the data, equal to 0.66. Similarly, this panel also suggests that if the public school were able to choose its optimal effort standard, it would maximize its profit at e^{pub}=0.60. The school's optimal standard is quite close to that implied by the data, indicating that public schools might play a strong role in the determination of effort standards. The optimal standard from the point of view of the school is high enough to attract a sufficiently large number of students, yet low enough to attract relatively few high-ability, high-income monitoring households.[20]

The effort standard has clear achievement and distributional impacts. Column 2 of Table 4 shows the equilibrium when the effort standard minimizes public school profit. For

[20] Since schools move last in this model and have an incentive to under-provide effort relative to their standard, one can view the public school's preferred e^{pub} as a commitment device by which the school forces itself to offer a positive rather than zero effort.

comparison, column 1 shows the benchmark equilibrium. Since the public school's optimal effort standard and the current standard are very close, so are the corresponding equilibria. Yet column 2 shows that in the zero-profit equilibrium, public school effort, attendance and monitoring are higher than in the baseline, and public schools use their revenues more efficiently. Greater school effort raises student effort and hence achievement. Although taxes are higher to pay for more public school students, welfare is also higher.[21]

4.3. The Role of the Two Frictions

One could ask whether the pattern displayed in Figure 1 is driven by the informational or the funding friction. Hence, in Figure 2 we compare public school profit, effort and attendance under imperfect and perfect observability (recall that the monitoring rate is zero under perfect observability). As the figure shows, public school profit, effort and attendance behave similarly in both cases with respect to the effort standard. In other words, those patterns seem largely driven by the funding friction. In the specific case of school profit, higher effort attracts more students into the school (hence raising total rents) but also raises per-student costs (hence lowering per-student rent). Profits rise or fall with respect to effort depending on whether the first or second effect prevails, respectively. Imperfect observability strengthens this pattern: on the one hand, it can lower agency costs for a given monitoring level; on the other hand, it can raise agency costs for a given effort level by attracting households that will choose to monitor.

In addition, note that under perfect observability actual effort falls on a 45 degree line, as promised and actual efforts are equal. Actual effort is always positive, though it is zero for low values of effort standard under imperfect observability. Despite this ever-positive effort, no household attends public schools when effort is very low. The reason is that absent the need to monitor, even the lowest-income, lowest-ability households prefer to attend private schools because these can offer levels of effort higher than e^{pub}. In contrast, under imperfect observability monitoring costs create a captive audience for public schools because the lowest-income, lowest-ability segment always chooses them.

[21] Costrell (1994) models the determination of output-based (graduation) standards and analyzes their achievement and distributional consequences. His setting is different from ours in that he does not model school effort, information asymmetries or equilibrium effects.

Moreover, effort is higher under perfect observability. Thus, for an effort standard above 0.27 public school attendance is higher as well. Higher effort raises attendance but also teacher costs relative to imperfect observability. As long as the first effect prevails, profits are higher under perfect than imperfect observability; the reverse happens when the second effect prevails.

In an environment with perfect observability and inflexible funding, the policymaker would minimize public school profits by mandating an effort less than or equal to 0.15. The profits would be eliminated simply because no household would attend public schools. If the policymaker were committed to keeping the public school open while still minimizing its rent, it would mandate an effort equal to 0.7 (higher levels of effort would generate negative profits). Once again, this is the same effort preferred by households, as we will see later.

Columns 4, 5 and 6 of Table 4 display the perfect observability equilibrium when the public effort standard completely eliminates profits, when minimizing them while keeping the public school open, and when maximizing them, respectively. For comparison, column 3 displays the perfect observability equilibrium. If one views column 4 as the first best in which neither informational nor funding distortions exist, then it is clear that the first best can be attained without public schools. As one would expect, of all the scenarios presented in this paper, this one commands the highest aggregate welfare. Yet relative to the other perfect observability scenarios (columns 3, 5 and 6), some households in the first best enjoy *lower* achievement given the absence of public schools with mandated effort standards, and lower utility. This is because left to their own devices, these households choose a lower school effort (and achievement) than the policymaker's. Thus, effort standards play an important role when the policymaker has a minimum-proficiency goal for every student in the population.

An interesting question is whether the two frictions in our model compound each other. To address this question, first note that average school effort is equal to 0.51 and 0.70 in the benchmark equilibrium and in the minimum-profit, perfect observability equilibrium respectively (see columns 1 and 5 of Table 4; column 5 depicts the best attainable scenario if one is committed to keeping public schools open and with fixed funding). The combination of the two frictions lowers average school effort by 27% in the benchmark equilibrium. As it turns out, the effect of the information asymmetry is indeed aggravated by the funding distortion: when the effort standard minimizes public school profit, the distortion in average effort is equal to 0.06 (compare 0.70 from column 5 with 0.64 from column 2), but when the effort standard is equal to the calibrated value of 0.66, the distortion in average effort is equal to 0.16 (compare 0.67 from column 3 with 0.51 from column 1). From a policy perspective, this says that while the information friction systematically leads to under-provision of effort, the policymaker could mitigate this effect by choosing the effort standard that minimizes public school profits – which is, again, the same standard preferred by households.

Nonetheless, the pervasiveness of information asymmetry suggests that lowering monitoring costs might deliver important gains by moving the economy closer to perfect observability. Public provision of information about schools is one way of doing this. Recent policies such as school choice and accountability have created a wealth of information about public school performance, and the literature documents that parents are indeed responsive to it (Figlio and Lucas 2004), including low-income parents (Hastings et al 2007).

5. Policy Analysis

In this section we study the effects of two alternative policies: public monitoring of public schools, and private schools vouchers. Then we explore the distribution of household preferences over policy parameters.

5.1. Public Monitoring

In order to simulate public monitoring, we need to choose values for its level (M_0) and unit cost (κ). We parameterize the level as follows: $M_0 = m_0 N$, and use N=21 in our calculations since this is the benchmark equilibrium public school attendance. Henceforth we refer to m_0 as the intensity of public monitoring, and use m_0 equal to 0.25, 0.5 and 0.75 to denote low-intensity, medium-intensity and high-intensity public monitoring respectively.

Hoxby (2002a) argues that accountability is a low-cost policy. While this may be true for the implementation of a mere testing system, we consider a kind of monitoring that actually affects school effort. This might entail detailed evaluations of public school performance, direct observation of classroom and administrative practices, etc. Lacking direct empirical evidence on the cost of this type of policy, we calibrate the unit cost of M_0, κ, as follows. We assume that the cost of public monitoring is proportional to total public school funding, i.e., $\kappa M_0 = \gamma XN$, where γ is a factor of proportionality. Hence, $\kappa = \gamma X / m_0$. We calculate κ as the unit cost of low-intensity monitoring in the baseline equilibrium, or $\kappa = \gamma * \$7{,}000 / 0.25$.

Columns 2 through 9 of Table 5 describe the equilibrium for several combinations of public monitoring intensity and unit cost. To facilitate comparisons, column 1 presents the benchmark equilibrium, without public monitoring. By raising the cost of deviating from the effort standard, public monitoring raises public school effort in all these scenarios. The more intense the public monitoring, the greater the effort for any given cost. The prediction that public monitoring leads to higher effort is indeed born in the data (Rouse et al 2007, Chiang 2009).

5.1.1. The Effect of Public Monitoring on Household Sorting and Monitoring

Public monitoring affects household school and monitoring choices, as shown in Figure 3. Relative to the benchmark equilibrium, public monitoring raises public school attendance by raising public school effort, as only the highest-ability, highest-income households remain in private school. However, the impact of public monitoring on household monitoring depends on several forces. On the one hand, public monitoring raises public school effort, hence attracting high-ability, high-income households away from private schools. The fact that these households monitor the public school can raise private monitoring, further increasing public school effort. On the other hand, public monitoring can crowd out private monitoring and thus lower it. An additional effect is that the entry of high-income, high-ability households into the public school can induce households for whom monitoring is more costly to free-ride on the newly arrived households and no longer monitor, also leading to a decrease in private monitoring.

The net outcome of these effects depends on the fiscal cost of public monitoring. When this cost is not too high the first effect prevails, yet the second and third effects dominate otherwise. For instance, Figure 3 shows that while public monitoring increases public school attendance and the number of monitoring households by attracting high-income, high-ability households into the public school, it also causes low-income households to stop monitoring when the fiscal cost of monitoring rises.[22]

To our knowledge, there have been no empirical studies of the response of private to public monitoring. The closest evidence we can find comes from Figlio and Kenny (2009), who document that when a school receives a low grade in the Florida accountability system, parents reduce their donations to the school because they perceive it as poorly run. Importantly, this is more pronounced among schools serving low-income or minority families. The reason is that disadvantaged parents tend to be less involved in the school and have less direct, first-hand information about the school's effectiveness. Thus, they rely more heavily on school grades and respond more strongly to them. In other words, public monitoring seems to crowd-out private monitoring more among disadvantaged parents, which is consistent with our model's predictions.

5.1.2. The Effect of Public Monitoring on Achievement and Welfare

An important question is whether public monitoring raises public school achievement. Once again, the answer to this question depends on the net effect of two forces. On the one hand, public monitoring raises public school effort and peer quality, both of which directly enhance achievement for a given level of household effort. In addition, both induce greater household learning effort. On the other hand, the fiscal cost of public monitoring lowers disposable income and hence the demand for household learning effort. When the unit cost of accountability is low, the first effect prevails and public monitoring raises household effort and achievement. When the unit cost of accountability is moderate or high, the second effect prevails and public monitoring lowers household effort and achievement. Hence, low-income households – who are often, in reality, the target of these policies – only gain when these policies cost little.[23]

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[22] To understand this response in monitoring behavior, recall that the cost of monitoring is related to household ability, yet its benefit is related both to income and ability. In addition, the fiscal cost of monitoring rises as the unit cost and/or the intensity of monitoring rise. This reduction in disposable income lowers the net payoff from monitoring for all households and makes low-income households stop monitoring. Although one could argue that public monitoring in reality might not be high enough to double or triple the benchmark fiscal burden as in the last columns of Table 5, we wish to emphasize that *effective* public monitoring might actually be quite costly. Hence, the kind of crowd-out and free-riding featured in these simulations might not be unlikely.

[23] The empirical evidence on the effect of accountability on achievement is quite mixed (see, for instance Figlio and Ladd 2008). Due to the lack of data, the literature does not disentangle the role of school and household (or student) effort in *school*-based accountability, although Jacob (2005) provides evidence that part of the achievement gains due to accountability in Chicago Public Schools were driven by greater student effort *at the test*.

Households that remain in private schools lose achievement because they lose disposable income as they pay higher taxes to fund public monitoring. Hence, they purchase less school effort and exert less household effort. Households that switch from private into public schools induced by public monitoring also lose achievement because of the loss of disposable income (that leads to lower household effort) and peer quality. Though the effect of public monitoring on *average* achievement is negative, most households gain achievement if the cost of public monitoring is sufficiently low. Interestingly, by raising school effort public monitoring attracts more households into public school and lowers student segregation across schools.

As Table 5 shows, public monitoring reduces public school rents, which is consistent with empirical evidence presented by Springer (2008).[24] Nonetheless, teacher compensation in public school (slightly) rises because public school teachers exert greater effort. In other words, public monitoring accomplishes the goal of raising teacher pay only as a function of effort.

The final effect of public monitoring on welfare depends on its effect on consumption (affected by the fiscal cost of public monitoring), achievement, and household learning and monitoring efforts. As Table 5 shows, only when the unit cost of accountability is very low ($\gamma < 0.05$) does public monitoring lead to welfare gains for most households. In other words, households would prefer to have no public monitoring if its cost were anything but very low.

