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 policy-maker, leading to moral hazard problems. Although households can monitor school effort, they differ in their ability to do so. Since private schools attract high-ability households, both competition and parental monitoring serve to mitigate (but not eliminate) the under-provision of private school effort. In contrast, the public school attracts low-ability households who free-ride in providing monitoring effort. Lower monitoring and monopoly power induce the public school to under-provide effort. Using our calibrated model, we simulate public monitoring of public schools and private school vouchers. While public monitoring in our simulations increases public school effort and attendance, it can also crowd out private monitoring and hence undermine its own effectiveness. In our simulations, vouchers do not benefit low-income, low-ability households because the monitoring they would need to exercise in private schools is prohibitively costly for them. These findings suggest that since neither monitoring-based policies (such as public school accountability) nor choice-based policies (such as vouchers) eliminate the informational asymmetries that lie at the root of underachievement, an effective program may require a combination of both types of tools rather than reliance on any of them alone.

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1. Introduction

An educated population is a fundamental ingredient for a well-functioning democracy as well as a key driver for 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 policy-maker often has a minimum goal of basic academic proficiency for every student in the economy. While some households invest in their children's education and meet the policy-maker's goal, others do not. Therefore, the educational achievement of some children is lower than the policy-maker's desired minimum, even after policy interventions in the marketplace for education such as the establishment and funding of public schools.

In this paper we focus on an information-based explanation for the lack of academic achievement, namely the information asymmetries among the policy-maker, households, and schools. For instance, school effort (from a school's administration or its teachers) is not fully observable to parents or policy-makers, 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, monitoring may itself introduce an additional distortion because it is subject to free-riding, as some households may benefit from 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 policy-makers and market participants, such as the regulation of natural monopolies, and managerial contracts in corporate settings.[2] Nonetheless, to our knowledge we are the first to model informational frictions in an equilibrium model 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 under-achievement, such as public school accountability and private school vouchers. In

[2] See, for instance, Laffont and Tirole (1983), and Laffont and Martimort (2002).

contrast, our framework allows us to conduct a more appropriate analysis of these policies and informs the design of more efficient mechanisms.

We develop a theoretical equilibrium model of household school and monitoring 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 complementary inputs: school effort, household learning effort, and peer quality. Importantly, school effort is unobservable to households and to the policy-maker both in public and private schools, which leads to moral hazard problems. The resulting under-provision of school effort hurts achievement as it reduces the productivity of the other educational inputs. Households have the ability to exert personally costly effort to monitor the school; monitoring mitigates but does not eliminate the moral hazard problem. However, households differ in their ability to monitor (i.e., the marginal cost of monitoring is lower for higher ability households). Further, since monitoring is a public good in the public school, households have incentives to free-ride on others' monitoring efforts. The underlying hidden action (agency) problem, along with the concomitant free-riding associated with household monitoring, is one of the frictions in our model.

The second friction is that the public school is not subject to direct competition, as we assume a single public school[3] whose funding is fixed regardless of its performance. Hence, the public school may exploit its monopoly power to seek rents. Private schools attract competition from other private schools as well as high-ability households who monitor school effort. Both competition and parental monitoring serve to mitigate the under-provision of private school effort. In contrast, the public school faces no direct competition, and attracts low-ability households that may rationally free-ride in providing monitoring effort. This, in turn, leads public schools to provide even less effort relative to the standards and funding established by the policy-maker.

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

[3] While extending the model to multiple districts or neighborhood schools would be of interest, it is beyond the scope of this paper. Hence, our model applies to districts with a single public school, or with multiple open-enrollment schools.

observable and monitoring unnecessary. In the baseline model, most households attend public schools, though only some public school households monitor while others free-ride on their effort. Under perfect observability, however, school effort would be higher in all schools, and public school attendance would also be higher.

In our model, the policy-maker sets an effort standard for the public school. This standard plays an important role determining public school profits, 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, perhaps indicating the strong influence of public schools in the actual determination of the standard. Interestingly, the level of this standard is high enough to attract a large student body, but not high enough to attract all the households with monitoring capacity. Whether households have a preference for low or high effort standards depends on their preference for private or public schools, respectively.

The frictions highlighted in our model suggest that policies that increase public school monitoring or that increase competition for the public school are potentially effective at increasing school effort and student achievement. Hence, we have conducted two policy simulations: public monitoring of public schools, and private school vouchers. While public monitoring can raise school effort and hence attract high-ability households into public schools, it can also crowd out private monitoring on the part of low-income, low-ability households. The net outcome of these forces determines the final effect on private monitoring and public school effort. In particular, if the cost of monitoring is high, then the crowding out of private monitoring is likely to prevail.

Private school vouchers increase private school attendance, although the lowest-income segment of the population does not take up the voucher because of their high cost of monitoring in private schools. The loss of high-ability households to private schools lowers public school peer quality and also its monitoring rate, further hurting the households left in public schools. By limiting voucher eligibility, an income-targeted voucher can mitigate these negative effects. The existence of informational frictions is central to the inability of vouchers to benefit low-income, low-ability households.

Our simulation results imply that in the presence of informational frictions, neither public monitoring nor private school vouchers provide a complete solution to the policy-maker's problem. A more complete solution would entail a combination of these tools, as would be the case of vouchers combined with public monitoring of private and/or public schools.[4]

Our work contributes to two distinct literatures. First, we contribute to the education literature by modeling information asymmetry with regard to school effort, and by modeling household monitoring as an equilibrium response to the asymmetry. Further, we model household learning effort. If student learning and school efforts are indeed complementary, omitting student effort leads to underestimating the total impact of an increase in school effort because of its multiplier effect on household learning effort. Whereas equilibrium models in education have been used to analyze a number of policies (see Epple and Romano 1998, Ferreyra 2007, Nechyba 1999 and the references therein), using them to frame the simultaneous treatment of school effort, and household learning and monitoring effort is novel in the literature.

McMillan (2003) studies a rent-seeking public school that faces a tradeoff in the provision of school effort because higher effort reduces per-pupil rent but increases enrollment. 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. Hence, information asymmetries are absent in his paper, as is monitoring. Others (Blankenau and Camera 2009, Urquiola and MacLeod 2009) study household learning effort but not the information asymmetries that are key to our work.

Second, we contribute to the agency literature by embedding a micro-based bilateral agency model into an equilibrium framework for education, where households sort across public and private schools, households and schools choose their own efforts, and school qualities and fiscal costs are determined endogenously. Well-known agency problems (such as Holmstrom 1979 and Sappington 1983) have been studied in a bilateral, partial equilibrium setting. Monitoring and the associated free-riding problems have been studied in professional partnership settings (see Legros and Matthews 1992, Miller 1997, and Huddart and Liang 2003, 2005). Our approach allows us to combine advantages of both the equilibrium and the agency literature.

[4] See Neal (2008) for further discussion of this issue.

Since the public school in our model receives funding and policy mandates from the policy-maker, our work is also related to incentive problems in government procurements (Laffont and Tirole 1993). The key question there is how to optimally design a procurement contract in order to mitigate the rent due to the information advantage of the government contractors. In contrast, our work does not model how funding or policy mandates are established, and it does not search for the optimal contract between the public school and the policy-maker. Rather, our focus is on policies that, while potentially not optimal, are commonly discussed as tools 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, and a policy-maker that funds public schools and sets policy parameters. Hence, in this section we describe these elements and the timeline of the model.

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 household ability, μ. There are a finite number of income types, I, and also a finite number of ability types, M. Thus, there are $H = I \times M$ 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.[5] 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:

[5] Without loss of generality, the model can be extended to more than one household per type.

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

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 $\beta > 0$.[6] Note that households incur disutility from exerting school and monitoring efforts, and this disutility is related to their ability, as effort is more costly for lower-ability households.

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

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

where t is the income tax rate and T is school tuition. In our formulation we assume that household learning and monitoring efforts are privately produced, as opposed to market-mediated. That is, unlike consumption and school effort which are purchased in the market subject to the household budget constraint, the cost of learning and monitoring effort consists of reducing household utility. In other words, we assume that these efforts cannot be outsourced and are thus "off-budget." This assumption reflects the fact that human capital accumulation requires some inputs that the agent himself must provide (for instance, nobody's effort can replace the student's own effort).[7] 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:

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[6] 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.

[7] It could be argued that the household might, in reality, 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. To avoid these complications, we assume 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 the parent may have to work multiple shifts and carry out more non-educational activities for the household, which would leave them with 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.

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

where e is the school effort at the school, 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 household will exert greater learning effort when attending a school where teachers work more, and where the other students are more able.

Private schools

School effort can be provided by private or public schools while incurring a production cost equal to Ae^{λ} (with $A > 0$ and $\lambda > 0$). This can be interpreted as the labor and administrative cost of running a school – for instance, wages paid to teachers or staff members who have a reservation wage for each level of effort e (with parameter A being positively related to the reservation level). We assume both private and public schools share the same production cost – for instance, because they procure school effort from the same market for teachers and staff.

