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General Equilibrium Benefit Analyses for Social Programs

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I. Introduction

The purpose of this paper is to describe the conceptual framework for incorporating general equilibrium effects into benefit-cost analyses of social programs. To make our description tangible we selected a specific example, the evaluation of reductions in the resources available for public primary education. We use a policy change that has been common in local public education, due to the economic downturn, - reductions in the teaching staff. To highlight the general equilibrium effects of exogenous reductions in the resources used to produce education and its effect on common measures of the quality of education, we use a locational sorting model applied to school districts in Maricopa County, AZ. Several of these districts experienced teacher cuts in the 2009-

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2010 school year and we use these cuts to illustrate how the model would work. Our approach provides an illustration of how the general equilibrium effects influence our understanding of both the severity and distribution of changes in household well-being arising as a result of changes to local social programs.

Most discussions of the distinctions between partial (PE) and general (GE) equilibrium frameworks for benefit cost analysis focus on policies that directly alter the prices of marketed goods and services and follow the seminal contributions described in Just, Hueth, and Schmitz [2004]. When these analyses are extended to policies that are intended to change the amounts, quality or conditions of access to non-market resources, there are added complexities. The basic concepts defining partial and general equilibrium measures of net benefits are comparable. Nonetheless there are several special features of the modeling structure that are sometimes taken as given in the terminology used when partial and general equilibrium analyses are considered in different applications in economics. We will describe how these features influence the logic used in structuring models and carrying out analysis tasks in the next section. To our knowledge a full discussion of these issues does not exist in the literature.[1]

After providing context, section three defines benefit concepts and explains the difference between partial and general equilibrium welfare measures. Section four describes two approaches for developing models capable of measuring general equilibrium effects with non-market interactions that might arise from social or environmental policies. The first of these approaches uses the computable general

[1] This comment is directed to applications of partial and general equilibrium welfare measures when there are both market and non-market adjustments possible.

equilibrium (CGE) logic originally developed by Scarf [1973] and made easily accessible through the MPSGE framework developed by Rutherford [1997].[2] The second modeling approach involves locational sorting models. The locational equilibrium approaches are distinctly different from the CGE logic and do not represent GE welfare measures in the same way that the conventional CGE framework does.[3] We discuss locational equilibrium models because they are especially relevant to situations where social programs are provided by local governments. In these situations an important challenge arises in representing how households respond to the diversity in local public goods available outside markets.

An important challenge in extending the CGE framework to include market and non-market policies arises in describing how the services that result from these programs influence preferences and / or production activities. To highlight the implications of this process we include a discussion of how most CGE models have addressed these questions. Our review is critical of the most popular maintained assumption of separability between market and non-market influences. While this is the most common assumption, we argue it misses one of the most important questions raised by the PE versus GE comparisons –namely the extent to which non-market feedback effects have an influence on observed market outcomes. To help document this point, we describe some of the existing analyses of PE versus GE measures associated with environmental policies.

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[2] Shoven and Whalley [1992] provide an introduction and early review of this literature.
[3] As we discuss in the next section the use of the term general equilibrium can have a number of interpretations from considering effects thru more than one market to a situation where the model describes a policy's effects on prices, incomes and non-market services affected by market decisions. It is this definition that we use when we refer to general equilibrium analyses.

Finally our example of PE versus GE welfare measures for educational policy is developed in two sections. Section five describes how a vertical locational sorting model is estimated to characterize household preferences for the quality of local public education. Our application is based on housing sales data and the differences in performance of primary school students on standardized tests for forty-six school districts in Maricopa County, Arizona. Our primary objective is to provide a tangible example. Nonetheless the empirical analysis is itself of interest as a detailed effort to characterize how the quality of schools can have a feedback effect on housing prices by influencing households' locational choices. We do not attempt to address all the concerns associated with measuring how school quality influences household locational choices.

Our analysis allows school quality to be endogenous to equilibrium household sorting and solves the model as a Nash equilibrium. Each household is assumed to respond to housing prices and to recognize what other households will do in response to exogenous changes in resources for public schools. Households decide to re-locate based on both housing prices and the implied effects of all household movements on the resulting school quality in each district, which is influenced by student/teacher ratios.