5.2. Private School Vouchers

Table 6 shows the effects of private school vouchers for universal and income-targeted vouchers (columns 2-3 and 4-5, respectively). For comparison, column 1 shows the benchmark equilibrium, without vouchers. Whereas all households are eligible for universal vouchers, only households whose income is below a threshold ($50,000 in these simulations) are eligible for income-targeted vouchers. Since public school spending per student is $7,000, we consider voucher amounts of $3,500 and $7,000 ("low" and "high" voucher, respectively). Although income-targeted vouchers may be politically more feasible given their lower eligibility rate,

[24] Springer (2008) provides evidence that while accountability systems have yielded gains for below-proficient students in failing schools, these gains do not seem to have occurred at the expense of high-performing students in those schools. This "Pareto improvement" suggests that schools may not have been operating efficiently before accountability - i.e., that they may indeed have had an operational slack and that accountability may have spurred them to greater efficiency.

universal voucher simulations are of interest because they show the full effects of an unrestricted voucher. Figure 4 depicts voucher effects on household school choice and monitoring.

5.2.1. Universal Vouchers

As one would expect, universal vouchers increase private school attendance, and only low-income or low-ability households remain in public school. Not even a high voucher can persuade the lowest-income households to leave public schools, because the monitoring required in private schools is too costly for them. The departure of higher ability households from public school hurts them because they lose peer quality, and because those households would monitor if they remained in public school. Thus, private monitoring rate falls in public school, with a concomitant decline in school effort.[25] In particular, a high universal voucher leaves the lowest-income segment in public school with a school effort (and achievement) of zero.

Many, but not all of the households that take up the voucher gain school effort, peer quality or achievement. For instance, low-voucher amounts lead to lower tax rates, which in turn raise disposable income. Although this should increase household learning effort, for some households the loss of school effort or peer quality prevails and leads to lower household learning effort.[26] Thus, some households gain achievement while others lose. The higher the income or the ability, the more likely the household is to gain. In particular, more than half of the population gains achievement in these simulations.

Public school profit falls with vouchers due to the loss of students, yet a *high* universal voucher exacerbates the pre-existing efficiency gap between public and private schools. In this case, public and private school funding per student is the same since no household supplements the voucher. However, while private schools devote almost 80 percent of their funding to

[25] This result is in contrast to the standard argument that by creating competition, vouchers would raise public school effort. The reason is that in our model, the public school takes attendance and monitoring as given when choosing effort. Hence, a policy that reduces household monitoring (without compensating with greater public monitoring) also reduces school effort. Nonetheless, if we modeled the public school effort standard e^{pub} as being determined, at least in part, by the public school, then the public school would optimally raise e^{pub} in response to vouchers in order to mitigate enrollment losses.

[26] Howell et al (2006) present evidence that voucher-using students are assigned more homework than in public schools, and that those who switch in the upper grades find the schoolwork more difficult in private than public schools. In other words, for these students the gains in school effort and peer quality seem to prevail and lead to greater learning effort.

purchase teacher effort, all the public school funding constitutes rent since the school provides zero effort. Consequently, public school teacher compensation is as high as possible ($7,000).

Universal vouchers raise aggregate welfare relative to the benchmark equilibrium. However, a low voucher accomplishes a greater improvement than a high voucher (and yields welfare gains for more households) because of its lower fiscal cost.

5.2.2. Income-Targeted Vouchers

Given the income target in our simulations, 40 percent of the population is eligible for these vouchers (i.e., the households with income below the 50th percentile). As the last row of Figure 4 shows, not all the eligible population takes up the voucher. The lowest-income households do not use it because the cost of monitoring in private schools would be prohibitive for them. Only the ablest households from the 30th percentile of the income distribution use the voucher. The monitoring rate in public schools also falls with income-targeted vouchers though not as much as with universal vouchers because fewer households leave public school, which means that public school effort does not fall as much either. This creates additional reasons for low-income, low-ability households to remain in public schools.

Relative to universal vouchers, low income-targeted vouchers bring welfare gains to more households because their lower voucher eligibility rate reduces the negative impact on public schools and lowers the fiscal cost of the program. However, in the case of a high income-targeted voucher only a small fraction of households gain – those that use the voucher.[27]

The inability of vouchers to improve outcomes for the lowest segment is highly related to the existence of informational frictions, as having to monitor in private schools (while losing the benefits of free-riding on public school monitoring) is prohibitive for those households. This raises the question of whether vouchers would be more effective in the absence of informational frictions. Hence, columns 2 through 5 of Appendix D's Table 1 show the effect of universal and income-targeted vouchers under perfect observability. In addition, Figure 5 shows household

[27] The fact that a small fraction of households benefits from the voucher raises the question of whether the voucher amount should be higher. We have conducted simulations (available under request) for vouchers higher than $7,000. In these simulations, the higher the voucher, the less likely the eligible households are to take it. The reason is that a higher voucher entails higher fiscal cost and hence greater decline in disposable income. This, in turn, lowers the payoff from the monitoring that the household would have to conduct in private schools. Thus, unless vouchers are funded through progressive taxes, the lowest-income households will not use them.

school and monitoring choices. Voucher use is indeed higher in the absence of informational frictions. Although the payoff to attending private school continues to be higher for higher-ability households because of peer quality, not having to monitor in private schools increases private school desirability for low-income or low-ability households. Hence, a higher fraction of low-income households experience achievement gains.

The comparison of vouchers under perfect and imperfect observability provides evidence that vouchers may not be effective at raising achievement for the low-income segment in the presence of informational frictions. In this case, a voucher program may need to be supplemented either by public monitoring of private schools to compensate for the lack of household monitoring in the schools attended by the lowest segment,[28] or by public monitoring of public schools to compensate for the loss of monitoring households on the part of public schools – while keeping in mind that this may crowd out private monitoring.

Our analysis of public monitoring and vouchers illustrates the more general conclusion that the combination of information asymmetries and equilibrium effects makes underachievement a very complex problem that cannot be solved with one simple tool. A well-designed combination of tools can help, as in the example above.[29] Moreover, our simulations suggest that reducing the funding distortion can mitigate the informational problem. In addition, the effectiveness of these tools can be enhanced by lowering monitoring costs. For instance, Hastings and Weinstein (2008) document that when low-income families participating in a public school choice program receive information on public school test scores, they are more likely to choose higher-performing schools.

5.3. Household Preferences Over Policy Parameters

[28] In reality, most voucher programs draw upon excess capacity in existing private schools. Thus, voucher-using students thus join schools where parents actively monitor school performance. To our knowledge, the Milwaukee voucher program is the only one that has spurred substantial entry of new schools to serve voucher students. The case of a few unscrupulous new entrants in Milwaukee has been one factor contributing to the recent implementation of extensive public monitoring and regulation for this voucher program (see, for instance, http://www.schoolinfosystem.org/pdf/2010/02/2010VoucherBrief.pdf)

[29] Neal (2009) argues that vouchers and state-wide performance measurement systems should be viewed as complements rather than substitutes, because the availability of school choice through vouchers provides parents with incentives to monitor their child's school. Chakrabarti (2008) provides empirical evidence that the combination of accountability and (the threat of) vouchers in Florida is indeed more effective than vouchers alone in Milwaukee.

Although so far we have viewed e^{pub} (effort standard), X (funding per student) and m_0 (public monitoring intensity) as exogenous, one can imagine that they are ultimately chosen by the households through a process such as voting. Hence, an interesting question is how preferences over them vary among households. Since some parameters may be harder to alter than others (at least in the short run), we have explored preferences over e^{pub}, (e^{pub}, X) pairs, m_0, (e^{pub}, m_0) pairs, and (e^{pub}, X, m_0) triplets. To study preferences over e^{pub}, we computed the equilibrium for values of e^{pub} between 0 and 1.2. For each household, we found the value of e^{pub} corresponding to the equilibrium in which the household attains its highest utility – that is the household's preferred e^{pub} (in this equilibrium, the household also makes an optimal school choice). We similarly studied preferences over the other policy parameters or combinations thereof.

Table 7 shows the outcome of this exercise. To facilitate comparisons, row 0 presents the benchmark equilibrium, computed for the current effort standard of 0.66, the observed funding per student, and no public monitoring. A theme in this exercise is the presence of two most preferred bundles – one preferred by households who choose public schools, and the other preferred by households who choose private schools. Hence, columns 3-5 and 6-8 characterize the bundle preferred by public and private school households, respectively, and column 9 shows the fraction of households who prefer public schools. In other words, columns 3-5 and 6-8 contain information on how households might vote in a poll over policy parameters, and column 9 shows the fraction that would support the bundle preferred by public school households. In this spirit, in what follows we refer to bundles as "chosen" or "preferred" in that hypothetical poll. In addition, Figure 6 displays the distribution of preferences among households that prevails for most instances of this exercise, as indicated in column 10 of Table 7.

<u>*Preferences over Effort Standard*</u>. As row 1 shows, public school households prefer e^{pub}=0.85, whereas private school households prefer e^{pub}<=0.20. Illustrating a theme of this analysis, the effort standard preferred by public school households is that which minimizes public school profits and maximizes public school effort, whereas the effort standards favored by private school households minimize public school attendance and hence the tax rate (see Figure 1). Given the distribution of income and ability in this population, the majority of households prefer an effort standard of 0.85 (see Figure 6).

<u>*Preferences over Effort Standard and Funding*</u> When households are allowed to choose both X and e^{pub} (row 2), two preferred bundles emerge: (e^{pub}=0.65, X=\$4,000) and (e^{pub}<=0.2,

X=\$1,000), preferred by the same households that prefer e^{pub}=0.85 and e^{pub}<=0.20 in the previous instance, respectively. Thus, when allowed to choose funding as well as effort standard, households that prefer public schools choose a (slightly) lower effort standard yet also a concomitantly lower funding relative to when they can only choose the effort standard.

These preferences convey an interesting message. If one believes that in reality funding can be hardly altered by households, then the fact that the current effort standard is lower than households' preferred standard suggests that public schools may bias the standard downward. If, on the other hand, one believes that in reality households can affect both funding and effort standard, then the fact that the current effort standard is almost the same as households' preferred level yet funding is higher suggests that even if households can set the effort standard, public schools may bias funding upward. Thus, both stories point to potential bargaining power on the part of public schools.

From an empirical perspective, Jacob (2010a, 2010b) provides evidence that when principals can dismiss probationary teachers more easily, they are more likely to dismiss teachers who add less to student achievement, with poorer educational credentials and higher absenteeism (i.e., teachers who provide less effort), and these personnel decisions reduce teacher absences (i.e., increase teacher effort). This indicates that parents may indeed have higher effort standards (internalized by principals once the institutional environment enables them to do so) than those preferred by public schools. Interestingly, Jacob (2010a) points that not all eligible principals use the new opportunity, perhaps showing the influence of public schools on the effort standard.

Preferences Under Perfect Observability Row 3 depicts household preferences over e^{pub} under perfect observability. The pattern is similar to that in Figure 6, although with more households choosing a low e^{pub} because more high ability households would attend private schools. These households would choose the effort standards that yield zero public school attendance, zero tax rate and zero public school profit (see Figure 2). In contrast, public school households choose the e^{pub} that minimizes public school profit conditional on the public school being open. The majority of households prefer a low e^{pub} (and hence no public schools).

When households living in perfect observability are allowed to choose funding as well as the effort standard (row 4), two preferred bundles emerge: (e^{pub}=0.55, X=\$4,000) and (e^{pub}<=0.15, X <=\$1,200), and the majority prefers the first one. As is the case under imperfect observability, public school households choose both lower effort standard and funding than when they can only choose the effort standard. In other words, households prefer to receive less public school effort in exchange for higher consumption.