In return for its services, a private school charges tuition T. If school effort e is a normal good and is perfectly observable by the consumer, 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 *promised private school effort*, denoted e^{pri}, from the actual, delivered, school effort e. We assume the school is free to choose a level of e different from e^{pri} , although it incurs an agency cost for doing so. In particular, per student, the profit of the private school is given by

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

Through the quadratic cost for the deviation we assume that small deviations from e^{pri} are costless to the school, so in equilibrium there will always be some deviation. Also, notice that household monitoring is critical in the effort provided by the school in equilibrium, as higher monitoring closes the gap between actual and promised effort. Note that we directly model the distortion induced by the agency problem while retaining the fundamental features of an otherwise full-blown agency model with optimal contracting. That is, in our reduced-form agency model, monitoring does not completely eliminate effort (input) distortion in equilibrium. In a full-blown agency model, specific achievement (output) measures such as test-scores and different teacher performance metrics are generated by various monitoring activities. These measures contain information about school effort, and are used explicitly in an optimized pay-for-performance contract. However, as long as these monitoring activities and the optimal contracting do not completely resolve the agency problem, the equilibrium in the full-blown model will still generate an effort distortion. Our reduced-form model captures this key agency feature, but not other insights from a fully-specified agency model, such as how specific performance metrics can be used in contract design.

In the computational version of the model, we assume that monitoring is a binary choice: $m \in \{0,1\}$. Assuming the school is price-taker with respect to T, then for any given e^{pri} requested by a consumer, the school chooses e to maximize π^{pri}. In other words,

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

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 a households of ability μ has $q = \mu$. Furthermore, we assume a single household per school.[8] Competition drives each private school's equilibrium profit to zero: $\pi^{pri} = 0$. Thus, the equilibrium tuition T^{*} for each e^{pri} (and the corresponding actual e) becomes

[8] Ferreyra (2007), McMillan (2003) and Nechyba (1999), and 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. With multiple households in the same private school, a household's monitoring effort may depend on the monitoring effort of the other household. If monitoring is a binary choice and all households of the same type behave the same way, 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 household per private school. The same thing is true for the no-monitoring equilibrium, if it exists. If both equilibria exist, full-monitoring dominates no-monitoring because it yields a positive school effort. Hence, in the paper we focus on the full-monitoring equilibrium. If monitoring is a continuous choice, multiple households (of the same type) attend the same private school, and all these households behave the same way, then free-riding may arise in private schools.

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

As a result, the equilibrium tuition compensates the production cost of the effort delivered *as well as* the agency cost, even though the private school market is competitive.[9] The agency cost is due to the inability of households to observe school effort perfectly. Thus, the price of any given effort is higher than its actual cost, leading to under-provision of school effort relative to the case of perfectly observable effort. This distortion is consistent with the standard intuition of agency theory (Holmstrom 1979), and is partially mitigated by monitoring, as higher monitoring leads to higher equilibrium school effort and lower agency costs.

Public school

In addition to private schools, a public school exists in this economy. All households are eligible to attend public school. This school derives its public character from its full funding through tax revenues, the absence of tuition,[10] and the fact that households in the school are not allowed to supplement school effort. We assume that the policy-maker establishes e^{pub}, or *promised public school effort.* Hence, households have a choice between attending a tuition-free public school whose promised effort cannot be altered by the household, and a private school whose cost is fully born by the household yet whose promised school effort is freely chosen by the household.

The public school is subject to an agency problem as well because neither the households nor the policy maker observe its effort.[11] The policy-maker, which procures services from the school but does not observe effort, pays X per student regardless of the school's effort. The implicit assumption is that the policy-maker can easily verify public school enrollment but not public school effort. The public school's profit is then

[9] The reason is that agency cost is systematic, as effort is not observable in any school. For instance, suppose a competing school wishes to undercut the incumbent by lowering the tuition from $T^*(e')$ to a tuition $T=A(e')^{\lambda}$ to a customer in the market of e' with a promised $e^{pri}=f^{-1}(e')$. In this case, choosing $e=e'$ leads to negative profit. If the undercutting school promises the household e' (i.e., $e^{pri}=e'$) and contemplates delivering e', the school, along with the household, would quickly realize that the optimal chose of e is $e''=f(e')$ not, e'.

[10] Of course, the school is not literally free in equilibrium, as households must pay taxes to support it.

[11] In reality, monitoring public schools may be harder than monitoring private schools because of the institutional distance between the household and the school's decision-maker. In particular, it may be easier, and more effective, to talk with a private school principal than with the board of education of a public school district.

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

where X is the per-student public funding, N is total enrollment, and M denotes the sum of monitoring efforts from households attending the public school. The second term of the objective function captures the agency cost. Unlike in private schools, monitoring at the public school is a public good. As long as some households provide monitoring effort, it may be optimal for some household to free-ride on others' effort and not provide its own. This free-riding introduces an additional distortion in the economy relative to private schools, as it leads to the under-provision of monitoring in public schools.[12]

Furthermore, the fixed pay received by the public school regardless of its performance may yield a rent to the public school. Unlike in the private schools market, where tuition is subject to competition so as to drive economic profit to zero, revenues for the public school are set exogenously. Hence, it is possible that in equilibrium the public school enjoys $\pi^{pub} > 0$ (we term this rent "monopoly rent" because it accrues to the monopolistic public school).[13] This additional distortion raises the fiscal cost associated to the public school.

Model summary and timeline

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

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

[12] To be fair, in reality free-riding in monitoring probably occurs in private schools as well. Our model captures the idea that the problem is more severe in public schools.

[13] Although we model a competitive teacher market, we can interpret the rents as being distributed among teachers, such that a public school teacher's total compensation exceeds that of a private school teacher for the same amount of effort.

[14] In reality, education occurs over an extended period of time, and achievement may only be perfectly measured and completely realized at the end of that period. This period may be equated to the one period assumed in our model. What our model does not capture, however, is 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' yearly 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.

We now elaborate on the sequence of events. First, we consider the funding level and promised public school effort as exogenous in the model. In reality, many forces can affect these two elements, including the conflicting influence of policy-makers, households and schools, social norms, etc. While modeling the determination of funding and promised effort is an interesting problem, we focus on information asymmetry and equilibrium monitoring. Second, given that the school chooses 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

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

Subject to

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

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

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

As we have seen earlier, the last two constraints may be replaced by equation (6). Further, 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 provides a positive equilibrium monitoring.

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

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

Subject to

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

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

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

[15] This timing is critical to the model. The key for household monitoring to have any impact on public school effort is for the monitoring (threat) to be credible. If monitoring is chosen last, 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 is monitoring from a non-household source, such as the state.

equilibrium values of the two school choices, the household attends the school which gives it the highest utility.

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

- Household rationality: conditional of prescribed choices made by every other household, each household has no incentive to deviate from the prescribed choices.
- School rationality: each school chooses school effort to maximize its own profit, and the school is open only is profits are non-negative.
- Market clearing: each household attends one and only one school and total tax revenue equals total public school funding: $t\sum_{i}^{H} y_i = XN$.

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.[16]

Policy-maker and policy alternatives

The equilibrium is a function of the policy-parameters, X and e^{pub}, established by the policy-maker. She can also adopt policies such as public monitoring and private school vouchers, for which we present simulations later in the paper. Public monitoring is inspired by various accountability programs that provide incentives for public schools to raise achievement while attaching consequences to school outcomes. In our model, we

[16] 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 even though our algorithm is capable of finding 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 costs (in the absence of this variety, only one equilibrium can happen). Assuming the public school includes such household variety, consider the bad equilibrium. A household with low-cost, high-payoff monitoring is always 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 is not sustainable.

operationalize the policy by introducing a public monitoring effort, m_0, which changes the public school profit function as follows:

$$(8)\quad \pi^{pub} = (X - Ae^{\lambda})N - \frac{\alpha\,(M + m_0)}{2}(e^{pub} - e)^2$$

In this formulation, public monitoring is a perfect substitute for household monitoring effort. Since we assume that public monitoring is costly, the state budget constraint changes to:

$$(9)\quad t\sum_{i}^{H} y_i = XN + \kappa m_0$$

where κ is the unit cost of public monitoring.

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 dollar amount of the voucher can potentially depend on household income denoted, as denoted by the voucher function $v(y)$. Universal vouchers implies $v(y)=v$ for all y. A household may supplement 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.

In these simulations, the state determines the voucher function $v(y)$ exogenously. The state funds the vouchers through income taxes, which also pay for public school expenses. Under vouchers, the household attending a private school faces the following budget constraint:

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

To summarize, in this section we have described our theoretical model. Since the model does not have a closed-form solution, we compute the equilibrium numerically. The next section provides details on the computational version of the model.

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 data for the United States K-12 educational system in year 2000. 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 10th, 30th, 50th, 70th and 90th percentile of the 2000 national income distribution for households with children in grades K through 12. This distribution comes from the 2000 School District Data Book All dollar amounts are expressed in dollars of 2000. We include five ability levels, equal to the 10th, 30th, 50th, 70th and 90th percentile of the IQ distribution (a normal distribution with mean equal to 100 and standard deviation equal to 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. Sensitivity analyses conducted for larger numbers of household types have shown the robustness of the equilibrium at the calibrated parameter values. Hence, for computational reasons we work with twenty-five household types. We set per-pupil spending in public schools, X, equal to the observed national average of $7,000. To facilitate the interpretation of our results, we assume that monitoring effort, m, is binary, which means that total monitoring in public school, M, equals the number of households who attend public school and monitor.