An outline of the conceptual features of this model and our example describing the PE and GE costs of eliminating different numbers of teachers in each of a subset of the school districts in Maricopa County are presented in section six. The last section summarizes what is known about developing general equilibrium benefit-cost assessments for social programs and outlines opportunities for future research.

II. Background

A. Conventional Practice

As we describe in more formal terms below, most of the economic analyses of the general equilibrium consequences of policies have been in the context of marketed goods and services. In this setting the research has focused on the effects of distortions in markets or the assessment of the welfare effects of new interventions. These can be pre-existing taxes, environmental regulations, or non-competitive markets. These effects are interpreted as creating differences in what demanders pay and suppliers receive for these marketed goods and services. There can be a number of surprising results. For example, a pre-existing distortion can influence the measured effects of a new tax depending on whether a partial versus general perspective is adopted. The measured excess burden from introducing a new, relatively small tax can vary substantially due to general equilibrium effects (see Goulder and Williams [2003]).

Another important issue in evaluating PE and GE effects is associated with defining the “size” of an intervention in relation to one or more markets. In most public economics applications involving taxes or regulations evaluation typically focuses on the direct effects of the tax or regulation on prices. For these applications, size in this context is often interpreted in terms of a policy’s effect on a PE or a GE measure of excess burden. In this type of application the direct effect on excess burden is often proportional to the square of the size of the policy. In this context, the policy is interpreted as a price wedge. The general equilibrium effects are often approximately linear in this price wedge. In contrast, for environmental applications size can have a somewhat different meaning. It can arise from a spatial dimension, such as the amount of undeveloped land that is preserved in a protected status or the number of households affected who might be demanders (or suppliers) of specific goods and services. In either context, size does not correspond to a price wedge in a single market. In these settings, Palmquist's [1992] arguments for how to evaluate localized externalities is frequently used as an analogy to describe how "size" affects benefit measures in differentiated markets. In this setting the issue is the number of home locations that experience an amenity change in relation to the whole urban housing market.[4] Small, in this context implies a non-changing hedonic price function that describes how all the sites prices are related in equilibrium.

Thus, the characterization of the market and the policy are jointly related in determining the equivalent of a price effect. In this case it is the price change for one or a small number of locations.[5] Related to this point is the logic used to describe how a non-market good is conveyed to a consumer. Many economic models do not describe the geographic extent of the market. For some applications this is not an important feature of market outcomes. The same conclusion is less likely to hold when we consider the geographic domain of non-market services. It might seem easy to come to the conclusion that non-market goods have virtual prices that can be defined without reference to the geography of the processes that influence their availability. Unfortunately this simplification usually has important implications for describing the adjustments people can make to policy and how those adjustments influence these resources. Our

[4] See Freeman [2003] pp 278-280 for discussion.
[5] Nonetheless as Kuminoff and Pope [2010] demonstrate this argument is best interpreted as an approximation.

development of two types of general equilibrium models will use examples to explain these differences.

B. Just, Hueth, and Schmitz's General Equilibrium Demand Functions

To develop context, consider the Just et al. [2004] explanation of the important features of general equilibrium demand functions. When an exogenous distortion, such as a tax or a regulation, is introduced into an otherwise undistorted market equilibrium their analysis demonstrates how the PE and GE benefit measures can be compared within a single market. Their explanation is based on the concept of a general equilibrium demand function. This relationship takes account of how changes in one good's price influences all other goods' markets and how the resulting price changes for these goods influence the market for the commodity we started with. In effect, the measure of how the quantity demanded of the original good changes with a change in its price is already adjusted by the contributions that substitute or complementary markets make to equilibrium outcomes (as a result of that one price change). When demand and supply functions describing all markets are linear the derivation is straight forward. The reduced form expressions for equilibrium prices in all markets are used to eliminate their price effects in the demand for the commodity of interest. The term describing the price effect is the algebraic counterpart to assuming equilibrium adjustments in all markets when evaluating a price change in one market. It allows general equilibrium welfare measures because there are no distortions in any other market. By assumption each consumer's marginal willingness to pay is equal to the marginal cost for each good in these other markets. The action in the market of interest does not change that outcome. It may change the levels of consumption of these goods, and correspondingly the levels for their marginal willingness to pay and marginal cost in the new equilibrium. Only the market with the intervention has a wedge if the intervention is a tax or regulation that affects demanders and suppliers differently. As a result, in their derivation of the general equilibrium demand function we take account of these other influences in how we measure the efficiency gain or loss. This property of the GE demand function implies that the analysis does not need to consider changes in economic surplus arising in other markets as they are already reflected in the demand function for the market experiencing the exogenous policy change.