Preferences over Public Monitoring Row 5 summarizes household preferences for public monitoring when its cost is very low (γ=0.01). Most households prefer intense public monitoring in this case; only private school households prefer no monitoring. Preferences over m_0 are similar for γ=0.03 and γ=0.05, except that the intensity preferred by the majority falls rapidly and becomes zero as soon as γ=0.10 (see rows 6-8). This is consistent with Table 5, which shows that no household gains welfare by having public monitoring unless its cost is very low.

Preferences over Effort Standard and Public Monitoring Raising the effort standard and introducing public monitoring are two options that raise public school effort, and households may view them as substitutes. Hence, we studied preferences for (e^{pub}, m_0) combinations for alternative costs of public monitoring (see rows 9-12). Comparing rows 9 and 1 shows that for very low monitoring costs, the ability to choose both e^{pub} and m_0 (as opposed to only e^{pub} when m_0=0) allows households to choose a (slightly) lower e^{pub} and compensate with high m_0. Comparing rows 9-11 with rows 5-7 shows that when monitoring costs are very low, the ability to choose both e^{pub} and m_0 (as opposed to only m_0) lets households support higher e^{pub} but lower m_0. Both comparisons indicate that households indeed trade effort standard for public monitoring. However, the preferred level of public monitoring for public school households drops rapidly as monitoring costs rise and eventually becomes zero (see rows 8 and 12). Private school households prefer zero public monitoring regardless of its cost.

Preferences over Effort Standard, Public Monitoring and Funding Rows 13-16 summarize preferences when households are allowed to choose all policy parameters – perhaps in the long run, when short-term political and/or contractual rigidities disappear. Relative to the case in which they can only choose e^{pub} and m_0, public school households choose lower e^{pub}, lower X and higher m_0. Once again they prefer a lower standard in exchange for greater consumption, and they compensate for the lower standard with higher public monitoring. Nonetheless, their preferred public monitoring quickly becomes zero as monitoring costs rise, in which case they compensate by raising the standard (compare row 16 to rows 13-15).

To summarize, household preferences over policy parameters are split along the lines of school choice. Households that prefer private schools always choose the policy parameters that minimize public school attendance and hence the fiscal burden, whereas the choices made by households that prefer public schools depend on the parameters that they can choose and, if choosing the level of public monitoring, on public monitoring's cost. Unless the latter is very low, they prefer not to use public monitoring. They view public monitoring and effort standard as substitutes, and are willing to optimally lower one while raising the other. If they are able to choose all policy parameters, public school households will choose an effort standard very close to the current one, but a lower funding and a positive (low-cost) public monitoring. In particular, a robust finding is that the current funding is above the level that households would choose, which may point to public schools' influence in the determination of their own funding.

6. Concluding Remarks

In this paper we have focused on the information asymmetry among the policymaker, households, and schools and its role on academic underachievement. We have built a simple hidden-action (moral hazard) model of school effort and have embedded it into an equilibrium model of education choice in which households sort across schools and exert learning and monitoring efforts. From a policy perspective, we have focused on reforms to raise achievement, and on whether they address the distortions created by the underlying information frictions. An important conclusion is that in order to be effective, policies –whether based on market or administrative mechanisms– must address the moral hazard associated with school effort and the intricacies of household monitoring of school effort. Moreover, they must do so in large-scale contexts in which these policies may have unintended effects that undermine their effectiveness.

We view our theoretical and computational model as a first step towards a systematic investigation of the problems facing a policymaker in an environment with public and private schools. We believe that a perspective rooted in information asymmetries will shed light on the problem and its possible solutions, and that extending our model in the directions indicated below will be particularly useful.

First, a good school accountability system should reward the value added by the school, which could be very high despite low student achievement. The issue, then, is how to measure value added. Our current agency model does not deal with measurement issues because no explicit output-based contingent contract is modeled. Instead, we model the productive (or input) distortion directly and focus on monitoring activities. An extension to an output-based modeling of agency costs would necessitate a model with more institutional features.

One commonly used output measure, achievement test scores, is a noisy measure of the underlying element of interest, intellectual skills. These skills may not be fully realized in the short run, which is when achievement tests are usually administered. This creates an incentive for schools to focus on the short-term skills measured by the tests, possibly to the detriment of more valuable long-term skills. These measurement problems have famously produced dysfunctional incentives when not properly accounted for in the design of reward systems (Holmstrom and Milgrom 1991). Further, when measurements are subject to manipulation by the very economic entity being measured, they invite performance management (akin to earnings management in corporate settings; see Liang 2004 for a partial equilibrium example). Monitoring and measurement problems have been studied in other settings, such as managerial performance evaluation and firm equity valuation (Dutta and Reichelstein 2005). However, the unique features of the educational setting add richness and complexity to the problem.

Second, teacher heterogeneity is an important element to consider because the reforms have the potential to adversely affect teacher sorting across schools. For instance, in the absence of good value-added measurement, a school attended by low-achievement students will face considerable difficulties attracting capable teachers. This, in turn, will only aggravate the initial underachievement problem.

Third, inducing household learning and monitoring efforts are a fundamental task of education reform, and our model illustrates the importance of these efforts. Some schools may have an advantage eliciting student effort. Furthermore, peer quality may depend not only on students' ability but also effort (as in Cooley 2010). In light of these considerations, exploring various mechanisms to raise student effort would be useful.

In closing, we emphasize that understanding the achievement problem requires a firm grasp of the informational frictions among the relevant parties, the incentives implied by alternative mechanisms to address these frictions, and the equilibrium effects of the large-scale implementation of these mechanisms. Through our work we hope to contribute to the understanding of this problem and the design of its solutions.

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TABLE 1
Parameter Values

Parameter	Definition	Value
β	Coefficient of consumption in utility	6.351
η_1	Elasticity of achievement with respect to school effort	0.843
η_2	Elasticity of achievement with respect to peer quality	2.754
λ	Elasticity of teacher salary with respect to teacher effort	2.044
A	Monotonic transformation of teachers' reservation utility	1.280
e^{pub}	Public school's promised effort	0.663
α	Agency cost	9.939
ρ_a	Disutility of household learning effort	4.06E+06
ρ_m	Disutility of household monitoring	2,000

TABLE 2
Predicted and Observed Values

Variable	Observed Value	Predicted Value
Fraction of Households with Children in Private Schools	0.16	0.16
Average Income for Households with Children in Private Schools	$82,800	$90,400
Average Private School Tuition	$5,000	$4,900
Difference in Teacher Salary between Public and Private School	0.44	0.53
Difference in Teacher Effort between Private and Public School	0	1.26
Difference in Achievement between Private and Public School	0.45	1.56
Difference in Ability between Private and Public School	0.76	1.45
Difference in Student Effort between Private and Public School	0.5	1.28
Monitoring Rate in Public School	0.76	0.76

Note: Measurement of each variable is described in the text. Dollar amounts rounded to the nearest hundred.

TABLE 3
Equilibrium with Imperfect and Perfect Observability

	Imperfect Observability (1)	**Perfect Observability (2)**
Fraction Hhs. In Public School	0.84	0.96
Average Income	$57,600	$57,600
Public School	$51,300	$55,000
Private School	$90,400	$119,400
Average Ability	100	100
Public School	97	99
Private School	116	119
Monitoring Rate	0.80	0.00
Public School	0.76	0.00
Private School	1.00	0.00
Average Spending per Student	$6,700	$7,000
Public School	$7,000	$7,000
Private School (tuition)	$4,900	$6,400
Average Promised School Effort		
Public School	0.66	0.66
Private School	0.69	0.71
Average Actual School Effort	0.51	0.67
Public School	0.50	0.66
Private School	0.55	0.71
Public School Profit	$60,800	$35,600
Average Teacher Compensation		
Public School	$6,000	$7,000
Private School	$3,900	$6,400
Average Use of School Revenues		
Public School		
Salaries	0.44	0.79
Agency cost	0.15	0
Rent	0.41	0.21
Private School		
Salaries	0.79	1
Agency cost	0.21	0
Rent	0	0
Avg. Household Learning Effort	0	0.06
Public School	-0.20	-0.06
Private School	1.07	3.08
Average Achievement	0	0.09
Public School	-0.25	-0.09
Private School	1.31	4.37
Income Tax Rate	0.1	0.12
Aggregate Welfare	8.34E+12	1.03E+13

Note: Dollar amounts are rounded to the nearest hundred. For "Use of School Revenues", we display the fraction of revenues that pays for salaries, agency cost or rent. Achievement and household learning effort are measured in units of standard deviation of the corresponding benchmark (imperfect observability) equilibrium distributions, which have zero mean and unit standard deviation.

TABLE 4

Equilibrium with Imperfect and Perfect Observability, Minimum and Maximum Public School Profit

	Imperfect Observ. (1)	Imperfect Observ. Zero Profit (2)	Perfect Observ. (3)	Perfect Observ. Zero Profit Low e^{pub} (4)	Perfect Observ. Minimum Profit High e^{pub} (5)	Perfect Observ. Maximum Profit (6)
Fraction Public School	0.84	0.96	0.96	0	0.96	0.84
Avg. Income Public School	$51,300	$55,000	$55,000		$55,000	$51,300
Avg. Income Private Sch.	$90,400	$119,400	$119,400	$57,600	$119,400	$90,400
Avg. Ability Public School	97	99	99		99	97
Avg. Ability Private Sch.	116	119	119	100	119	116
Monitoring Rate Pub. Sch.	0.76	0.79	0.00		0.00	0.00
Avg. Spending per Student	$6,700	$7,000	$7,000	$3,500	$7,000	$6,700
Public School	$7,000	$7,000	$7,000		$7,000	$7,000
Private School	$4,900	$6,400	$6,400	$3,500	$6,400	$4,900
Avg. Promised Sch. Effort						
Public School	0.66	0.85	0.66	Up to 0.15	0.70	0.50
Private School	0.69	0.80	0.71	0.50	0.71	0.62
Avg. Actual School Effort	0.51	0.64	0.67	0.50	0.70	0.52
Public School	0.50	0.64	0.66		0.70	0.50
Private School	0.55	0.64	0.71	0.50	0.71	0.62
Public School Profit	$60,800	$3,000	$35,600	$0	$19,900	$81,800
Avg. Teacher Compensat.						
Public School	$6,000	$5,300	$7,000		$7,000	$7,000
Private School	$3,900	$5,100	$6,400	$3,500	$6,400	$4,900
Avg. Use of Sch. Revenues						
Public School						
Salaries	0.44	0.74	0.79		0.88	0.44
Agency Cost	0.15	0.25	0		0	0
Rent	0.41	0.02	0.21		0.12	0.56
Private School						
Salaries	0.79	0.79	1	1	1	1
Agency Cost	0.21	0.21	0	0	0	0
Rent	0	0	0	0	0	0
Avg. Hh. Learning Effort	0	0.04	0.06	0.48	0.08	0.03
Public School	-0.20	-0.08	-0.06		-0.04	-0.20
Private School	1.07	2.75	3.08	0.48	3.08	1.23
Avg. Achievement	0	0.04	0.09	0.60	0.12	0.06
Public School	-0.25	-0.10	-0.09	0	-0.05	-0.25
Private School	1.31	3.52	4.37	0.60	4.37	1.68
Income Tax Rate	0.1	0.12	0.12	0	0.12	0.1
Aggregate Welfare	8.34E+12	9.35E+12	1.03E+13	3.55E+13	1.10E+13	9.41E+12

Note: Column (1) and (3) are the same as columns (1) and (2) from Table 3, respectively. Column (5) corresponds to the value of e^{pub} that yields the lowest non-negative public school profit under perfect observability. “Hh.” is short for “household”; “Sch.” is short for “school.”