To calibrate the model, we choose the parameter point that best matches the observed values of nine variables of interest. The first is fraction of households with children in private schools (equal to 0.16), from the 2000 School District Data Book. The second is average income for households with children in private schools (equal to $82,800), from the 2000 School District Data Book. The third is average private school tuition (equal to $5,000), from the 2002 Digest of Education Statistics.[17] The fourth is

[17] The actual average is slightly lower ($4,700). 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 fact that our model does not capture. For a model that incorporates this subsidy, see Ferreyra (2007).

proportional difference between average public and private school teacher salaries (equal to 0.44). 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. When we compute predicted values, we work with teacher compensation rather than salaries, as we assume that school profits are re-distributed among teachers as part of their compensation. Hence, teacher compensation equals teacher salaries in private schools, and equals teacher salaries plus profit per teacher in public schools. The fifth variable is proportional difference between average effort among private v. public school teachers (equal to 0), measured in units of standard deviation. 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. 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 is difference in average achievement between private and public school students (equal to 0.45), measured in units of standard deviation. 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 (4th, 8th or 12th) and the subject (math or reading). The seventh variable is difference in average ability between private and public school students (equal to 0.76), measured in units of standard deviation. Based on the National Education Longitudinal Survey, Epple, Figlio and Romano (2004) report that 8th grade scores among private school high students are 0.76 standard deviations higher, on average, than for public school high 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 is difference in average student effort between private and public schools (equal to 0.5), measured in units of standard deviation. As with teacher effort, we are confronted with the lack of good empirical measures for student effort. Hence, we use average number of hours spent doing homework per week among high school students in 2004 from the 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 is the fraction of households who monitor in public schools, or public school monitoring rate (equal to 0.76). The Digest of Education Statistics reports the percent of children whose parents report having participated 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 for public schools, and 91.4, 85, 81.7 and 63.8 for private schools. Constructing a simple average over 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 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. Thus, we choose the value for θ that minimizes the following distance between the data and the model's predictions:

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

where the distance for each variable 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. We believe that for the remaining 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 1997, 1998). Similarly, our measure of student effort does not include other activities that require student effort, such as attending class or behaving in class. The 2002 Digest of Education Statistics reports indeed higher attendance among private than public schools students. Both our ability and achievement difference are likely to be biased downwards because they are both 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. Similarly, 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.[18] For these reasons, we attach to the first four variables a weight ten times as large as that of the remaining variables. Note that 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 exercise. Table 2 lists the observed and predicted values for the matched variables. The first four variables are matched better than the following four, as one would expect based on our previous discussion. Moreover, the fifth through eight variables are over predicted, as we would expect from their measurement. Overall, we are encouraged by the fit of the model to the data.

In an equilibrium model such as ours, changes in one parameter trigger changes in several endogenous variables. Nonetheless, it is still possible to identify computationally the first-order effects of these 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 levels of effort. However, since the optimal level of 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.

[18] As McGhee Hasrrick and Schneider (2008) 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.

A higher reservation utility for teachers (A) raises the cost of any given level of teacher effort. However, it raises compensation for private school teachers more than public school teachers because total compensation for public school teachers is less vulnerable to changes in the market value of teacher effort than to changes in public school spending per student. Hence, a higher value of A lowers the public school premium on teacher compensation. It also lowers the demand for teacher effort in all schools, though proportionally more in private schools, thus reducing the variance of the effort distribution and leading to an *increase* in the difference in teacher effort between private and public schools when measured in units of standard deviation. Since teacher effort is usually less than one, a lower elasticity of teacher wages with respect to effort (λ) raises the cost of teacher effort. A lower λ also reduces the public school premium on teacher compensation and the demand for teacher effort in all schools, but raises the variance of the effort distribution and leads to a decrease in the difference in teacher effort between private and public schools when measured in units of standard deviation.

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 promised effort 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.

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 (equivalently, 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 policy parameters.

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 4 shows, high-ability, high-income households attend private schools. All private school households monitor, yet some public school households (with low income) do not monitor. Although monitoring costs are inversely related to household ability, its benefits are related both to ability and income. Since achievement and consumption are normal goods, the demand for school and student effort are also normal. When a household decides whether to monitor, it does so based on its expected impact on school effort and student achievement relative to its monitoring cost. Higher school effort leads to higher student effort because both efforts are complementary. However, the normality in student effort leads to a greater increase in student effort (and hence achievement) for higher-income households. Thus, households of the same ability but different incomes may differ in their monitoring behavior in public school.

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 (full) monitoring in private schools, which in turn ensures higher school 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 monopoly rent. If the school were subject to competition, it would charge a tuition equal to $4,130 (0.59*$7,000). The absence of competition thus creates a monopoly rent equal to $2,870 per student. Private schools, in contrast, enjoy zero profits and spend almost 80 percent of their revenue to purchase 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 effort. As a result of having more of each input, private schools deliver higher achievement. To pay for public schools, the state raises an income tax of 0.10, and the aggregate welfare in the economy is equal to 8.34E12. We will use this measure to compare aggregate welfare among several scenarios.

Column 2 of Table 3 describes the equilibrium under perfect observability. Relative to imperfect observability, average school effort is 31 percent higher, both because deviating from their promised effort is infinitely costly for schools, and because schools that no longer need to pay agency costs can buy more teacher effort. Although eliminating the need to monitor makes private schools more attractive, higher public school effort makes public schools more attractive and hence raises pubic school attendance. As the top panel of Figure 6 shows, only the highest-income, highest-ability type remains in private school. Household learning effort rises across the board as a response to higher school effort. This, in turn, boosts average achievement by 23 percnt and improves the relative standing of public v. private schools.

Note, however, that perfect observability does not eliminate public school monopoly rents, which are due to the funding being 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.

The Role of Promised Effort

We have assumed so far that funding is relatively inflexible, perhaps due to institutional rigidities in the educational budget allocation process. Nonetheless, effort standard (e^{pub}) is likely more flexible. As is clear from (7), changes in the effort standard will alter public school profits. Furthermore, it may also alter spublic 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 or promised effort (recall that at our parameter values, e^{pub}=0.663). The bottom panel depicts the equilibrium actual public school effort, fraction of households attending public schools, and the public school monitoring rate also as a function of promised effort.

For low values of promised effort, profits are positive but flat, and only 20 percent of households attend public schools. These households are at the bottom of the income distribution, because with such low values of promised effort the actual effort is even lower, making public schools unattractive except for those households with negative payoffs from monitoring. Since these households do not monitor, they allow the school to deliver zero effort and enjoy a monopoly rent of $7,000 per student.

As values of promised effort rise, profits first rise and then fall. However, public school attendance, effort and monitoring rate rise steadily. This is because a higher promised effort 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 monopoly rents (i.e., expand the first term of (7)), higher effort and monitoring reduces profits (i.e., shrink the second term of (7)). As long as the first effect dominates, profit is increasing in promised effort; 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 policy-maker can eliminate or at least minimize monopoly rents by choosing the right effort standard – 0.85, in this case (a higher effort standard would yield negative profits to the public school). This standard is certainly higher than that implied by the data, equal to 0.663. 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.

Columns 2 and 3 of Table 4 show the equilibrium when the effort standard is chosen to minimize or maximize public school profit, respectively. For comparison, column 1 shows the benchmark equilibrium. A comparison of columns 1 and 3 shows that since the public school optimal effort is very close to the effort standard implied by the data, household school and monitoring choices are the same, and the equilibrium is quantitatively very similar. Column 2 shows that in the zero-profit equilibrium, public school effort, attendance and monitoring are higher. Furthermore, the use of public school revenues resembles that of perfect observability (see column 4), or that of private schools. Greater school effort raises student effort and hence achievement. Although taxes are higher to pay for more public school students, welfare is also higher.

One could ask how much of the pattern displayed in Figure 1 is attributable to informational frictions, and how much to the public school's monopoly power. 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). Whereas public school profit, effort, and attendance behave similarly with respect to promised effort, some differences are worth mentioning.

First, notice that under perfect observability actual effort falls on a 45 degree line, as promised and actual effort are equal. This means that actual effort is always positive, whereas it is zero for low values of promised effort under imperfect observability. Despite this ever-positive effort, no household attends public schools when effort is very low. The reason is that given that they no longer need to monitor, even the lowest-income, lowest-ability households prefer to attend private rather than public schools because they can obtain higher levels of effort than e^{pub}. For those low e^{pub} values, public school profits are zero (since the schools are empty).[19] In other words, under imperfect observability monitoring costs create a captive audience for public schools because the lowest-income, lowest-ability segment always chooses them.

Second, effort is always higher under perfect observability. Thus, for values of promised effort above 0.25, public school attendance is also higher. Higher effort raises

[19] One can view public school effort in this case as the off-equilibrium effort that the public school would offer if it actually had students.

attendance but also teacher costs. As long as the first effect prevails, profits are increasing in promised effort; the reverse happens when the second effect prevails.

In an environment with perfect observability and inflexible funding, the policy-maker would minimize public school profits by mandating an effort less than or equal to 0.15. Profits would be eliminated simply because nobody would attend public schools. If the policy-maker 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). On the other hand, if the public school were to maximize its profit, it would choose an effort of 0.5. Optimal public school effort is lower under perfect than imperfect observability because the rise in public school enrollment, which drives the rising portion of profits, is faster under perfect observability, hence causing profits to peak earlier.

Columns 5, 6 and 7 display the perfect observability equilibrium when the effort standard completely eliminates profits, when minimizing them while keeping the public school open, and when maximizing them, respectively. For comparison, column 4 displays the perfect observability equilibrium. If one views column 5 as a first best in which neither informational nor monopolistic 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, some households in the first best enjoy lower achievement given the absence of mandated effort standards. Furthermore, low-ability households enjoy lower utility, given that they have the least to gain from private schools and the most to gain from the fiscal redistribution that finances public schools.

Of the scenarios presented in table 4, column 6 depicts the one in which public schools behave most efficiently given that they are open (and that their funding is fixed). The combination of perfect observability and minimum rents leads to a peak of 88 percent of public school funding used to purchase teacher effort. Interestingly, teacher compensation is always higher under perfect observability, either because public schools do not pay an informational rent, hence leaving the full revenue to be allocated among teachers, or because private schools hire more effort.