When we consider the analog for non-market goods a parallel result could be stated. That is, if a policy intervention in one market did not alter the equality of marginal willingness to pay and marginal cost for other non-market goods we need not be concerned about changes in their amounts or in economic surplus associated with these other services. However, this condition is unlikely to hold. There are no mechanisms that assure the equality of marginal willingness to pay and marginal cost in the first place. Usually the ways that are available to households to select different amounts of non-market goods are limited if they exist at all. Moreover, there are few opportunities to trade these services because they often have some non-rival and non-exclusive attributes.

III. How Should the Net Benefits of a Public Intervention be defined?

The question posed in this heading seems quite general, but our focus here will be more targeted. We accept a conventional economic definition for what constitutes a benefit. It is either the amount a person would be willing to give up to realize some specific change from his (or her) baseline conditions (in the case of a willingness to pay for a desirable change) or it is the amount of compensation a person would require to be indifferent between having the change versus remaining with the baseline condition and receiving monetary compensation (the willingness to accept measure). There are numerous, detailed treatments describing the formal definitions for these concepts, their properties, and interrelationships (see Freeman [2003] as one example). We will not attempt to summarize these issues here, but instead jump to algebraic definitions below after briefly discussing some context for these definitions.

A key element in the PE versus GE distinction is the characterization of "the change." In most standard discussions it would be described as a price, quantity, or quality change. However, when one moves from the conceptual domain to the domain of policy evaluation, a key question is the process of translating the source of that change, usually a policy of some type, into changes in the exogenous factors that influence people's (and firms') decisions. This translation is directly connected to the differences we will classify into PE and GE measures of net benefits and are related to the examples we gave at the outset. In many policy situations in public economics, it is straight forward to transform a tax or a regulation into an equivalent price change. In the case of social policy this close connection may not be as direct. This is another reason for considering different modeling approaches for evaluating the effects of policies directed at activities taking place outside markets.

A. Some Definitions

The ideal economic measure of the benefit from a policy intervention is a Hicksian consumer surplus. This concept maintains that we can represent a person's choices within a constrained utility maximizing framework. In the simplest static case, the constraint is a budget constraint relating income to the prices of the goods and services consumed. The outcome of these choices is represented with an indirect utility function, where realized well being is a function of income, prices, and any other exogenous factors contributing to well being and outside a person's control.

We will adopt the convention that a superscript zero (0) defines the baseline condition and a one (1) is the new or altered condition with the policy. Equation (1) defines the well being or utility that is realized in the baseline as a function of income, prices, policy goods, and other exogenous factors contributing to well-being.[6]

$$V^0 = V(m^0, p^0, Z^0, q^0) \tag{1}$$

where: m = income

p = a vector or prices of marketed goods

q = a vector of public goods (produced by local governments) and / or available natural assets such as air quality

[6] These definitions do not require a cardinal measure of utility or well being. This characterization is an analytical abstraction. It allows formal definitions for the concept being measured (provided we make a set of assumptions about the functional forms for relationships linking variables describing choices and constraints).