TABLE 5
Public Monitoring of Public School

	Imperfect Observ. (1)	Very Low Cost - Medium Intensity (2)	Very Low Cost - High Intensity (3)	Low Cost - Medium Intensity (4)	Low Cost - High Intensity (5)	Moderate Cost - Medium Intensity (6)	Moderate Cost - High Intensity (7)	High Cost - Medium Intensity (8)	High Cost - High Intensity (9)
Fraction Public School	0.84	0.92	0.96	0.92	0.96	0.96	0.96	0.96	0.96
Monitoring Rate – Public	0.76	0.78	0.79	0.78	0.79	0.79	0.75	0.75	0.58
Avg. Actual Public School Effort	0.50	0.55	0.57	0.55	0.57	0.55	0.57	0.55	0.56
Public School Profit	$60,800	$55,700	$54,900	$55,700	$54,900	$58,000	$55,400	$58,600	$57,400
Public Teacher Compensation	$6,000	$6,200	$6,300	$6,200	$6,300	$6,200	$6,300	$6,200	$6,200
Use of Revenues – Public									
Salaries	0.44	0.54	0.58	0.54	0.58	0.54	0.57	0.54	0.55
Agency Cost	0.15	0.07	0.05	0.07	0.05	0.07	0.05	0.07	0.05
Rent	0.41	0.35	0.33	0.35	0.33	0.35	0.33	0.35	0.34
Avg. Hh. Learning Effort	0	-0.01	-0.01	-0.07	-0.10	-0.19	-0.26	-0.32	-0.39
Public School	-0.20	-0.12	-0.12	-0.16	-0.19	-0.26	-0.31	-0.36	-0.41
Private School	1.07	1.22	2.67	0.98	2.03	1.45	0.99	0.63	0.12
Avg. Achievement	0.00	-0.02	-0.02	-0.08	-0.10	-0.18	-0.23	-0.27	-0.33
Public School	-0.25	-0.17	-0.16	-0.20	-0.21	-0.26	-0.29	-0.32	-0.36
Private School	1.31	1.66	3.42	1.35	2.60	1.88	1.31	0.86	0.26
Proportion of Households Who Gain Achievement		0.84	0.84	0.84	0.64	0	0	0	0
Among Low-Income Hhs.		1	1	1	0	0	0	0	0
Income Tax Rate	0.10	0.11	0.12	0.13	0.15	0.18	0.21	0.25	0.31
Aggregate Welfare	8.34E+12	7.90E+12	7.73E+12	5.93E+12	5.01E+12	2.95E+12	1.80E+12	1.02E+12	3.24E+11
Proportion of Households Who Gain Welfare		0.88	0.88	0	0	0	0	0	0

Note: Column (1) is the same as column (1) in Table 3 – the benchmark equilibrium for imperfect observability, with no public monitoring. Very low-, low-, moderate- and high-cost monitoring correspond to values of γ equal to 0.01, 0.10, 0.3 and 0.6 respectively. Medium and high-intensity monitoring correspond to values of m_0 equal to 0.5 and 0.75, respectively. "Proportion of Households Who Gain Achievement" and "Proportion of Households Who Gain Welfare" are calculated relative to the benchmark equilibrium. "Public" is short for "Public School". "Low-Income" means income = 10^{th} percentile.

TABLE 6 - *Private School Vouchers under Imperfect Observability*

	No Voucher (1)	Universal Vouchers Low Voucher (2)	Universal Vouchers High Voucher (3)	Income-targeted Voucher Low Voucher (4)	Income-targeted Voucher High Voucher (5)
Fraction Public School	0.84	0.36	0.2	0.64	0.68
Avg. Income Public School	$51,300	$38,000	$13,400	$49,300	$55,800
Avg. Income Private School	$90,400	$68,600	$68,600	$72,300	$61,400
Avg. Ability Public School	97	91	100	94	95
Avg. Ability Private School	116	105	100	111	111
Monitoring Rate Public School	0.76	0.44	0.00	0.69	0.71
Avg. Tuition Private School	$4,900	$4,500	$7,000	$4,600	$6,000
Avg. Actual School Effort	0.51	0.49	0.53	0.50	0.53
Public School	0.50	0.42	0.00	0.48	0.49
Private School	0.55	0.53	0.66	0.53	0.61
Public School Profit	$60,800	$31,800	$35,000	$48,100	$50,600
Avg. Teacher Compensation					
Public School	$6,000	$5,700	$7,000	$5,900	$5,900
Private School	$3,900	$3,600	$5,500	$3,600	$4,700
Avg. Use of School Revenues					
Public School					
Salaries	0.44	0.31	0	0.41	0.42
Agency Cost	0.15	0.18	0	0.16	0.15
Rent	0.41	0.5	1	0.43	0.43
Private School					
Salaries	0.79	0.79	0.79	0.79	0.79
Agency Cost	0.21	0.21	0.21	0.21	0.21
Rent	0	0	0	0	0
Avg. Hh. Learning Effort	0	0.13	0.08	0.04	-0.02
Public School	-0.20	-0.32	-0.49	-0.25	-0.16
Private School	1.07	0.38	0.22	0.55	0.29
Avg. Achievement	0	0.16	0.13	0.05	-0.02
Public School	-0.25	-0.34	-0.41	-0.29	-0.24
Private School	1.31	0.44	0.26	0.65	0.45
Prop. who Gain Achievement		0.52	0.64	0.36	0.16
Among Low-Income Hhs.		0	0	0	0
Income Tax Rate	0.1	0.08	0.12	0.09	0.1
Aggregate Welfare	8.34E+12	1.41E+13	1.21E+13	9.85E+12	7.88E+12
Prop. Who Gain Welfare		0.52	0.48	1	0.16

Note: Column (1) is the benchmark equilibrium for imperfect observability. Income-targeted vouchers are for households with incomes below $50,000. "Low-Income" means income = 10th percentile.

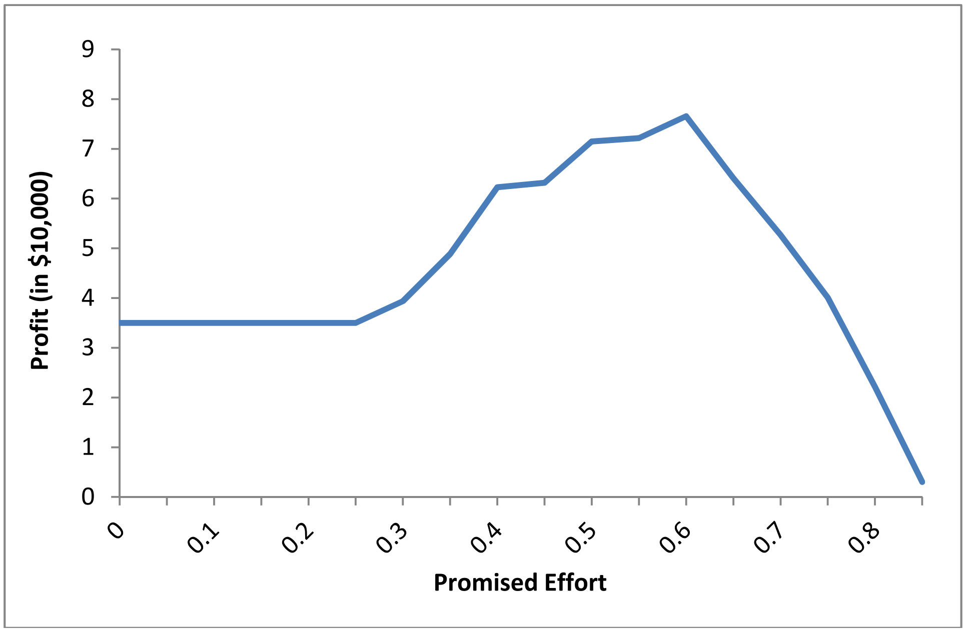
TABLE 7
Household Preferences over Policy Parameters

Observability	Monitoring cost (γ)	Public School Households			Private School Households			Fraction Public School	Distribution depicted in Figure 6?
		e^{pub}	X	m_0	e^{pub}	X	m_0		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0. Imperfect (Benchmark)	n/a	0.66	$7,000	0	0.66	$7,000	0	0.84	
1. Imperfect	n/a	***0.85***	$7,000	0	**<=*0.20***	$7,000	0	0.60	Yes
2. Imperfect	n/a	***0.65***	***$4,000***	0	**<=*0.20***	***$1,000***	0	0.60	Yes
3. Perfect	n/a	***0.70***	$7,000	0	**<=*0.15***	$7,000	0	0.36	
4. Perfect	n/a	***0.55***	***$4,000***	0	**<=*0.15***	**<=*$12,000***	0	0.56	
5. Imperfect	$\gamma = 0.01$	0.66	$7,000	***1.7***	0.66	$7,000	***0***	0.88	
6. Imperfect	$\gamma = 0.03$	0.66	$7,000	***0.4***	0.66	$7,000	***0***	0.88	
7. Imperfect	$\gamma = 0.05$	0.66	$7,000	***0.3***	0.66	$7,000	***0***	0.84	
8. Imperfect	$\gamma >= 0.10$	0.66	$7,000	***0***	0.66	$7,000	***0***	0.84	
9. Imperfect	$\gamma = 0.01$	***0.80***	$7,000	***0.85***	**<=*0.20***	$7,000	***0***	0.60	Yes
10. Imperfect	$\gamma = 0.03$	***0.85***	$7,000	***0.05***	**<=*0.20***	$7,000	***0***	0.60	Yes
11. Imperfect	$\gamma = 0.05$	***0.85***	$7,000	***0.05***	**<=*0.20***	$7,000	***0***	0.60	Yes
12. Imperfect	$\gamma >= 0.10$	***0.85***	$7,000	***0***	**<=*0.20***	$7,000	***0***	0.60	Yes
13. Imperfect	$\gamma = 0.01$	***0.60***	***$4,000***	***1.20***	**<=*0.20***	***$1,000***	***0***	0.60	Yes
14. Imperfect	$\gamma = 0.03$	***0.60***	***$3,500***	***0.15***	**<=*0.20***	***$1,000***	***0***	0.60	Yes
15. Imperfect	$\gamma = 0.05$	***0.60***	***$3,500***	***0.15***	**<=*0.20***	***$1,000***	***0***	0.60	Yes
16. Imperfect	$\gamma >= 0.10$	***0.65***	***$4,000***	***0***	**<=*0.20***	***$1,000***	***0***	0.60	Yes

Note: "Fraction Public School" is the fraction of households that prefers public schools under its preferred parameter combination. Row 0 corresponds to the benchmark equilibrium. In each row, values in bold and italics correspond to cases in which households are allowed to choose the corresponding policy parameter, and the remaining values are from the benchmark equilibrium. For instance, row 1 corresponds to the case in which households are allowed to choose e^{pub} only. Hence, $e^{pub} = 0.85$ is preferred by public school households, $e^{pub} <= 0.2$ is preferred by private school households, and X and m are equal to $7,000 and 0 respectively. $\gamma < 0.10$ represents very low monitoring costs; $\gamma >= 0.10$ represents low, moderate or high costs.