It is worth noting that public school's optimal promised effort is not zero either in the perfect or imperfect observability case. The actual effort associated with this optimal promised effort is not zero either. Both under perfect and imperfect observability, the public school has an incentive to lower effort in order to reduce teacher costs and raise the per-student monopoly rent, yet also an incentive to raise effort in order to attract more students and raise total monopoly rent. However, under imperfect observability the public school faces additional incentives associated with the agency cost. On the one hand, for a given effort standard it wishes to raise effort in order to avoid the penalty associated with the term $(e^{pub}-e)^2$. On the other hand, the greater the effort it offers, the greater the number and ability of the households that it attracts. These, in turn, lead to tighter monitoring and thus higher agency costs, which the school wishes to avoid.

The preceding analysis allows us to disentangle the role of two separate frictions - imperfect observability of effort, and fixed public school funding. Average school effort is equal to 0.51, 0.67 and 0.70 in the benchmark equilibrium, perfect observability equilibrium, and in the minimum-profit, perfect observability equilibrium respectively. The total effort distortion is hence equal to 0.19 (=0.70-0.51), yet 84 percent of it (=(0.67-0.51)*100/0.19) is due to informational frictions. In other words, informational frictions are the main culprit for the effort distortion.

Household Preferences Over Policy Parameters

Although so far we have taken the effort standard as chosen exogenously by the policy-maker, one can imagine that it is ultimately chosen by households through some political process such as voting. Hence, a question of interest is how preferences for effort standards differ among households. To answer this question, we have computed the equilibrium for values of the effort standard between 0 and 1.2. For each household, we have found the effort standard corresponding to the equilibrium in which the household attains its highest utility.

Figure 3 depicts the outcome of this exercise. Given our distribution of income and ability, the majority of households prefer a promised effort of 0.85, whereas the others prefer a promised effort no greater than 0.25. The former households are likely to choose public schools given their income and ability; the latter are likely to choose private schools. Thus, households that prefer public schools demand the effort standard that minimizes public school profits and maximizes effort, whereas households that prefer private schools demand an effort standard that minimizes public school attendance and hence the tax rate.

One can go one step further and view public school funding X as also being chosen by households in a similar fashion. Hence, we have performed a similar exercise computing the equilibrium for the same effort standard range, and values of X ranging between \$500 and \$12,000. We have looked for the pair of effort standard and public school funding that delivers the highest equilibrium utility for each household. Once again, two preferred bundles emerge: (e^{pub} = 0.65, X=\$4,000) and (e^{pub}<=0.2, X = \$500), and preferred by the same households that prefer e^{pub} =0.85 and e^{pub} <=0.25 in the previous exercise, respectively.[20] Note that when allowed to choose funding as well as effort standard, households that prefer public schools choose a *lower* effort standard yet also a concomitantly lower funding. Remarkably, similar patterns emerge when one considers perfect observability.

These preferences convey an interesting message. If, in reality, funding is fixed and households simply express preferences over the effort standard, then the majority chooses the effort standard that minimizes public school rent (see above). The fact that our calibrated effort standard is lower (equal to 0.663) speaks to bargaining power on the part of public schools. If, on the other hand, households express preferences over both funding and effort standard, then the effort standard chosen by the majority (0.65) is almost the same as the one implied by the data, but the preferred funding is lower (\$4,000 < \$7,000). In other words, both stories speak to public schools' bargaining power.

5. Policy Analysis

In this section we first study the effects of introducing public monitoring of public schools, and then explore the effects of private schools vouchers.

[20] Only one household displays different preferences in the second relative to the first exercise. The household's income is at the 30th percentile, and its ability is at the 70th percentile. Thus, the household is on the "boundary" between the two sets of households displayed in Figure 3.

Public Monitoring

In order to simulate public monitoring, we need to choose values for its intensity (m_0) and unit cost (κ). We use the term "low-intensity public monitoring" to denote the value of m_0 (equal to 5) that would deliver a total monitoring (M+m_0) equal to 21 in the benchmark equilibrium, holding everything else constant. "Medium-intensity public monitoring" corresponds to m_0 = 10.5 (equal to half the number of public school households in the benchmark equilibrium), and "high-intensity public monitoring" corresponds to m_0 = 16 (in order to double total monitoring in the benchmark equilibrium, holding other things constant).

Hoxby (2002a) argues that accountability is a low-cost policy. While that may be true for the implementation of a testing system, the kind of monitoring we consider in this paper is one that actually affects school effort. This might entail detailed evaluations of public school performance, practices and records, direct observation of classroom and administrative practices etc. In the absence of 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, $\kappa = \gamma XN / m_0$. We calculate κ as the unit cost of low-intensity monitoring in the baseline equilibrium, or $\kappa = \gamma * \$7{,}000 * 21/5$. "Low-cost accountability" assumes γ=0.2 (and κ=\$5,880); "high-cost accountability" assumes γ=0.6 (and κ=\$17,640).

Columns 2 through 7 of Table 5 describe the equilibrium under different combinations of public monitoring intensity and 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. Public monitoring also affects household school and monitoring choices, as shown in Figure 4. Relative to the benchmark equilibrium, public monitoring raises public school attendance by raising public school effort. Only the highest-ability, highest-income household remains in private school. Moreover, the high-income, high-ability households that switch from private into public schools provide monitoring.

Whether public monitoring increases household monitoring rate depends on the net effect of several forces. On the one hand, public monitoring raises public school effort, hence attracting households away from private schools. The fact that these high-ability, high-income households monitor the public school can raise the monitoring rate, further increasing public school effort. On the other hand, public monitoring is a substitute for private monitoring and can hence crowd it out, thus lowering the monitoring rate. An additional effect is that the entry of high-income, high-ability households into the public school can induce households for whom monitoring is costly to free-ride on the newly arrived households and no longer monitor, also leading to a decrease in monitoring. Furthermore, while the final effect on public school effort can be positive as in these simulations, this need not be the case, depending on the relative effect of these forces.

The net outcome of these effects on household monitoring depends on the cost of public monitoring. When the cost is low the first effect prevails, yet the second and third effects dominate when the cost is high. For instance, the last row of Figure 3 (high-cost public monitoring) 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.

To understand this change in monitoring behavior, recall from the discussion in our previous section 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, as illustrated by the growing income tax rate at the bottom of Table 5. This reduction in disposable income thus 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 these simulations, we wish to reiterate that *effective* public monitoring might actually be quite costly. Hence, the kind of crowd-out and free-riding featured in these simulations is not unlikely.

As Table 5 shows, public monitoring reduces monopoly rents and public school profits. 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.

An important question is whether public monitoring raises achievement. On the one hand, public monitoring raises public school effort and peer quality, which in turn induce greater household learning effort. On the other hand, public monitoring has a fiscal cost that lowers disposable income and hence the demand for household learning effort. Since the second effect prevails in our simulations, public monitoring does not raise achievement.[21] Furthermore, achievement falls even among households who remain in private schools, because the reduction in disposable income lowers their demand for school and household learning effort. It is not surprising, then, that public monitoring lowers aggregate welfare, even when monitoring cost and intensity are low.

Private School Vouchers

Table 6 shows the effects of private school vouchers for two kinds of programs: universal and income-targeted vouchers (columns 2-3 and 4-5, respectively). For ease of comparison, column 1 shows the benchmark equilibrium, without vouchers. Whereas all households are eligible for universal vouchers, only households whose income is above a certain threshold (equal to \$50,000 in these simulations) are eligible for income-targeted vouchers. Since public school spending per student, X, is \$7,000, we consider voucher amounts of \$3,500 and \$7,000 ("low" and "high" voucher, respectively). Although income-targeted vouchers are politically more feasible given their lower eligibility rate, universal voucher simulations are of interest because they show the full effects of an unrestricted voucher.

Figure 5 depicts the effects of vouchers on household school choice and monitoring. We begin our analysis with universal vouchers. As one would expect, they

[21] We conjecture that results might be different if accountability were funded through a progressive rather than a proportional income tax. In ongoing work we are seeking to find the minimum cost and intensity for public monitoring to actually raise achievement.

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 hurts them because they lose peer quality, and because those households would monitor if they remained in public school. Monitoring rate thus falls in public school, with a concomitant fall in school effort. In particular, a high universal voucher leaves the lowest-income segment in public school with a school effort (and achievement) of zero.

It has been argued that by creating competition, vouchers would raise public school effort. That is not the case in our simulations. The reason is that in this 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.

Not all 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. Thus, some households gain achievement while others lose. The lower the income or the ability, the more likely the household is to lose. s

Public school profit falls with vouchers due to the loss of students. However, under high vouchers public school teacher compensation is as high as possible ($7,000) because all revenue consists of monopoly rent. In the case of a high universal voucher, public and private school funding per student is the same since nobody supplements the voucher. While private schools devote almost 80 percent of their funding to purchase teacher effort, the public school in this case turns all of its funding into monopoly rent. In other words, the high universal voucher exacerbates the pre-existing efficiency gap between public and private schools.

Universal vouchers improve aggregate welfare relative to the benchmark equilibrium. However, a low voucher accomplishes a greater improvement than a high voucher because of its lower fiscal cost.

We now turn to the analysis of income-targeted vouchers. Given the income target in our simulations, 40 percent of the population is eligible for vouchers (i.e., the households with income below the 50^{th} percentile). As the last row of figure 5 shows, not all the eligible population takes up the voucher. The lowest-income households do not take it up because the cost of monitoring in private schools would be prohibitively high for them. Only the most able households from the 30^{th} percentile of the income distribution take up the voucher. Monitoring rate also falls with income-targeted vouchers though not as much as with universal vouchers, 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.