Z = a vector of quasi fixed private commodities assumed outside an individual's direct control

As a rule, we define willingness to pay as the income a person would be willing to give up in order to obtain some desirable change. Thus, if we assume one price (in our example the price for the first good) is lower than baseline conditions so the vector p^1 corresponds to $p^1 = [p_1{}^1 p_2{}^0 p_3{}^0 ... p_k{}^0]$ and $p^0 = [p_1{}^0 p_2{}^0 p_3{}^0 ... p_k{}^0]$, then the willingness to pay (WTP) for this improvement (from p_1^0 to p_1^1) is defined in (2a) and the willingness to accept (WTA) in (2b).

$$V_1(m^0 - WTP, p^1, Z^0, q^0) = V(m^0, p^0, Z^0, q^0) \qquad (2a)$$

$$V(m^0, p^1, Z^0, q^0) = V(m^0 + WTA, p^0, Z^0, q^0) \qquad (2b)$$

For some specifications of $V(.)$ we could have a situation where WTP = WTA. This is not the case for a general specification of preferences. A great deal of effort has been devoted to explaining the size of the difference between the two measures. For example, Willig [1976] described the difference as *small for price changes*, based on the size of the income elasticity and the size of the Marshallian consumer surplus relative to the person's income. More recently, Hanemann [1991] has demonstrated this intuition does not readily apply to situations involving quantity (or quality) changes where the commodity may not be available at a unit price. In this case the price flexibility of income contributes to the definition of the Willig bound and does not have a simple relationship to the income elasticity of demand. This distinction is important because we usually have some intuition about income elasticity of demand, considering necessities versus luxuries. The same intuition is not readily available for the price flexibility which describes how the marginal willingness to pay changes with income. The simplest summary would suggest that the relationship depends on the structure of preferences, especially the availability of substitutes for the commodity affected by a policy and how its contribution to individual well-being changes with income. Both of these considerations can be important to the difference between PE and GE measures of the benefits from a policy.

The transition from the relationships described by equations (2a) and (2b) in partial equilibrium to the difference between PE and GE measures of WTP and WTA requires us to introduce a source for the change in p_1. This source is often illustrated by supposing a tax is introduced. For example, we might suggest $p_1^1 = p_1^0 + t$ for the representative consumer. However, even this specification makes an implicit assumption about market conditions. As we noted earlier, analyses often maintain that there are constant marginal costs (perfectly elastic supply). In this case we would expect each consumer would experience the full effect of the tax. Otherwise, the effects would be distributed between suppliers and consumers.[7] Thus, in this general case the single tax might be described as changing the price of the taxed good and other prices, or in our formulation income.

[7] Of course, in general equilibrium the proverbial "supplier" is simply another name for the economic agents who receive the profits from production activities (or the returns to capital in a competitive setting).

More generally, assume there is a policy designated with the symbol θ. It could be a regulation, a tax, or new information about a product or service. The definition is not limited to situations where only one thing changes. It could be a new rule together with a tax change to pay for the enforcement of the rule so that θ is a vector of actions.[8] In this context a general equilibrium measure would consider the change in θ from θ^0 (the baseline conditions) to θ^1. Evaluating this change requires a model of how the change influences the variables taken to be exogenous from the individual's perspective. Thus, with direct effects of θ impacting several prices through some mechanism outside each individual's choice process, we would define the GE measure of WTP as:

$$V(m^0 - WTP^{GE}, p(\theta^1), Z^0, q^0) = V(m^0, p(\theta^0), Z^0, q^0) \tag{3}$$

We could assume Z^0 and q^0 also change but, in this case, the process that causes them to change would need to be specified. Income could also be assumed to change either thru the re-valuation of endowments, a change in the wage, or both. As a rule the specific features of a GE benefit measure cannot be considered to be completely separate from the model used to estimate them. This conclusion stems from the ability of different modeling structures to capture the elements of the policy delivery system that are outside market exchanges. In the environmental case most policies are linked to a spatial

[8] See Hoehn and Randall [1989] for a discussion of piecemeal policy evaluation as compared to a strategy that defines policy composites. They suggest without composite strategies for defining policies the potential biases in using benefit-cost analyses for individual projects can lead to movements away from efficiency when a sequences of individual choices is compared to the composite of the policies treated as an integrated whole. Their argument can be interpreted as reflecting factors that also contribute to the distinction between partial and general equilibrium benefit cost analyses.

delineation of people's choices. In the case of social policy, the process can be spatially delineated if the policy is delivered at a local level or is conditional on the local situation. However it need not be spatial. Equally important, there is increasing recognition of the importance of the heterogeneity of consumer preferences to the outcomes of policy. Often people can respond outside of markets in ways that influence the policy outcomes. Thus, in these situations the ways in which models incorporate preference heterogeneity will influence this dimension of their ability to represent GE effects.