FIGURE 1

Public School Profit, Effort, Attendance and Monitoring under Imperfect Observability



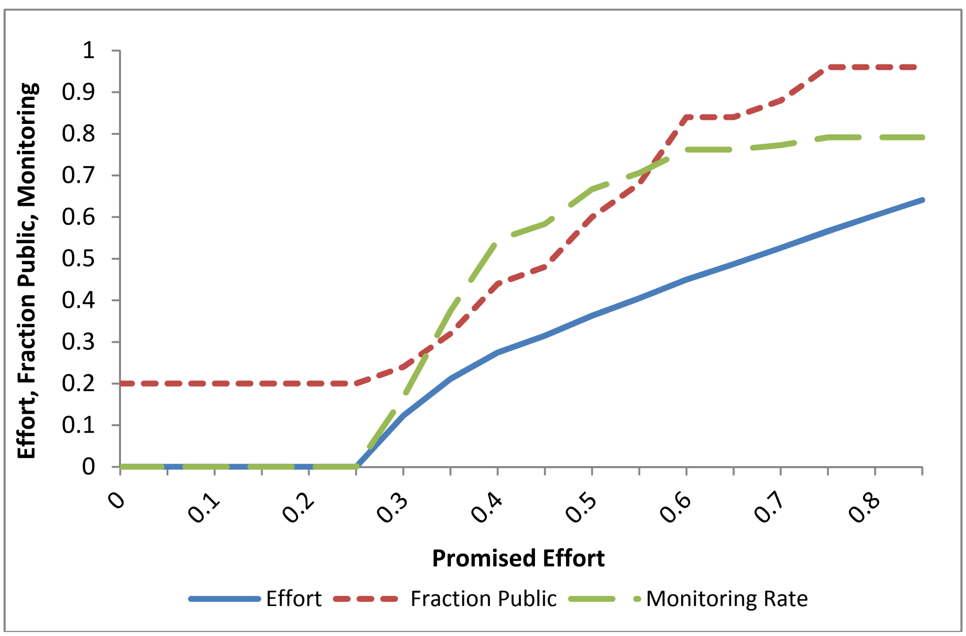


FIGURE 2

Comparing Public School Profit, Effort, and Attendance under Perfect and Imperfect Observability

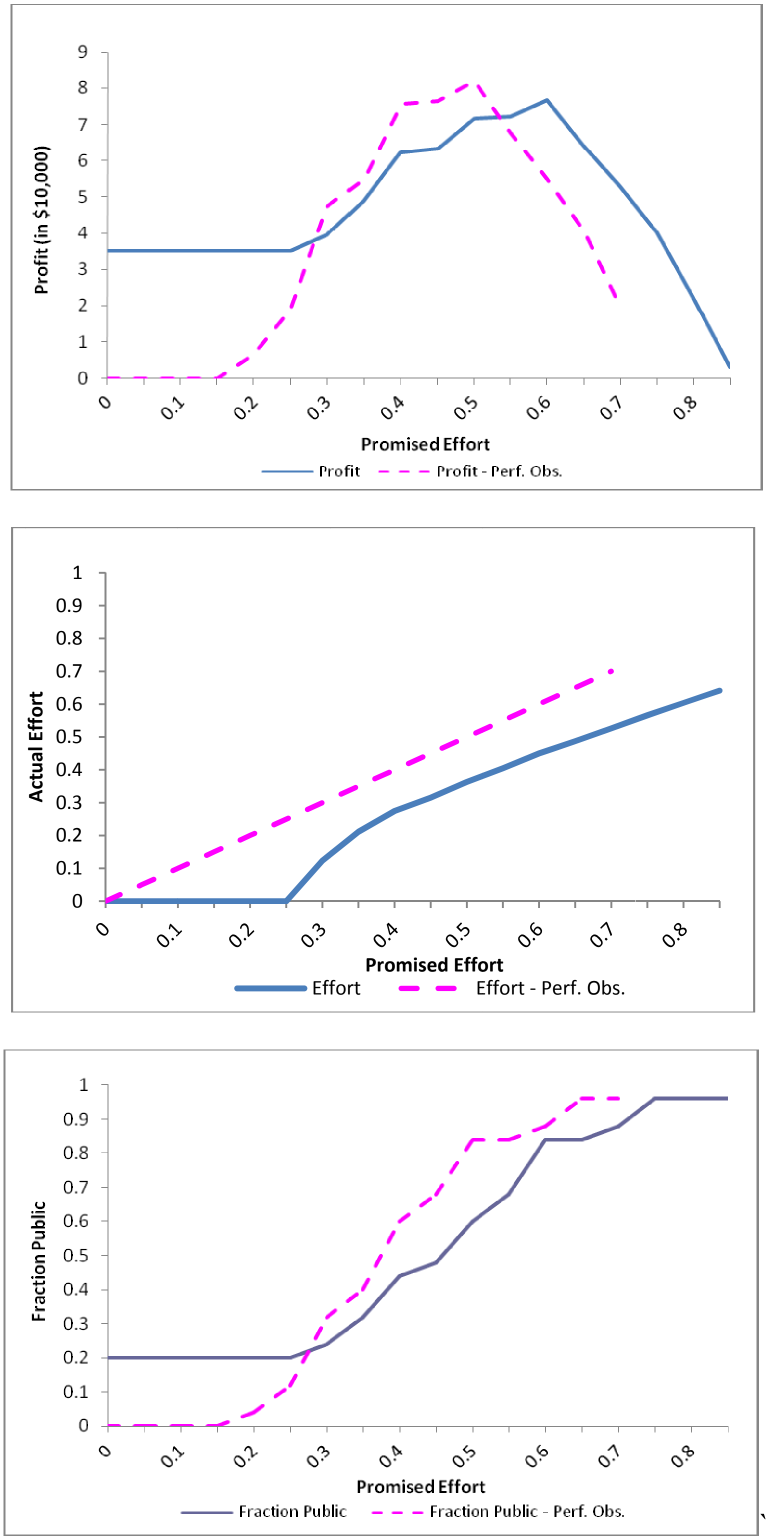
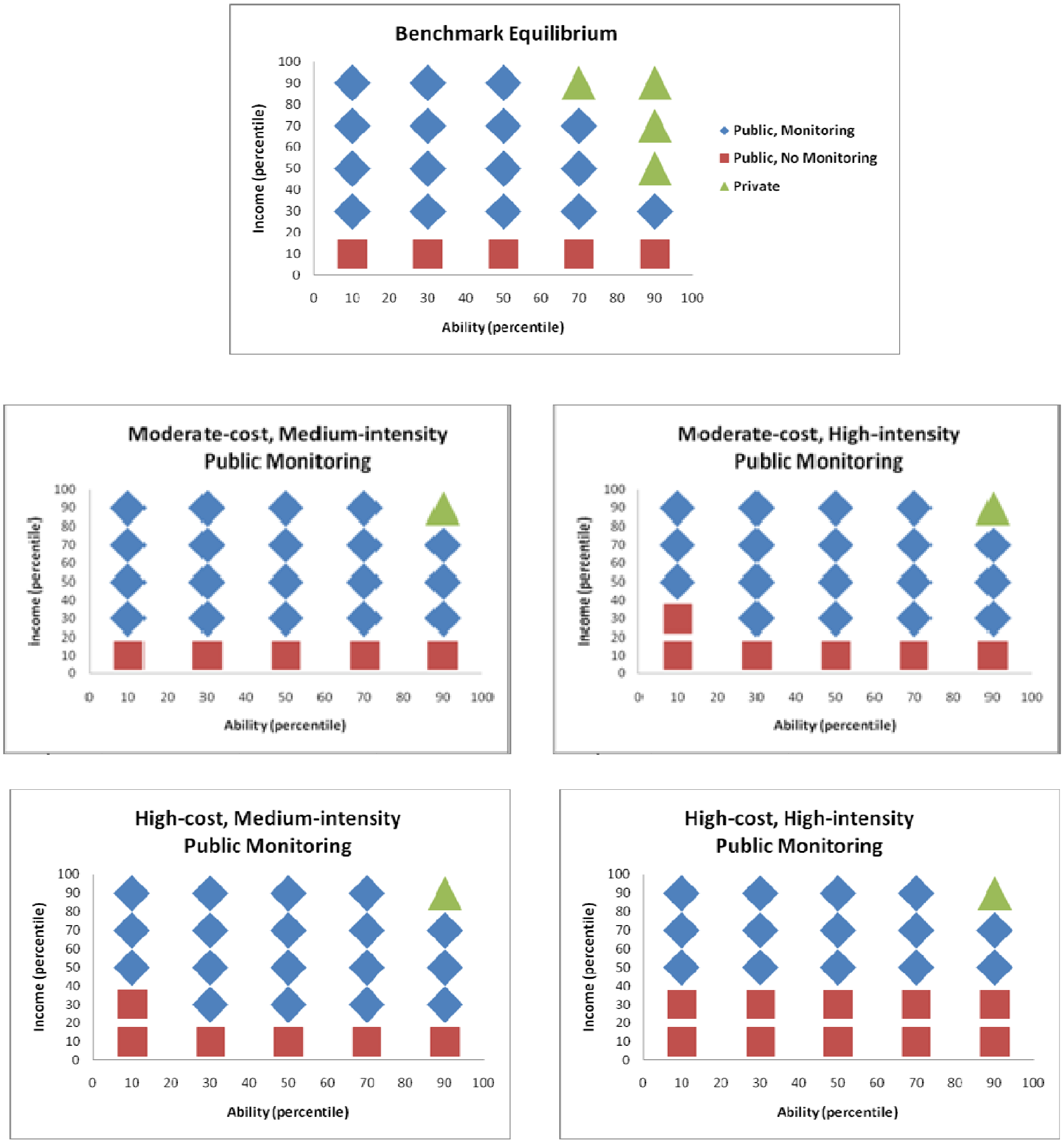