In terms of aggregate welfare, income-targeted vouchers fare worse than universal vouchers because they generate achievement gains to fewer households while failing to deliver greater fiscal savings. Moreover, a high income-targeted voucher lowers aggregate welfare relative to the benchmark because only the households that take up the voucher experience welfare gains. Households remaining in public schools lose because of lower peer quality and school effort, and households that already attended private schools do not experience welfare changes.

The fact that the lowest-income households do not take up even a high voucher raises the question of whether the voucher should actually be higher. We have conducted simulations (not reported here) for vouchers higher than $7,000. Interestingly, the higher the voucher, the less likely those households are to take it. The reason is that a higher voucher entails a higher fiscal cost, even if it is income-targeted to avoid the high take-up rates of universal vouchers. The higher fiscal cost brings a decline in disposable income, which in turn lowers the payoff from the monitoring that the household would have to conduct in private schools. Thus, unless the voucher can be funded with some kind of progressive tax system, lowest-income households will not take it.

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 prohibitively costly 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 Table 7 show the effect of high and low universal and income-targeted vouchers under perfect observability. For ease of comparison, column 1 shows the perfect observability baseline equilibrium, without vouchers. In addition, Figure 6 shows household school and monitoring choices. Under universal vouchers, the take-up rate is higher than in the presence 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.

For income-targeted vouchers, the take-up rate is also higher under perfect observability. Interestingly, these vouchers prompt some high-income, high-ability households that attend public schools in the perfect observability benchmark equilibrium, to switch into private schools. This is because as high-ability eligible households take up the voucher, public school peer quality suffers.

The comparison of vouchers under perfect and imperfect observability provides evidence that vouchers' effectiveness at raising achievement for the low-income segment depends on whether informational frictions exist or not. In particular, the presence of informational frictions may render vouchers ineffective. In the presence of such frictions, then, 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, or by public monitoring of public schools to compensate for the loss of monitoring households on the part of public schools.

6. Concluding Remarks

In this paper we have argued that the primary cause of the underachievement problem is the information asymmetry among the policy-maker, households, and schools. We have built a simple hidden-action (moral hazard) model of school effort and embedded it into an equilibrium model of education choice in which households sort across schools and exert learning and monitoring efforts. From the point of view of policy, we have focused on reforms aimed at improving achievement, and on whether they address the distortions created by the underlying information frictions. An important conclusion is that neither a complete market-based solution (such as vouchers) nor a complete "administration-based" solution (monitoring) is the answer to the problem. Rather, the solution is likely to combine elements from each approach.

We view our theoretical and computational model as a first step towards a comprehensive and systematic investigation of the problems facing a policy-maker in an environment including public and private schools. We believe that a perspective rooted in information asymmetries will shed light on the problem and its possible solutions. In particular, we believe 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 evaluation or output-based contingent contract is modeled. Instead, we model the productive (or input) distortion directly and focus instead on monitoring activities. In this sense, our agency cost is modeled in a reduced-form fashion. Presumably, monitoring generates informative signals which are in turn used in implicit or explicit contracting among the public school, households and policy-makers.

An extension to an output-based modeling of agency costs would require more institutional features in the model. One commonly used output measure, namely 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, yet achievement tests are usually administered in the short run. 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 based on performance metrics (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 educational setting has unique features that add richness and complexity to the problem.

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

Third, as our model indicates, inducing household learning and monitoring efforts are a fundamental task of education reform. To this end, some schools may have an advantage in eliciting student effort and hence attaining high performance. If this is indeed the case, then inducing low-effort students to attend those schools may be more desirable than providing them with short-term incentives, because those schools can help the students develop work habits that enhance their human capital in the long run. Furthermore, if peer quality were a function of a school's average household ability and effort, the school might succeed at implementing an environment where students work hard in response to the hard work of their peers.[22]

In closing, we reiterate our view that understanding the achievement problem in public schools requires a firm grasp of the existing informational frictions between the policy-maker, households and students, the incentives implied by alternative mechanisms that address the 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 to the design of its solutions.

[22] See Cooley (2008) for an empirical model of peer effects which depend on endogenous choices of student effort.

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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	1000

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 Public and Private 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	12
Monitoring Rate	0.80	0.00
Public School	0.76	0.00
Private School	1.00	0.00
Spending per Student	$6,700	$7,000
Public School	$7,000	$7,000
Private School (tuition)	$4,900	$6,400
Promised School Effort		
Public School	0.66	0.66
Private School	0.69	0.71
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
Teacher Compensation		
Public School	$6,000	$7,000
Private School	$3,900	$6,400
Use of School Revenues		
Public School		
Salaries	0.44	0.79
Informational Rent	0.15	0
Monopoly Rent	0.41	0.21
Private School		
Salaries	0.79	1
Informational Rent	0.21	0
Monopoly Rent	0	0
Household learning effort	588	662
Public School	342	511
Private School	1876	4291
Achievement		
Public School	-0.25	-0.16
Private School	1.31	3.82
Income Tax Rate	0.1	0.12
Aggregate Welfare	8.34E+12	1.03E+13

Note: in all tables, dollar amounts are rounded to the nearest hundred. Ability and household learning effort are rounded to the nearest integer. For "Use of School Revenues", we display the fraction of revenues that pays for salaries, informational rent or monopoly rent. Achievement is shown in units of standard deviation (average achievement = zero).

TABLE 4

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

	Imperfect Observ. (1)	Imperfect Observ. Zero Profit (2)	Imperfect Observ. Maximum Profit (3)	Perfect Observ. (4)	Perfect Observ. Zero Profit Low e^{pub} (5)	Perfect Observ. Minimum Profit High e^{pub} (6)	Perfect Observ. Maximum Profit (7)
Fraction Public School	0.84	0.96	0.84	0.96	0	0.96	0.84
Average Income	$57,600	$57,600	$57,600	$57,600	$57,600	$57,600	$57,600
Public School	$51,300	$55,000	$51,300	$55,000		$55,000	$51,300
Private School	$90,400	$119,400	$90,400	$119,400	$57,600	$119,400	$90,400
Average Ability	100	100	100	100	100	100	100
Public School	97	99	97	99		99	97
Private School	116	119	116	12	100	119	116
Monitoring Rate	0.80	0.80	0.80	0.00	0.00	0.00	0.00
Public School	0.76	0.79	0.76	0.00		0.00	0.00
Private School	1.00	1.00	1.00	0.00	0.00	0.00	0.00
Spending per Student	$6,700	$7,000	$6,700	$7,000	$3,500	$7,000	$6,700
Public School	$7,000	$7,000	$7,000	$7,000		$7,000	$7,000
Private School	$4,900	$6,400	$4,900	$6,400	$3,500	$6,400	$4,900
Promised School Effort							
Public School	0.66	0.85	0.60	0.66		0.70	0.50
Private School	0.69	0.80	0.69	0.90	0.50	0.71	0.62
Actual School Effort	0.51	0.64	0.47	0.67	0.50	0.70	0.52
Public School	0.50	0.64	0.45	0.66		0.70	0.50
Private School	0.55	0.64	0.55	0.71	0.50	0.71	0.62
Public School Profit	$60,800	$3,000	$76,600	$35,600	$0	$19,900	$81,800
Teacher Compensation							
Public School	$6,000	$5,300	$6,100	$7,000		$7,000	$7,000
Private School	$3,900	$5,100	$3,900	$6,400	$3,500	$6,400	$4,900
Use of School Revenues							
Public School							
Salaries	0.44	0.74	0.36	0.79		0.88	0.44
Inform. Rent	0.15	0.25	0.12	0		0	0
Monopoly Rent	0.41	0.02	0.52	0.21		0.12	0.56
Private School							
Salaries	0.79	0.79	0.79	1	1	1	1
Inform. Rent	0.21	0.21	0.21	0	0	0	0
Monopoly Rent	0	0	0	0	0	0	0
Household learning effort	588	633	565	662	1160	685	620
Public School	342	497	315	511		535	345
Private School	1876	3896	1876	4291	1160	4291	2066
Achievement							
Public School	-0.25	-0.15	-0.26	-0.16		-0.15	-0.26
Private School	1.31	3.6	1.34	3.82	0	3.68	1.34
Income Tax Rate	0.1	0.12	0.1	0.12	0	0.12	0.1
Aggregate Welfare	8.34E+12	9.35E+12	7.81E+12	1.03E+13	3.55E+13	1.10E+13	9.41E+12

Note: Column (1) and (4) are the same as columns (1) and (2) from Table 1, respectively. Column (6) corresponds to the value of ePub that yields the lowest non-negative public school profit under perfect observability