To help develop this point in the remainder of this section we discuss partial equilibrium benefit measures at the individual level. Partial equilibrium measures select a subset of the effects of a policy. One of the best examples of how this separation of effects can influence the way models are developed is to consider the organization of most benefit-cost staffs conducting policy evaluation. As a rule, one group does costs and another group does benefits. This classification assumes each part can be done separately from the other. In a partial equilibrium world we might be willing to accept this assumption. In a GE world we are not as likely to be satisfied with this division.

To illustrate how this formulation can be important, consider the argument developed more completely in Smith and Carbone [2007][9]. Suppose we invert the indirect utility function (equation (1)), solving for the total expenditures needed to realize a given utility level. This function is usually described as the Hicksian expenditure

[9] Their analysis was developed to explain the conditions required for Hazilla and Kopp's [1990] analysis of the social costs of environmental regulations to be valid.

function.[10] The definitions for WTP and WTA parallel to (2a) and (2b) using expenditure functions (designated here with the function, e(.)) are in equations (4a) and (4b).

$$WTP = e(p^0, Z^0, q^0, u^0) - e(p^1, Z^0, q^0, u^0) \tag{4a}$$

$$WTA = e(p^0, Z^0, q^0, u^1) - e(p^1, Z^0, q^0, u^1) \tag{4b}$$

u describes the utility level with the superscript of zero (0) corresponding to the baseline condition and one (1) the new situation. Our definition follows the standard convention in applied welfare economics.[11] Note that in our example of a tax, we might assume $p_1^1 > p_1^0$, where the subscript 1 indicates this price is for the first good. If we maintain for this discussion that none of the other prices are affected, then both WTP and WTA would be negative. We would expect it is necessary to spend more with the higher prices to realize the baseline utility. Similarly the level of well being with the higher prices would be lower in the new situation ($u^1 < u^0$) so that income would need to be reduced in the baseline condition to be equivalent. Of course, reversing the ordering of the expenditure functions in the differences presented in (4a) and (4b) would define what a person would pay to avoid the change and the compensation required to accept it.

A second issue of interpretation arises when we consider the connections between (2a) and (2b) with (4a) and (4b). The definitions acknowledge that income (or

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[10] See Diamond and McFadden [1974] for discussion of the duality features of the function and its role in early public economics.
[11] See Freeman [2003] pp.53-63 for further discussion.

expenditures) are constant when evaluated at the baseline and at the new price and utility so

$$m^0 = e(p^0, Z^0, q^0, u^0) = e(p^1, Z^0, q^0, u^1) \tag{5}$$

This relationship implies that the two measures could also be defined in alternative ways. They might be described as different ways of evaluating (monetizing) the change in well-being due to the policy (i.e. using the new prices – WTP or using the old prices – WTA)[12].

Turning to the relationship between these definitions and the separate computation of benefits and costs, suppose the tax policy in our example uses the tax revenues to improve q from q^0 to q^1. The WTP measure for an individual's benefits ignoring effects of the change in p_1 and q on other prices would be given in equation (6).

$$WTP^{PE} = e(p^0, Z^0, q^0, u^0) - e(p^1, Z^0, q^1, u^0) \tag{6}$$

Here the sign of WTP^{PE} is not clear. Indeed this might be described as the individual level net benefits of introducing t to improve q. Hazilla and Kopp [1990] used this logic to define what the social costs of policy would be. Their example was environmental policy and they asked about the importance of a GE perspective for measuring these social costs. Before turning to this point, we might ask what conditions are required for equation (6) to be consistent with separately measuring the costs and benefits of a policy.

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[12] This characterization—monetizing utility changes –has caused considerable confusion in the literature as summarized by Freeman's discussion cited in note # 7.