FIGURE 3

Household School Choice and Monitoring under Public Monitoring

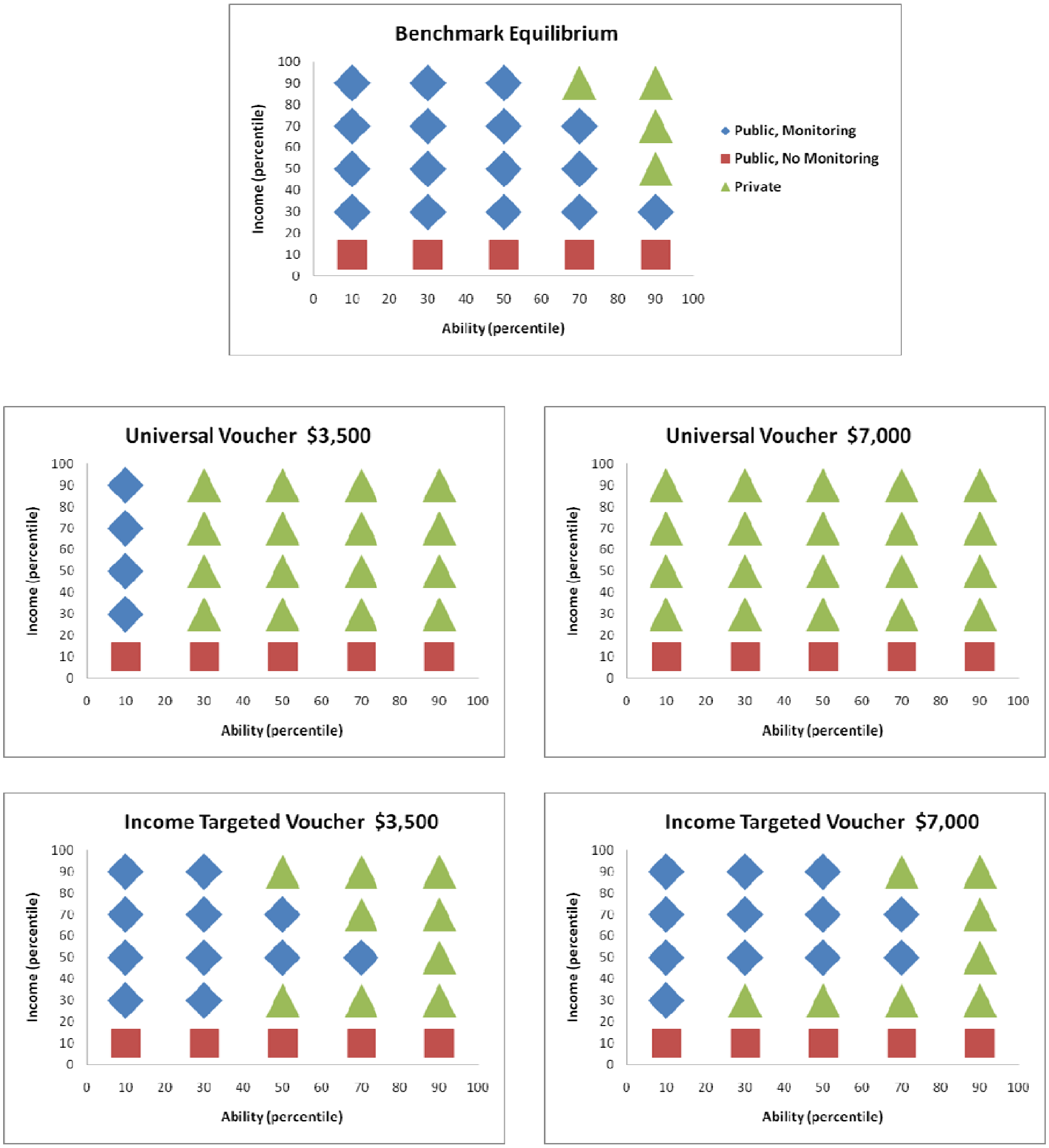


Note: each (income, ability) combination represents a household. Benchmark Equilibrium is the equilibrium for imperfect observability. "Public, Monitoring" means that the household attends public school and monitors; "Public, No Monitoring" means that the household attends public school and does not monitor; "Private" means that the household attends private school (and hence monitors). Moderate- and high-cost monitoring corresponds to values of γ equal to 0.30 and 0.60 respectively. Medium and high-intensity monitoring corresponds to values of m_0 equal to 0.5 and 0.75, respectively.

FIGURE 4

Household School Choice and Monitoring under Private School Vouchers

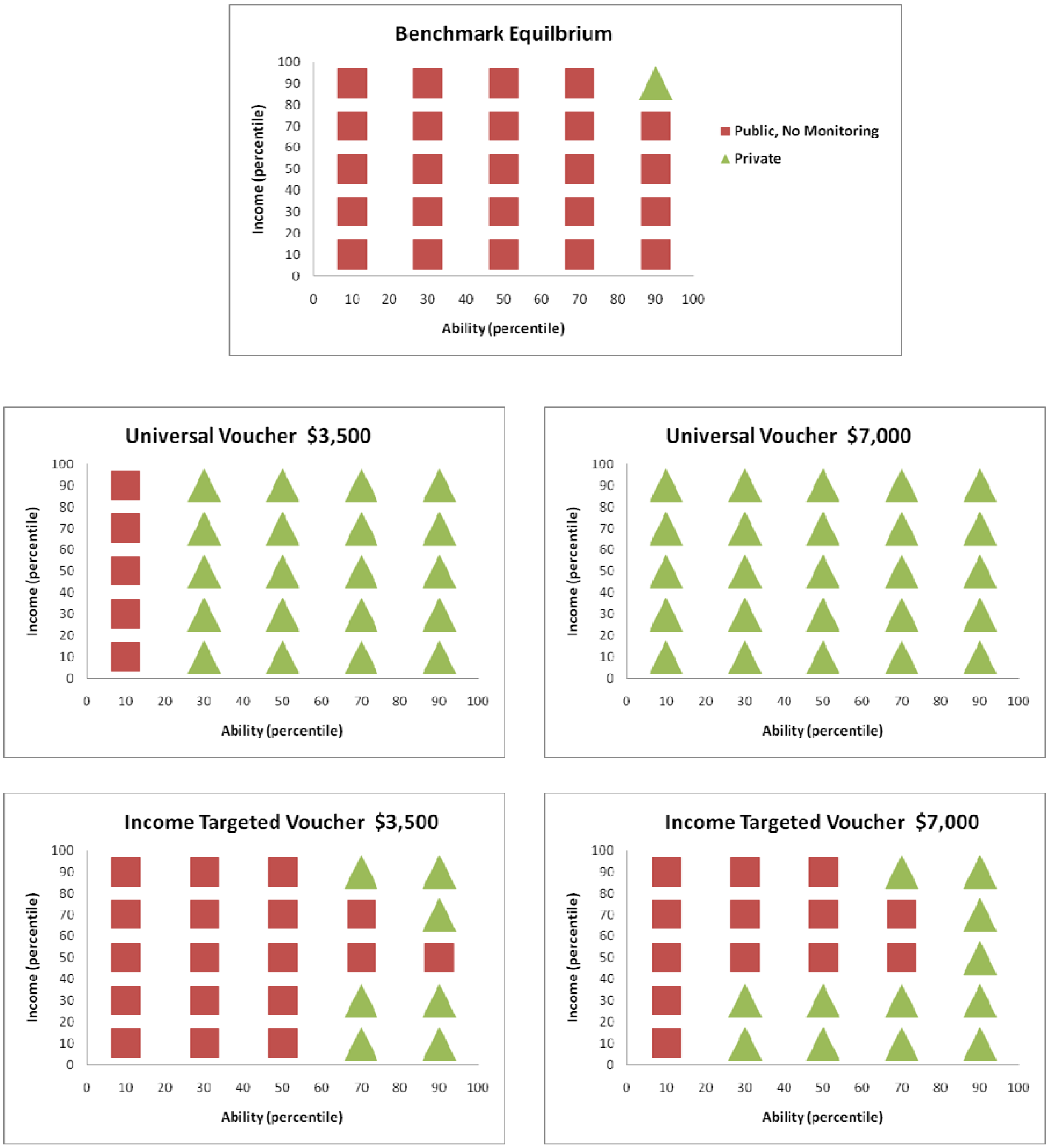
Imperfect Observability



Note: Benchmark Equilibrium is the equilibrium for imperfect observability.

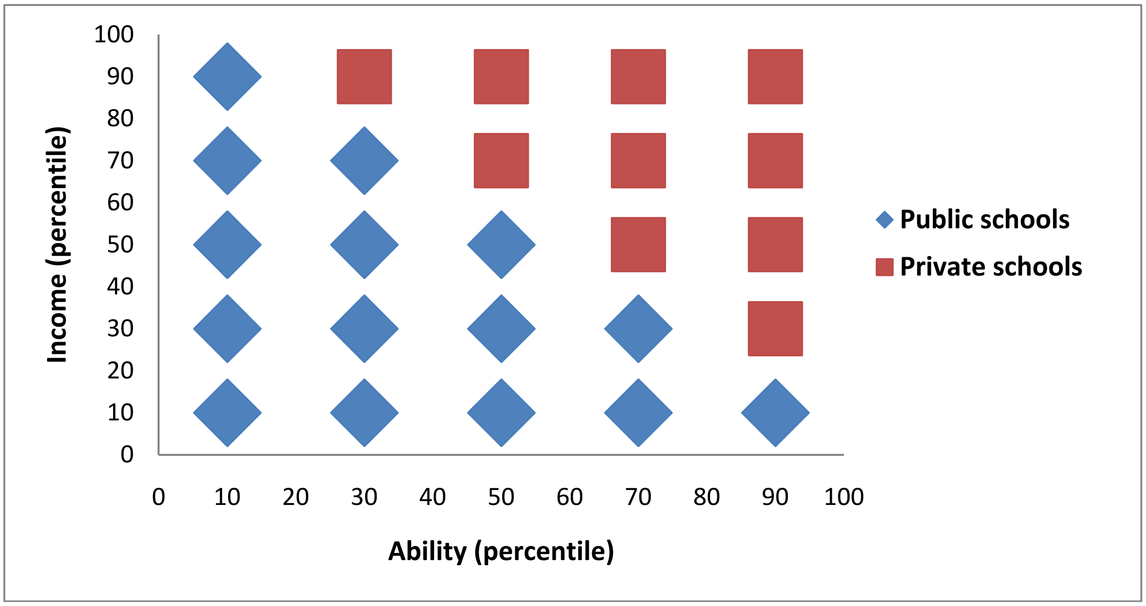
FIGURE 5

Household School Choice and Monitoring under Private School Vouchers
Perfect Observability



Note: Benchmark Equilibrium is the equilibrium for perfect observability.

FIGURE 6
Household Preferences over Policy Parameters



Note: The diamond represents the bundle chosen by households that prefer public schools, and the square represents the bundle chosen by households that prefer private schools. For instance, when examining preferences over the effort standard (row 1 in Table 7), the household with a 10th percentile ability and a 30th percentile income prefers public school, and an effort standard of 0.85.

Appendix A: Output- versus Input-Based Agency Model

In section 2 of the paper, we laid out an agency setting where households exert monitoring effort m to mitigate agency costs, thus increasing school effort e. This model is a reduced-form version of a standard agency model with hidden effort. In particular, it specifies directly the school's payoff as determined by its deviation from the effort (input) standard. This contrasts with the standard agency model in which the school's payoff would be determined by the deviation from the school's output with respect to the output standard. Nonetheless, these approaches are similar in that greater monitoring induces greater effort. To show this similarity, in this appendix we provide a brief extension of our model in which monitoring (exerted by the households and/or the policymaker) produces output-based signals that are informative of the school's effort. These signals are used optimally in an explicit compensation contract between the school and the household, and the school's payoff depends on this contract.

In this extension, the household is the principal and the school is the agent. Let signal y be informative about school effort e such that $y=(e^{pub} - e) + \varepsilon$, where ε is normally distributed with variance σ^2/m. For instance, y can consist of a test score, which is an imperfect measure of achievement (output) and reflects the school's effort e, the other inputs in the achievement production, and random factors. Delivering effort e has a cost equal to C(e) for the school. Assume that compensation w is linear in y: $w = a - by$, where b>0 denotes the bonus rate. The household seeks to find the optimal a and b in order to minimize expected compensation for any given level of actual school effort.

This compensation scheme creates risk for the agent, as her compensation depends on the realization of the random signal y. Assuming CARA utility, the agent's expected utility can be represented by its certainty equivalent equal to $a - b\ \mathrm{E}[y] - .5\ \ b^2r\sigma^2/m - C(e^{pub}) + \Delta C(e^{pub} - e)$. Here, r measures the agent's risk aversion and $\Delta C(e^{pub} - e)$ is the cost saving from exerting e as opposed to e^{pub}. The term $.5\ \ b^2r\sigma^2/m$ is the agent's risk premium, or agency cost – i.e., it represents the compensation needed by the agent in order to enter the risky contract. The risk premium is higher the higher the bonus rate b and the lower the monitoring effort m. This is because higher monitoring provides a more precise measure of effort e. In the case of test scores, higher parental monitoring means that the household is able to obtain more precise information about school effort based on test scores. For instance, parents who interact very frequently with teachers and other parents can assess teacher effort better than those who only rely on test scores.

The agent chooses optimal effort e to maximize her expected utility (or equivalently, its certainty equivalent), trading off cost savings (decreasing in e) and expected bonus (increasing in e). The first order condition of the agent's problem implies $b = -\Delta C_e > 0$, where $\Delta C_e < 0$ denotes the partial derivative with respect to school effort e. The higher the bonus rate b, the higher the effort that the agent exerts.