TABLE 5
Public Monitoring of Public School

	Imperfect Observ. (1)	Low Cost Low Intensity (2)	Low Cost Medium Intensity (3)	Low Cost High Intensity (4)	High Cost Low Intensity (5)	High Cost Medium Intensity (6)	High Cost High Intensity (7)
Fraction Public School	0.84	0.88	0.96	0.96	0.88	0.96	0.96
Average Income	$57,600	$57,600	$57,600	$57,600	$57,600	$57,600	$57,600
Public School	$51,300	$51,300	$55,000	$55,000	$51,300	$55,000	$55,000
Private School	$90,400	$103,700	$119,400	$119,400	$103,700	$119,400	$119,400
Average Ability	100	100	100	100	100	100	100
Public School	97	98	99	99	98	99	99
Private School	116	115	119	119	115	119	119
Monitoring Rate	0.80	0.80	0.80	0.80	0.80	0.76	0.60
Public School	0.76	0.77	0.79	0.79	0.77	0.75	0.58
Private School	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Spending per Student	$6,700	$6,800	$7,000	$7,000	$6,800	$6,900	$6,900
Public School	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000
Private School	$4,900	$5,500	$6,100	$5,900	$5,200	$5,500	$5,000
Promised School Effort							
Public School	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Private School	0.69	0.74	0.78	0.77	0.72	0.74	0.71
Actual School Effort	0.51	0.54	0.56	0.57	0.53	0.55	0.56
Public School	0.50	0.53	0.55	0.57	0.53	0.55	0.56
Private School	0.55	0.59	0.62	0.61	0.57	0.59	0.56
Public School Profit	$60,800	$57,700	$58,000	$54,900	$57,700	$58,600	$57,400
Teacher Compensation							
Public School	$6,000	$6,100	$6,200	$6,300	$6,100	$6,200	$6,200
Private School	$3,900	$4,400	$4,800	$4,700	$4,100	$4,300	$4,000
Use of School Revenues							
Public School							
Salaries	0.44	0.5	0.54	0.58	0.5	0.54	0.55
Inform. Rent	0.15	0.1	0.07	0.05	0.1	0.07	0.05
Monop. Rent	0.41	0.37	0.35	0.33	0.37	0.35	0.34
Private School							
Salaries	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Inform. Rent	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Monop. Rent	0	0	0	0	0	0	0
Household learning effort	588	508	418	360	371	208	118
Public School	342	296	320	278	219	161	92
Private School	1876	2059	2783	2337	1489	1344	736
Achievement							
Public School	-0.25	-0.25	-0.16	-0.16	-0.25	-0.16	-0.15
Private School	1.31	1.81	3.92	3.83	1.8	3.8	3.66
Income Tax Rate	0.1	0.13	0.16	0.18	0.17	0.25	0.31
Aggregate Welfare	8.34E+12	6.13E+12	4.12E+12	3.04E+12	3.27E+12	1.02E+12	3.24E+11

Note: Column (1) is the same as column (1) in Table 1 – the benchmark equilibrium for imperfect observability, with no public monitoring. Low- and high-cost monitoring corresponds to values of κ equal to 12.348 and 37.044 respectively. Medium and high-intensity monitoring corresponds to values of m_0 equal to 0.5 and 0.75, respectively.

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
Average Income	$57,600	$57,600	$57,600	$57,600	$57,600
Public School	$51,300	$38,000	$13,400	$49,300	$55,800
Private School	$90,400	$68,600	$68,600	$72,300	$61,400
Average Ability	100	100	100	100	100
Public School	97	91	100	94	95
Private School	116	105	100	111	111
Monitoring Rate	0.80	0.80	0.80	0.80	0.80
Public School	0.76	0.44	0.00	0.69	0.71
Private School	1.00	1.00	1.00	1.00	1.00
Spending per Student	$6,700	$5,400	$7,000	$6,100	$6,700
Public School	$7,000	$7,000	$7,000	$7,000	$7,000
Private School	$4,900	$4,500	$7,000	$4,600	$6,000
Promised School Effort					
Public School	0.66	0.66	0.66	0.66	0.66
Private School	0.69	0.67	0.84	0.67	0.76
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
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
Use of School Revenues					
Public School					
Salaries	0.44	0.31	0	0.41	0.42
Inform. Rent	0.15	0.18	0	0.16	0.15
Monop. Rent	0.41	0.5	1	0.43	0.43
Private School					
Salaries	0.79	0.79	0.79	0.79	0.79
Inform. Rent	0.21	0.21	0.21	0.21	0.21
Monop. Rent	0	0	0	0	0
Household learning effort	588	742	684	633	568
Public School	342	198	0	289	394
Private School	1876	1048	855	1244	939
Achievement					
Public School	-0.25	-0.34	-0.39	-0.3	-0.22
Private School	1.31	0.19	0.1	0.52	0.47
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

Note: Column (1) is the same as column (1) in Table 1 – the benchmark equilibrium for imperfect observability. Income-targeted vouchers are for households with incomes below $50,000.

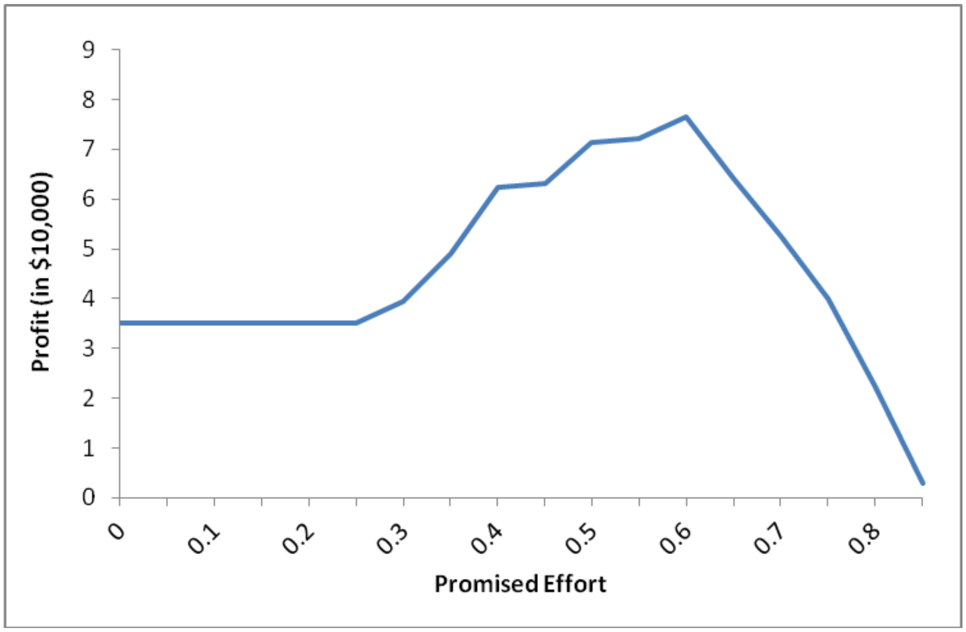
TABLE 7
Private School Vouchers under Perfect Observability

	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
Average Income	$57,600	$57,600	$57,600	$57,600	$57,600
Public School	$55,000	$57,600		$57,600	$68,800
Private School	$119,400	$57,600	$57,600	$57,500	$45,400
Average Ability	100	100	100	100	100
Public School	99	81		94	92
Private School	12	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
Spending per Student	$7,000	$4,900	$7,000	$6,300	$6,700
Public School	$7,000	$7,000		$7,000	$7,000
Private School	$6,400	$4,400	$7,000	$4,400	$6,300
Promised School Effort					
Public School	0.66	0.66		0.66	0.66
Private School	0.90	0.73	0.94	0.74	0.88
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
Teacher Compensation					
Public School	$7,000	$7,000		$7,000	$7,000
Private School	$6,400	$4,400	$7,000	$4,400	$6,300
Use of School Revenues					
Public School					
Salaries	0.79	0.79		0.79	0.79
Inform. Rent	0	0		0	0
Monop. Rent	0.21	0.21		0.21	0.21
Private School					
Salaries	1	1	1	1	1
Inform. Rent	0	0	0	0	0
Monop. Rent	0	0	0	0	0
Household learning effort	662	871	754	696	649
Public School	511	397		491	611
Private School	4291	989	754	1223	689
Achievement					
Public School	-0.16	-0.31		-0.21	-0.15
Private School	3.82	0.08	0	0.54	0.16
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

Note: Column (1) is the same as column (2) in Table 1 – the benchmark equilibrium for perfect observability. Income-targeted vouchers are for households with incomes below $50,000.