One answer, as Smith and Carbone [2007] note, follows from the definition of the expenditure function, provided it is separable in *q*, and can be written as:

$$e(p^0, Z^0, q^0, u^0) = \tilde{e}(p^0, Z^0, u^0) - h(q^0) \tag{7}$$

In this case the net benefit measure can be separated into a cost and a benefit computation, as in equation (8).

$$WTP^{PE} = \underbrace{\tilde{e}(p^0, Z^0, u^0) - \tilde{e}(p^1, Z^0, u^0)}_{\text{Incremental cost}} + \underbrace{(h(q^1) - h(q^0))}_{\text{Incremental benefit}} \tag{8}$$

In this context the distinction between general and partial equilibrium welfare measures depends on whether the analysis takes account of the full price effects of a policy change.

That is, we assume there is a policy change from θ^0 to θ^1 and we ask how, given everything else is held constant, does this change influence the set of exogenous conditions that constrain each individual's ability to realize a given level of utility. The policy could be confined to one market, or a small number of markets. Alternatively it could influence conditions outside markets. The PE/GE distinction arises in how we convert the policy changes into changes in the prices and other exogenous conditions that influence people's choices.

For example, a carbon tax to address concerns about atmosphere accumulation of carbon dioxide (CO_2) would increase the prices of goods and services that emit carbon. It would also reduce emissions of CO_2. It may well reduce the emissions of other air pollutants as well. To differentiate between a PE and GE measure we need to consider what gets counted as a result of the policy.

A second example, in the context of social policy, involves education programs. Heckman [2006, 2008] has argued that efforts to improve pre-school programs for children will improve educational outcomes for these children. He notes this improvement is also associated with lower rates of teen pregnancy, drug addiction, crime, and other consequences of high dropout rates. It also limits the choice set for future activities that can involve further education or jobs for some teenagers and young adults. Do we count all of these effects as a result of the policy improving pre-school programs or a subset? This question illustrates the general equilibrium versus partial equilibrium question. For us it depends on how we model the process leading to these outcomes and the reliability of the frameworks describing the connections of policies to outcomes. Can the results leading to changes in education outcomes, teenage pregnancy, drug addiction and so forth be attributed to the policy intervention in a convincing way that leads to reliable predictions?

In a different context, involving education, the side effects don't have to be positive. Improvements in educational outcomes in one school district may well attract more families. This in migration could lead to greater competition for homes in the neighborhoods that are assigned to the district. With a fixed supply of houses in the districts with better schools, we would expect that home prices would increase. Those households' owning homes in the district would gain while renters would lose as their rents increase. Indeed, poorer households could well lose because higher rents might force them to leave and accept a lower quality school district in order to obtain affordable housing. This outcome would not be intentional and would be missed with a framework that failed to allow for the full scope of general equilibrium adjustments.

In general the importance of a GE / PE distinction depends on the size of the program being evaluated, the size of the markets, the social / economic context being described as relevant to the policy, and the assumed interconnections between the market and non-market influences to individual behavior. At this point we need to highlight an important implication. This situation can be different from one that involves intervention in one market and the general equilibrium effects through multiple markets. If our model focuses on the pure exchange of goods and services, the concepts of size and context have a different meaning. However, add a small amount of spatial context and ask how well an addition to the tax on gasoline in one county in the U.S. affects the world market price of gasoline and the answer is direct—not at all. However, if we recognize that even within a small region there is variation in the price of gasoline, the effect of such a tax on the prices of other fuels in that region may well depend on the volume of gasoline sold in the county relative to adjoining counties that might be part of the same metropolitan area. Now consider another tax example. Suppose a small tax was introduced on a product nationally to remedy a situation in one small region. For example, one might impose a small tax on cigarettes to pay for improvements in a specific lung cancer clinic. Gauging the difference in a PE versus a GE assessment of the welfare effects of the tax depends on what we assume. As Goulder and Williams demonstrate, with pre-existing labor taxes (at forty percent) small taxes on a product such as cigarettes can lead to large percentage errors in PE compared to GE measures of excess burden. Their analysis does not consider using the tax revenue for a non-market intervention. At a national scale this can make a large difference, as Carbone and Smith [2008] demonstrate using their model of energy taxes. A small tax (five percent) with the same pre-existing labor tax and recognition of the non-market effects (on air pollution) of the tax can increase the differences in PE and GE by one hundred percent when leisure and air pollution are complements as compared to reducing the discrepancy by about fifty percent when they are substitutes. Of course, the absolute size of the error in excess burden is large in this case as well. Now if we return to the spatial dimension of the policy --a small regional clinic -- then it is unlikely the feedback effects would be important at a national level. However, an analysis at a local level might need to consider another type of feedback. If the improvements in the clinic's quality of care were dramatic and capacity at the clinic remained limited, the net results for local patients might not be completely positive. There could well be congestion and delayed treatment for patients due to that congestion. These examples suggest that market and non-market effects can both matter. Moreover the spatial scale that we use in representing the non-market process and who is affected by a policy also matters. This is how the choice of models influences the characterization of PE and GE welfare measures. Some models will not be able to easily reflect the spatial dimensions of the social process or the heterogeneity in agents and their opportunities to adjust. Decisions to use simple market oriented general equilibrium models to evaluate social processes then "build in" these potentially important conditioning assumptions. Thus, the definitions of GE and PE are straightforward, but the real "action" arises in the definition of the models and their implementation.