Competition among identical agents means that the agent will only earn her reservation (or minimium) certainty equivalent, denoted by $\underline{CE}$. Hence, for a given b, the principal will set a to be equal to $\underline{CE} + b\,\mathrm{E}[y] + .5\ b^2 r\, \sigma^2/m + C(e^{pub}) - \Delta C(e^{pub} - e)$. As for the optimal choice of b, the principal will seek to minimize the expected cost of procuring a given level of effort, which is equal to $\mathrm{E}[w] = a - b\mathrm{E}[y] = \underline{CE} + .5\ b^2 r\, \sigma^2/m + C(e^{pub}) - \Delta C(e^{pub} - e)$. This expression highlights the classical trade-off between inducing effort and insuring the agent that the principal faces in agency models: a high b induces high effort but raises the agent's risk premium and hence the principal's agency cost; a low b induces low effort but lowers the agent's risk premium and hence the principal's agency cost.

The principal's optimal b is a function of the monitoring effort m. Raising m lowers the signal's variance and hence the agency cost, leading to a marginal benefit for the principal equal to $.5\ b^2\ r\sigma^2/m^2$. Thus, the principal will choose the level of m whose marginal benefit equals marginal cost. Since higher monitoring m reduces the variance of the signal, it allows the principal to pay a higher bonus rate b (see the $\mathrm{E}[w]$ expression above). The agent responds by optimally raising its effort e. As a result, higher m leads to higher e, just as in the reduced-form model in the text.

This analysis will carry through if y is a vector instead of a scalar, though the reduced-form model will not capture some features of the extended models such as possible different weights on each signal in y. If e is a vector instead of a scalar, the model becomes considerably more involved. See Holmstrom and Milgrom (1991) and Feltham and Xie (1994) for details and insights on multi-task, multi-signal agency models.

Appendix B: Characterization of the Equilibrium

This appendix proves the properties that characterize the benchmark equilibrium. Here we assume binary monitoring – namely, m is either 0 or 1. If monitoring is continuous, we cannot characterize the equilibrium analytically, and the computations become significantly more complex.

After substituting the achievement production function (3) and the budget constraint (2) into the household utility function (1), we write the latter as follows

$$U = ((1-t)y - T)^{\beta} e^{\eta_1} q^{\eta_2}\, a - \rho_a \frac{a^2}{2\mu} - \rho_m \frac{m^2}{2\mu} \tag{B1}$$

The optimal a is

$$a = ((1-t)y - T)^{\beta} e^{\eta_1} q^{\eta_2}\, \frac{\mu}{\rho_a} \tag{B2}$$

Substituting (A2) back into (A1), we have

$$U = \left[\left((1-t)y - T\right)^{\beta} e^{\eta_1} q^{\eta_2}\right]^2 \frac{\mu}{2\rho_a} - \rho_m \frac{m^2}{2\mu} \tag{B3}$$

Recall that at public school, the household receives the bundle $\{e(e^{pub}, M), T{=}0\}$. If the household attends a private school, it receives its optimal (conditional on attending private school) bundle $\{e, T^*(e)\}$. Define the utilities of the private and public school options as

$$U^{PRI}(e|y,\mu) = \left[\left((1-t)y - T^*(e)\right)^{\beta} e^{\eta_1} \mu^{\eta_2}\right]^2 \frac{\mu}{2\rho_a} - \frac{\rho_m}{2\mu} \tag{B4}$$

$$U^{PUB}(m|y,\mu,q,e(e^{pub},M_{-},m))$$
$$= \left[\left((1-t)y\right)^{\beta} e(e^{pub},M_{-},m)^{\eta_1} q^{\eta_2}\right]^2 \frac{\mu}{2\rho_a} - \rho_m \frac{m^2}{2\mu} \tag{B5}$$

where $U^{PRI}(e|y,\mu)$ denotes the utility of a household with income y and ability μ that procures an actual school effort of e from a private school, and $U^{PUB}(m|y,\mu,q,e(e^{pub}, M_{-}, m))$ denotes the utility of a household with income y and ability μ that attends a public school and chooses monitoring m. The actual school effort offered by this school, $e(e^{pub},M_{-},m)$, is the school's optimal effort as a function of e^{pub}, total monitoring from other households M_{-}, and monitoring m by the household under consideration.

Define school quality Q as $Q = e^{\eta_1} q^{\eta_2}$. Then, our household utility function satisfies single-crossing in income (SCI), or

$$\partial\left(\frac{\partial U/\partial Q}{\partial U/\partial y}\right)/\partial y > 0$$

as in Epple and Romano (1998). In other words, the household demand for educational quality has positive elasticity.

Now we prove the following properties of the equilibrium:

1) Income and ability stratification over school choice:
   a) If a household attends a private (public) school in equilibrium, any household with the same ability but higher (lower) income will also attend a private (public) school.
   b) If a household attends a private (public) school in equilibrium, any household with the same income but higher (lower) ability will also attend a private (public) school.
2) Income and ability stratification over parental monitoring in public school:
   a) If a household monitors the public school in equilibrium, any public school household with the same ability but higher income (or with the same income but higher ability) will also monitor it.
   b) If a household does not monitor the public school in equilibrium, any public school household with the same ability but lower income (or with the same income but lower ability) will not monitor it either.
3) Greater effort distortion in public school for a given school effort standard. The school effort distortion is larger in public than private schools as long as not all public school households monitor.

To prove claim 1a, consider household 1 with $\{y_1, \mu_1\}$ that prefers to attend private school instead of attending public school and monitoring:

$$U^{PRI}(e_1^*|y_1,\mu_1) > U^{PUB}(m=1|y_1,\mu_1,q,e^{pub}) \quad \text{(B6)}$$

We need to show that if $y_1 < y_2$, then we have

$$U^{PRI}(e_2^*|y_2,\mu_1) > U^{PUB}(m=1|y_2,\mu_1,q,e^{pub}) \quad \text{(B7)}$$

From (B6), we derive

$$\left((1-t)y_1 - T^*(e_1^*)\right)^{\beta}(e_1^*)^{\eta_1}\,\mu_1^{\eta_2} > \left((1-t)y_1\right)^{\beta} e(e^{pub},M_-,1)^{\eta_1}\,q^{\eta_2} \quad \text{(B8)}$$

Multiplying both sides of (B8) by $(y_2/y_1)^{\beta}$ yields

$$\left((1-t)y_2 - T^*(e_1^*)\frac{y_2}{y_1}\right)^{\beta}(e_1^*)^{\eta_1}\,\mu_1^{\eta_2} > \big((1-t)y_2\big)^{\beta} e(e^{pub}, M_{-}, 1)^{\eta_1}\,q^{\eta_2} \quad \text{(B9)}$$

Because $y_2/y_1>1$, we have

$$\left[\big((1-t)y_2 - T^*(e_1^*)\big)^{\beta}(e_1^*)^{\eta_1}\,\mu_1^{\eta_2}\right] > \left[\big((1-t)y_2\big)^{\beta} e(e^{pub}, M_{-}, 1)^{\eta_1}\,q^{\eta_2}\right] \quad \text{(B10)}$$

This implies

$$U^{PRI}(e_1^*|y_2,\mu_1) > U^{PUB}(m=1|y_2,\mu_1,q,e^{pub}) \quad \text{(B11)}$$

which means that household 2, characterized by $\{y_2,\ \mu_1\}$ would also prefer a private school procuring the school effort that is optimal to household 1 (e_1^*) instead of attending public school and monitoring it. This result is driven by SCI. Hence, at the optimal school effort for household 2 (e_2^*), household 2's utility would be even higher:

$$U^{PRI}(e_2^*|y_2,\mu_1) \geq U^{PRI}(e_1^*|y_2,\mu_1) > U^{PUB}(m=1|y_2,\mu_1,q,e^{pub}) \quad \text{(B12)}$$

which implies (B7). So a household with $\{y_2,\ \mu_1\}$ must also choose private school. The reverse argument applies for public school choice, with households having a weak preference for public school.

To prove 1b, consider household 2 with $\{y_1,\ \mu_2\}$, and $\mu_1 < \mu_2$. (A8) implies

$$\big((1-t)y_1 - T^*(e_1^*)\big)^{\beta}(e_1^*)^{\eta_1}\,\mu_2^{\eta_2} > \big((1-t)y_1\big)^{\beta} e(e^{pub}, M_{-}, 1)^{\eta_1}\,q^{\eta_2} \quad \text{(B9')}$$

This, in turn, implies

$$U^{PRI}(e_1^*|y_1,\mu_2) > U^{PUB}(m=1|y_1,\mu_2,q,e^{pub}) \quad \text{(B11')}$$

In other words, household 2 would prefer to attend the private school that is optimal for household 1 rather than attending public school and monitoring it. This means that household 2 would attain an even higher utility from attending a private school that provides household 2's optimal effort (e_2^*):

$$U^{PRI}(e_2^*|y_1,\mu_2) \geq U^{PRI}(e_1^*|y_1,\mu_2) > U^{PUB}(m=1|y_1,\mu_2,q,e^{pub}) \quad \text{(B12')}$$

The reverse argument applies for public school choice, with households having a weak preference for public schools. Sufficient conditions for property 1b are that the marginal benefit of household learning effort *a* is linear, that the cost of *a* is quadratic and enters additively in the utility function, and that the cost of monitoring enters additively in the utility function with monitoring being a binary choice.

To prove claim 2a, consider household 1 with $\{y_1, \mu_1\}$ that chooses to monitor, or:

$$U^{PUB}(m = 1|y_1, \mu_1, q, e^{pub}) \geq U^{PUB}(m = 0|y_1, \mu_1, q, e^{pub}) \tag{B13}$$

We need to show that if $y_1 < y_2$, then we have

$$U^{PUB}(m = 1|y_2, \mu_1, q, e^{pub}) \geq U^{PUB}(m = 0|y_2, \mu_1, q, e^{pub}) \tag{B14}$$

From (B13), we derive

$$[e(e^{pub}, M_-, 1)^{2\eta_1} - e(e^{pub}, M_-, 0)^{2\eta_1}]\left[\left((1-t)y_1\right)^{\beta} q^{\eta_2}\right]^2 \frac{\mu_1}{2\rho_a} \geq \rho_m \frac{1}{2\mu_1} \tag{B15}$$

If $y_1 < y_2$, then we have

$$[e(e^{pub}, M_-, 1)^{2\eta_1} - e(e^{pub}, M_-, 0)^{2\eta_1}]\left[\left((1-t)y_2\right)^{\beta} q^{\eta_2}\right]^2 \frac{\mu_1}{2\rho_a} > \rho_m \frac{1}{2\mu_1} \tag{B16}$$

which implies (B14). In other words, household 2 with $\{y_2, \mu_1\}$ that attends public school must also choose to monitor. This result is driven by SCI. Similarly, (B15) also implies that if $\mu_1 < \mu_2$, then

$$[e(e^{pub}, M_-, 1)^{2\eta_1} - e(e^{pub}, M_-, 0)^{2\eta_1}]\left[\left((1-t)y_1\right)^{\beta} q^{\eta_2}\right]^2 \frac{\mu_2}{2\rho_a} > \rho_m \frac{1}{2\mu_2} \tag{B17}$$

Hence, household 2 with $\{y_1, \mu_2\}$ that attends public school must also choose to monitor. The following conditions are sufficient for this result: the marginal benefit of household learning effort a is linear, the cost of a is quadratic and enters additively in the utility function, and the cost of monitoring enters additively in the utility function with monitoring being a binary choice. 2b is proved by reversing the arguments and replacing the weak inequalities with strict inequalities.