FIGURE 1

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



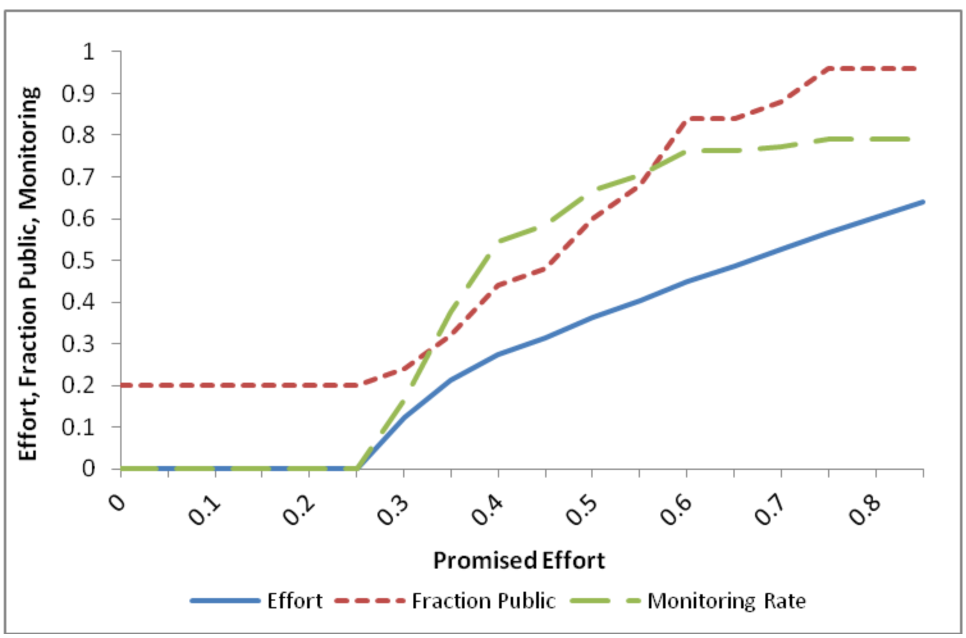


FIGURE 2

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

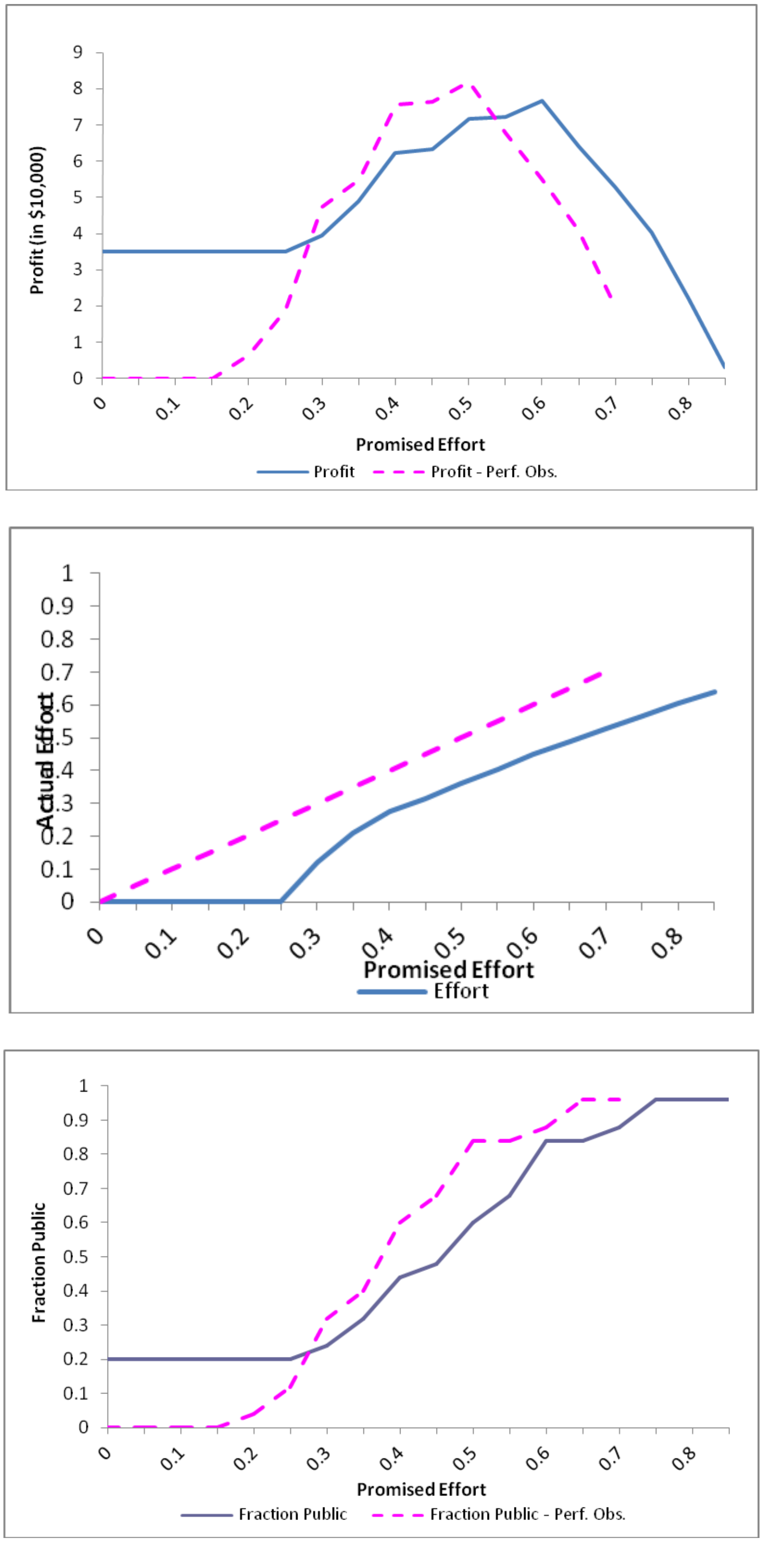
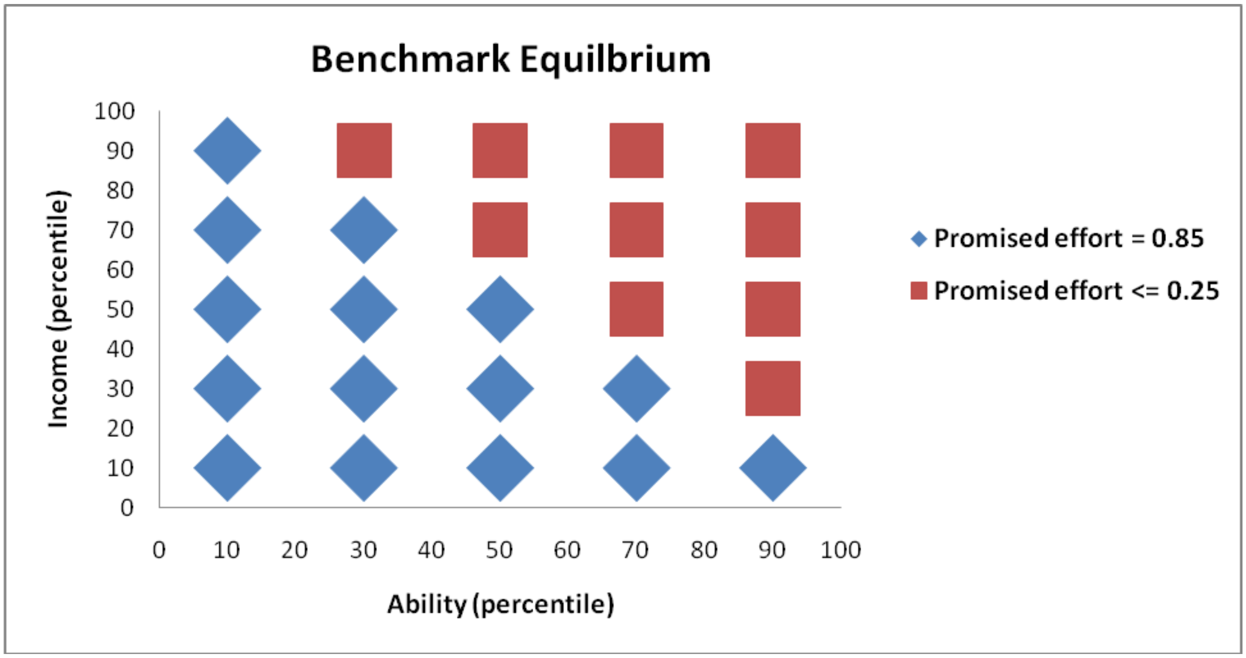


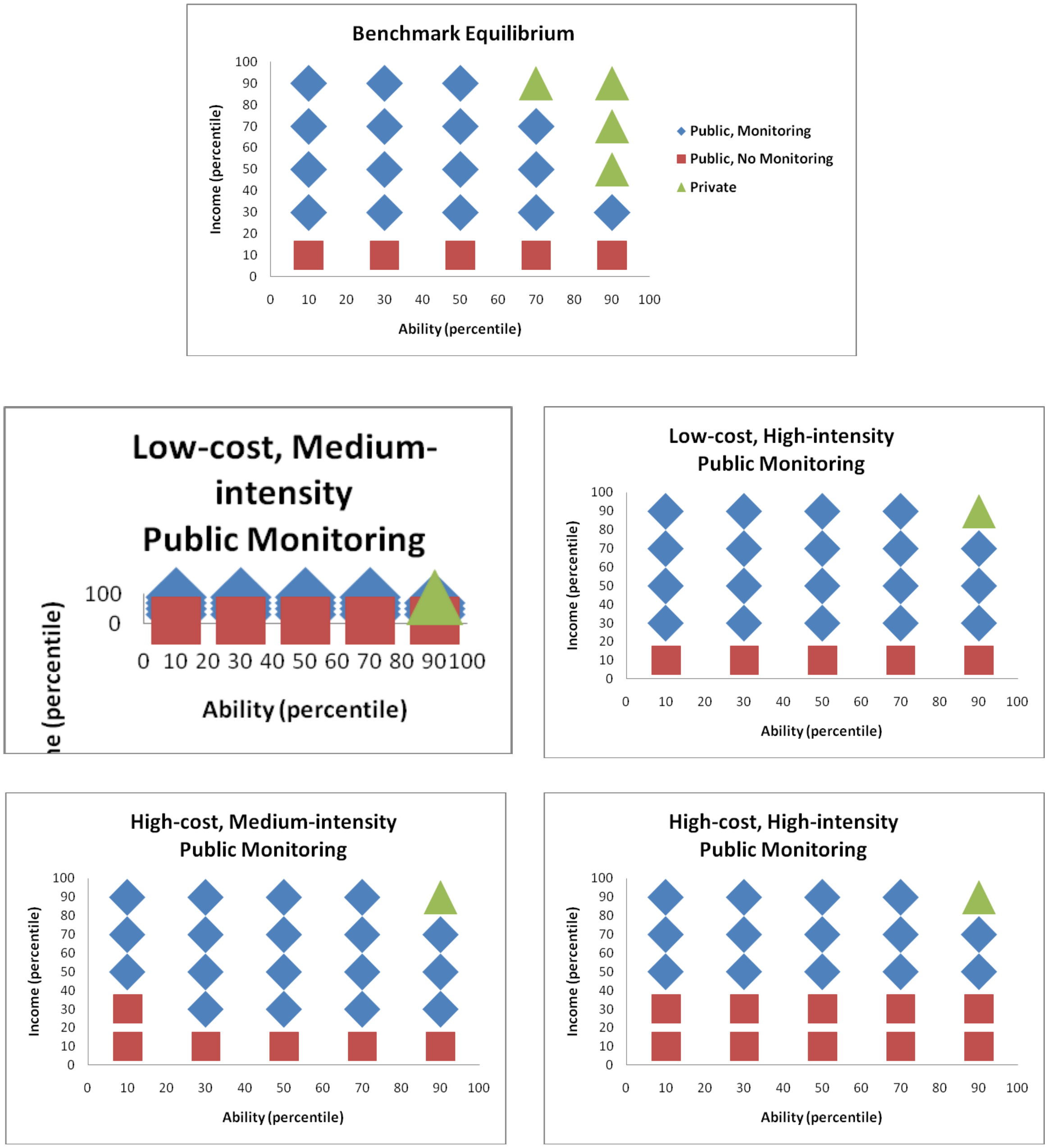
FIGURE 3
Household Preferences on Public School Promised Effort



Note: each (income, ability) combination represents a household. For instance, the household with a 10th percentile ability and a 30th percentile income prefers a promised effort of 0.85 over all others.