With that background, PE measurement selects a subset of the possible effects of the change in θ and measures WTP for the change in θ recognizing only that subset of changes. GE includes everything. Examples are in equations (9a) and (9b).

$$WTP^{PE} = e(p_1^{\,0}, Z^0, q^0, u^0) - e(p_1(\theta^1), p_2(\theta^1), \ldots p_k(\theta^0), Z^0, q^0, u^0) \quad (9a)$$

$$WTP^{GE} = e(p^0, Z^0, q^0, u^0) - e(p(\theta^1), Z(\theta^1), q(\theta^1), u^0) \quad (9b)$$

Notice we have assumed all elements in the vectors p, Z, and q could change in (9b) while for the PE version we selected a subset. One of our points is that the subset selected depends on the model that is used to describe what the policy does. The importance of the difference depends on the nature of the policy and the nature of the model.

Another important issue that is implicit in these definitions and is also described in some of our examples arises from the differences in the WTP measures for different individuals. As previously discussed, when people are assumed to be heterogeneous the PE / GE distinction must be considered together with the distribution of effects across people. There are at least two aspects of this issue.

People may well experience the same price changes but react (due to preference heterogeneity) quite differently. Moreover, once we admit effects outside markets, there may not be complete mechanisms to adjust to differences. It is also possible that the adjustment could well have feedback effects on the policy intervention. Households in different circumstances may well be more or less prone to being impacted by these non-market effects as well.

B. Approximations

As a practical matter it is often difficult to measure the full GE willingness to pay. With revealed preference information we usually have the ability to estimate a subset of the demand functions or will specify a choice function that assumes each person has a limited range of decisions and other choices are not affected by the one under study. Equally important, most policy applications of benefit cost analysis rely on the existing literature to adapt a point estimate to evaluate the benefits from a policy. Here we will define two of many such approximations and describe one potential GE / PE distinction. These measures use the virtual price or marginal willingness to pay for a change in something available outside the market. Thus, they are most often used for goods that are pure public goods or have some public good features. The marginal willingness to pay for a change in one element in q (say q_1) would then be given in equation (10) using the indirect utility function in (1).[13]

$$MWTPq_1 = \frac{V_{q1}}{V_m} \tag{10}$$

[13] For small changes this would equal $\frac{\partial e}{\partial q}$; the definition in equation (10) holds income constant and in terms of the expenditure function, well-being or utility is assumed held constant.