To prove claim 3, we need to show that if $e^{PUB} = e^{PRI} = e^{STD}$, then $e^{STD} - e(e^{STD}, M) > e^{STD} - e(e^{STD})$ if and only if $M < N$, where $e(e^{STD}, M)$ denotes the optimal effort chosen by the public school in response to $e^{PUB} = e^{STD}$ and total monitoring M, and $e(e^{STD})$ denotes the optimal effort chosen by the private school in response to $e^{PRI} = e^{STD}$. In other words, we need to show that if the effort standard (or promised effort) is the same for public and private schools but the monitoring rate is higher in the private school, then the effort distortion is higher in the public school.

Recall from the text that taking m as given, the private school's objective function (equation 4 in the text) is

$$\pi^{pri} = T - Ae^{\lambda} - \frac{\alpha\, m}{2}(e^{pri} - e)^2 \tag{B18}$$

And taking *N* and M as given, the public school's objective function (equation 7 in the text) is

$$\pi^{pub} = \left(X - Ae^{\lambda}\right)N - \frac{\alpha\, M}{2}(e^{pub} - e)^2 \tag{B19}$$

Since *N* is taken as given by the public school when choosing *e*, (B19) can be transformed to

$$\left(X - Ae^{\lambda}\right) - \frac{\alpha\, M/N}{2}(e^{pub} - e)^2 \tag{B20}$$

With respect to the school's control variable *e*, (B18) and (B20) are equivalent. Both public and private schools choose effort according to the same function, taking two parameters as given - the effort standard (e^{PUB} or e^{PRI} for public and private schools, respectively) and the monitoring rate (*m* or *M/N* for public and private schools, respectively). Below, we show that along the optimal school effort function, *e* is increasing in *m* and in *M/N*. This suffices to prove claim 3.

Consider a public and private school subject to the same effort standard, e^{STD}. In this case, the first order conditions for (A18) and (A20) have the following form:

$$-\lambda Ae^{\lambda-1} + \alpha\,\theta(e^{STD} - e) = 0 \tag{B21}$$

where θ is either *m* or *M/N* for private and public school, respectively. Totally differentiating (B21) yields

$$\frac{de}{d\theta} = \frac{\alpha(e^{STD} - e)}{\lambda(\lambda - 1)Ae^{\lambda-2} + \alpha\, m} > 0 \tag{B22}$$

The inequality comes from the fact that $e^{STD} - e > 0$, $\lambda > 1$, and *A, a, m>0*. Hence, along the optimal school effort function, *e* is increasing in θ.

Since households always monitor in private schools, we have $\theta = m = 1$. For public school, $\theta = M/N$. Given (B22), the necessary and sufficient condition for $e^{STD} - e(e^{STD}, M) > e^{STD} - e(e^{STD})$ (i.e., a larger school effort distortion in public school) is $M/N < m = 1$ or $M < N$ (i.e., not all public households monitor in equilibrium).

Appendix C: Computational Considerations

In this appendix we offer details regarding the construction of the variables matched in the calibration, the algorithm used to compute the equilibrium, and the first-order effect of each parameter in the model.

Measurement of the Variables Matched in the Calibration

The first and second variables we match (fraction of households with children in private schools, and average income for household with children in private schools) are straightforward to construct. The third variable is average private school tuition. The actual average is $4,700 according to US Department of Education (2002). We match an average of $5,000 to account for the fact that Catholic schools comprise almost half of the private school enrollment in 2000, and their tuition is often subsidized (Guerra and Donahue 1990), a feature that our model does not capture. For a model that incorporates this subsidy, see Ferreyra (2007).

The fourth variable matched in the calibration is proportional difference between average public and private school teacher salaries. According to the 1999-2000 Schools and Staffing Survey, the average salary for public and private school teachers is $42,900 and $29,800 respectively – namely, a 44% premium for public over private school teachers.

The fifth variable matched in the calibration is difference between average effort among private v. public school teachers. According to the 1999-2000 Schools and Staffing Survey, teachers in public and private schools work virtually the same number of weekly hours (about 38 hours required at school, and 50 hours including all school-related activities). Hence, we consider the observed value for the proportional difference in teacher effort to be zero.

The sixth variable matched is difference in average achievement between private and public school students. According to the 2000 National Assessment for Educational Progress, private school students score between 0.40 and 0.50 standard deviations higher than public school students depending on the grade (4^{th}, 8^{th} or 12^{th}) and the subject (math or reading). Hence, we match a value of 0.45 standard deviations for this variable.

The seventh variable matched is difference in average ability between private and public school students. Based on the National Education Longitudinal Survey, Epple et al (2004) report that 8^{th} grade scores among private high school students are 0.76 standard deviations higher, on average, than among public high school students. While 8th grade scores are not an ideal measure of ability, we do not know of other evidence on ability sorting across public and private schools.

The eighth variable matched is difference in average student effort between private and public schools, measured in units of standard deviation. We use data from the 2004 Digest of Education Statistics, as data for the variable is not available for 2000. This average is equal to 8.5 and 5.9 hours for private and public school students, respectively.

The ninth variable matched is the fraction of households who monitor in public schools, or public school monitoring rate. The Digest of Education Statistics reports the percent of children whose parents participate in general school meetings, parent-teacher conferences, class events, and volunteering activities. For 1999, these percents were equal to 76.8, 71.4, 63.5, and 33.8 respectively for public schools, and 91.4, 85, 81.7 and 63.8 for private schools. Constructing a simple average of the four activities, and normalizing the private school average to 100 since our model views private schools as a benchmark of full parental monitoring, we arrive at a public school monitoring rate of 0.76.

We believe that for the fifth through ninth variables, our measures are either a lower or an upper bound on the actual constructs of interest. For instance, an hour of effort by a private school teacher may yield a higher educational input (i.e., a higher value of *e*) than an hour of effort by a public school teacher if the former is more qualified than the latter. Some empirical literature suggests that this may indeed be the case (Hoxby 2002b, Ballou 1996, Ballou and Podgursky 1998). Similarly, our measure of student effort does not include other activities that require student effort, such as attending class or behaving in class, though attendance is indeed higher among private than public schools students (US Department of Education 2002). Both ability and achievement differences are likely to be biased downwards because they are based on test scores, which are truncated at the top. The monitoring rate is also likely to be biased, as the survey on which it is constructed does not specify the frequency with which parents exert their monitoring activities. For instance, while parents may participate in the monitoring activities listed in the survey, they may not participate in other activities such as communicating regularly with the teacher and other parents. As Hassrick and Schneider (2009) note, teachers are difficult to monitor because they work in relatively closed classroom spaces, yet parents differ widely in their ability to “open” the closed classroom door and exert everyday teacher surveillance in the classroom. For these reasons, we attach to the first four variables a weight ten times as large as that of the remaining variables.

Computation of the Equilibrium

Our algorithm to compute the equilibrium proceeds as follows: for a given θ, we consider all possible (N, M, q) combinations by drawing an extremely fine grid for public school peer quality q (recall that N and M are integers in our representation, with N ranging between 0 and 25 and $M<=N$). We compute household and school choices for each of these combinations. This yields a predicted (N', M', q') for each (N, M, q). If (N', M', q') = (N, M, q) and public school profits are non-negative, then we have an equilibrium. Thus, our algorithm is capable of finding all equilibria for a given θ. We have never found multiple equilibria.

First-Order Effect of Parameter Changes

A higher coefficient of consumption in the utility function (β) raises the share of consumption allocated to income and lowers private school tuition. A higher elasticity of achievement with respect to school effort (η_1) raises the demand for school effort, hence raising private relative to public school teacher effort and increasing private school attendance. A higher elasticity of achievement with respect to peer quality (η_2) raises demand for private schools on the part of high-ability households and increases private school attendance. A lower disutility of household learning effort (ρ_a) makes every household exert higher more effort. However, since the optimal effort is increasing in household income and ability and school peer quality, students in private schools raise their effort to a larger extent, hence widening the gap between private and public school student effort. A lower disutility of monitoring effort (ρ_m) raises the public school monitoring rate and the public school effort, hence raising public school attendance.

A higher reservation utility for teachers (A) raises the cost of any given level of teacher effort. It lowers the demand for teacher effort in all schools, though more so in private schools because teacher compensation in private schools is more sensitive to changes in the market value of teacher effort. Hence, a higher A lowers the difference in teacher effort between private and public schools. Since teacher effort is usually less than one, a lower elasticity of teacher wages with respect to effort (λ) also raises the cost of teacher effort but can lower the agency cost, particularly at the high-effort private schools attended by the highest-income households. This can lead to an increase in the demand of teacher effort in these schools and hence to a greater effort gap between private and public school teachers.

A higher agency cost (α) raises private and public school effort. In addition, it raises the payoff to household monitoring, hence raising the public school monitoring rate. However, when α is very high, it leads to lower monitoring rate. The reason is that the higher effort attracts some high-ability, monitoring households into public schools, hence leading lower-ability households to no longer monitor. A higher effort standard in public schools (e^{pub}) leads to higher effort in public schools, lower gap between public and private school efforts, and higher public school attendance and monitoring rate. However, very high levels of e^{pub} create negative profits for the public school and hence drive it out of business.

Appendix D

TABLE 1 - *Private School Vouchers under Perfect Observability*

	No Voucher (1)	Universal Vouchers Low Voucher (2)	Universal Vouchers High Voucher (3)	Income-targeted Voucher Low Voucher (4)	Income-targeted Voucher High Voucher (5)
Fraction Public School	0.96	0.2	0	0.72	0.52
Avg. Income Public School	$55,000	$57,600		$57,600	$68,800
Avg. Income Private School	$119,400	$57,600	$57,600	$57,500	$45,400
Avg. Ability Public School	99	81		94	92
Avg. Ability Private School	119	105	100	114	109
Monitoring Rate	0.00	0.00	0.00	0.00	0.00
Public School	0.00	0.00		0.00	0.00
Private School	0.00	0.00	0.00	0.00	0.00
Avg. Tuition Private School	$6,400	$4,400	$7,000	$4,400	$6,300
Avg. Promised School Effort					
Public School	0.66	0.66		0.66	0.66
Private School	0.71	0.58	0.74	0.59	0.70
Avg. Actual School Effort	0.67	0.60	0.74	0.64	0.68
Public School	0.66	0.66		0.66	0.66
Private School	0.71	0.58	0.74	0.59	0.70
Public School Profit	$35,600	$7,400		$26,700	$19,300
Avg. Teacher Compensation					
Public School	$7,000	$7,000		$7,000	$7,000
Private School	$6,400	$4,400	$7,000	$4,400	$6,300
Avg. Use of School Revenues					
Public School					
Salaries	0.79	0.79		0.79	0.79
Agency Cost	0	0		0	0
Rent	0.21	0.21		0.21	0.21
Private School					
Salaries	1	1	1	1	1
Agency Cost	0	0	0	0	0
Rent	0	0	0	0	0
Avg. Hh. Learning Effort	0.06	0.24	0.14	0.09	0.05
Public School	-0.06	-0.16		-0.08	0.02
Private School	3.08	0.33	0.14	0.53	0.08
Avg. Achievement	0.09	0.33	0.24	0.13	0.09
Public School	-0.09	-0.27	0	-0.14	-0.09
Private School	4.37	0.48	0.24	0.83	0.29
Prop.Who Gain Achievement		0.48	0.60	0.28	0.40
Among Low-Income Hhs		0.40	0.60	0.40	0.60
Income Tax Rate	0.12	0.07	0.12	0.1	0.1
Aggregate Welfare	1.03E+13	1.96E+13	1.47E+13	1.16E+13	1.01E+13
Prop. Who Gain Welfare		0.60	0.60	1	0.36

Note: Column (1) is the benchmark equilibrium for perfect observability. Income-targeted vouchers are for households with incomes below $50,000. "Low-Income" means income = 10^{th} percentile.