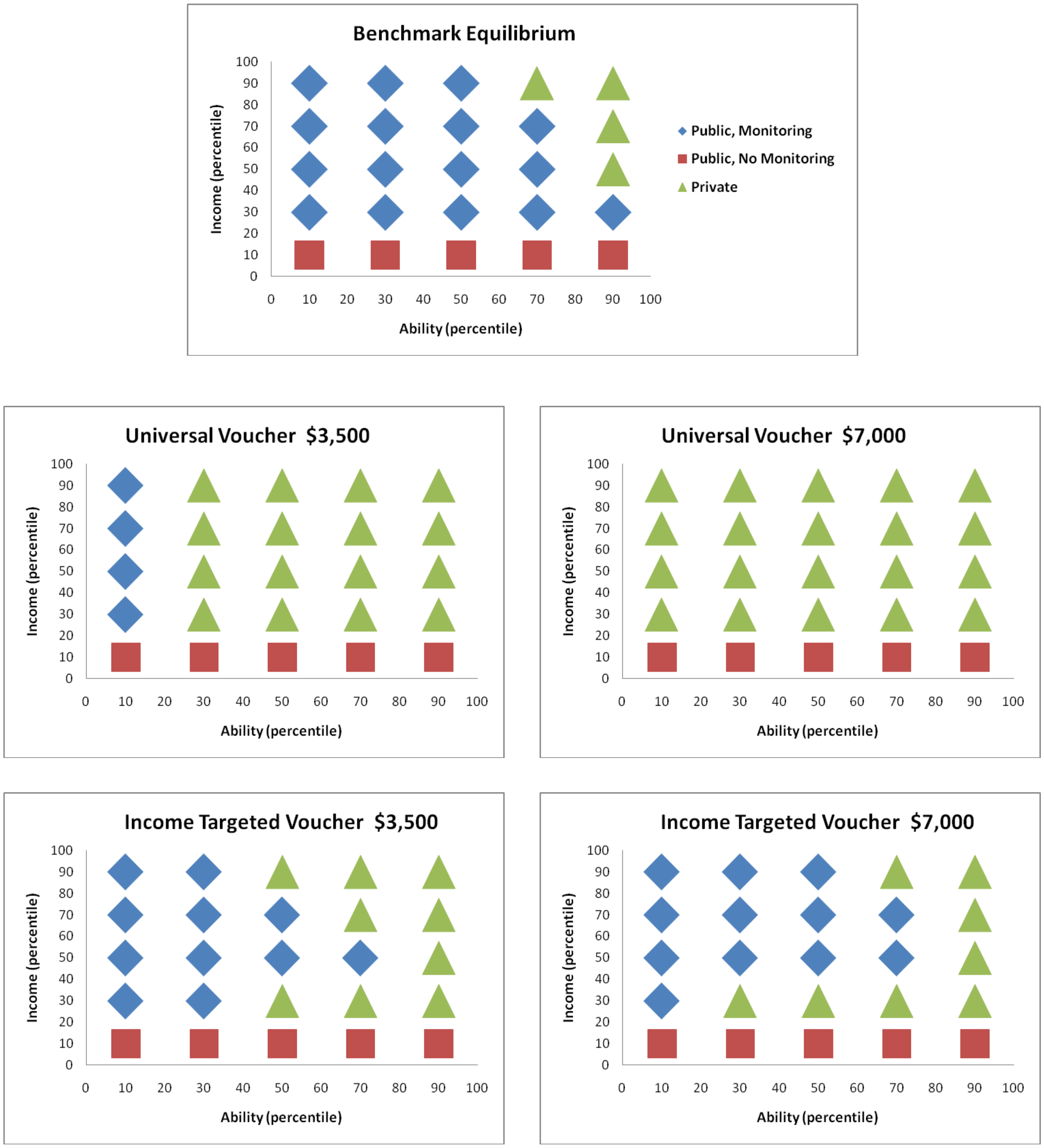
FIGURE 4

Household School Choice and Monitoring under Public Monitoring



Note: 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). Low- and high-cost monitoring corresponds to values of κ equal to 12.348 and 37.044 respectively. Medium and high-intensity monitoring corresponds to values of m_0 equal to 0.5 and 0.75, respectively.

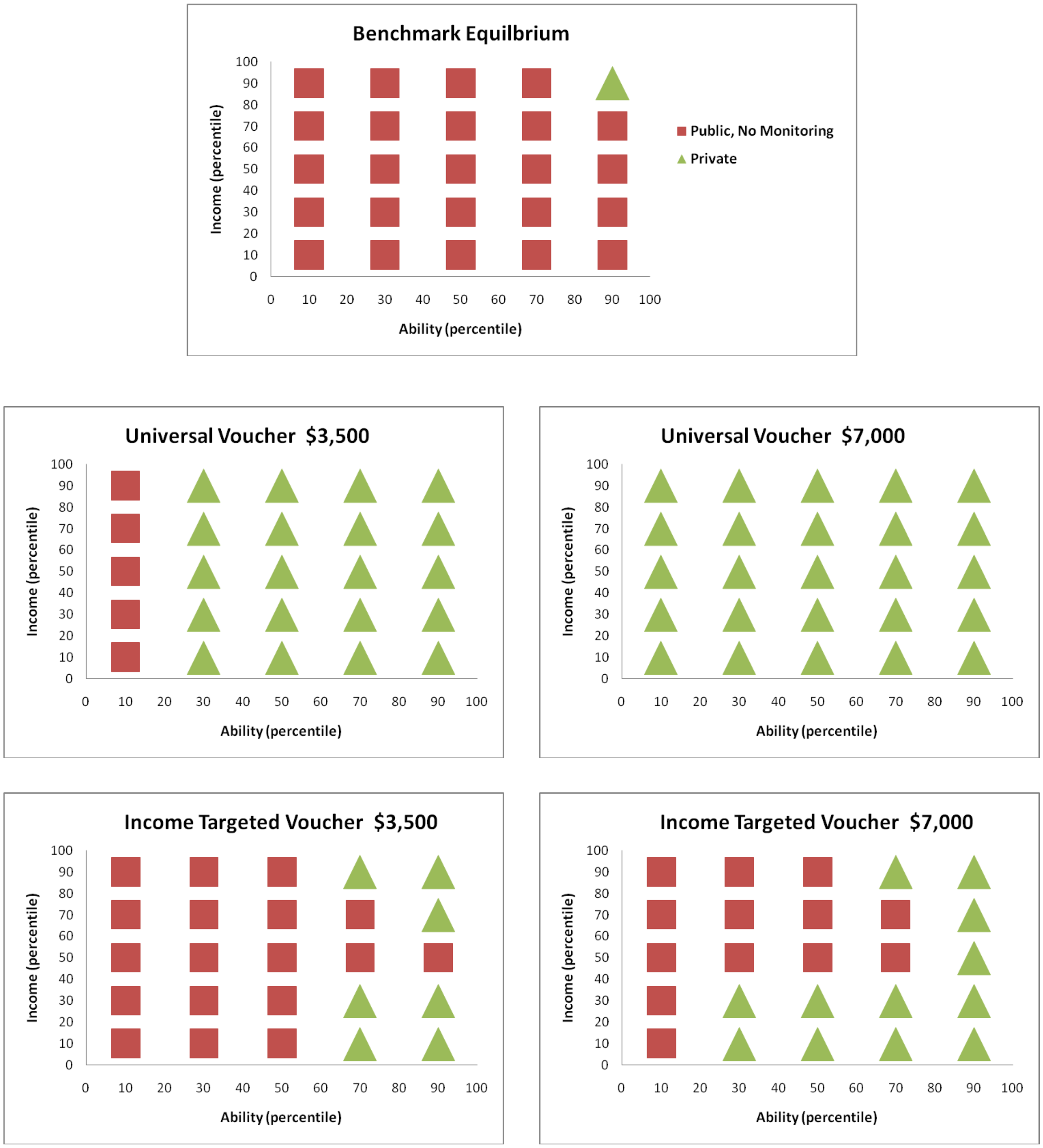
FIGURE 5
Household School Choice and Monitoring under Private School Vouchers
Imperfect Observability



Note: Benchmark Equilibrium is the equilibrium for imperfect observability.

FIGURE 6

Household School Choice and Monitoring under Private School Vouchers
Perfect Observability



Note: Benchmark Equilibrium is the equilibrium for perfect observability.