The distinction between PE and GE measures in this context might arise with whether the virtual price is evaluated at the baseline levels of prices (and other "parameters" entering the indirect utility function) or at the new level, after the policy change. Thus (11a) would be PE and (11b) GE with the superscript (0) designating the point of evaluation.

$$\Delta B^{PE} = \frac{V_{q1}{}^{0}}{V_m{}^{0}} \bullet \Delta q_1 \tag{11a}$$

$$\Delta B^{GE} = \frac{V_{q1}{}^{1}}{V_m{}^{1}} \bullet \Delta q_1 \tag{11b}$$

Smith and Carbone discuss these measures as adjustments to measures of excess burden of a tax to reduce pollution externalities and, using a small scale computable general equilibrium model, find the differences due to PE versus GE evaluation points for the virtual price can be important if the link between the outcome of what is taxed and the improved quality (Δq) is highly nonlinear. As noted in Smith and Carbone, both the nature of the relationship between q and other goods and the character of the link between the source of the externality and the q entering preferences were important to the GE / PE effects on these approximations.[14]

C. General Equilibrium Market Demand

[14] In that example one good had a pre-existing tax and the presence of it influenced the size of the excess burden for a new tax. The relationship of q to the good with the pre-existing tax was especially important.

As we noted in the previous section, applied welfare economists recognize that in situations with undistorted markets prior to some change in a single market, the welfare costs (or gains) associated with a change can be evaluated using the affected market alone. They must be evaluated using the aggregates of compensated demand functions across individuals consuming the good involved and aggregate commodity supply functions. Both must be evaluated at the values of the general equilibrium prices after the change.

The reason for this ability to focus on one market stems from two key assumptions. First, it assumes all markets are in equilibrium before and after the intervention. The second maintains that all the GE effects are exclusively through markets. Since there is only the one market affected, the GE price effects of the intervention on other goods' prices will be the same for households and firms. Thus, the line integral (measure of the contribution to economic surplus) will be exactly zero, given the equilibrium condition. In the market experiencing the change in price, the size of the price change realized by consumers compared to what is experienced by suppliers will be different. It depends on the relative elasticities of the demand and supply functions. Thus, even though this market is also in equilibrium after the intervention, the sharing of the price change due to the new distortion is different. As a result we have the consumer and producer contributions to economic surplus.[15]

In the context of non-market effects, the same result would hold in marginal willingness to pay for each non-market good equal to marginal social cost before and after a change. However, there is no mechanism that assures that this would be the case.

[15] See Just et al. [2004] pp. 360-361 especially equation (9.49) and the discussion.

Thus, in this context the need for a general equilibrium framework is direct – both to compute the full GE responses and to consider the distribution of their effects. In practice, as we discuss in the next section, the full GE analyses to date have been quite simple, usually assuming constant returns to scale (and constant marginal costs).

IV. General Equilibrium Models with Non-Market Interactions

The discussion to this point is intended to persuade readers that the "action" in general equilibrium welfare measurement for benefit cost analysis is in the implementation of the models used to describe the GE effects. The theory concerning what should be measured is reasonably straightforward. This section considers two different, static approaches describing a composite of market and non-market general equilibrium outcomes. The first extends the logic of computable general equilibrium models to include non-market effects. The primary non-market effects that have been represented in these models to date focus on environmental externalities. While other social programs could, in principle, be represented there are significant information gaps that would need to be addressed. The second modeling strategy is not a full general equilibrium framework. It is a locational sorting model. These models describe situations where price determination is possible for multiple land / housing markets. This set of prices can influence and be influenced by non-market outcomes, but the model does not allow a complete description of an economy.

At this stage it is useful to clarify the distinction between varieties of general equilibrium models. A computable general equilibrium model, as developed by Goulder and Williams [2003] describes price determination for final goods, intermediate goods and factor inputs. Endowments are given. Of course many other details such as international trade flows are omitted. Nonetheless, for a given baseline specification of a social accounting matrix describing how total expenditures, factor payments and a government sector relate to each other, it fully describes the price and income determination process. In their model a single representative agent is assumed to characterize all households in the economy but this specification is not essential. Multiple consumers could be represented. Our focus here is on the fact that the model describes the process determining relative prices and income levels (given endowments).

By contrast, in a sorting model incomes are usually assumed to be given and relative prices for housing (or land) are determined by the model. This specification could be expanded to wages with non-wage income exogenous as in Kuminoff [2009]. Nonetheless, as a rule there remains a component of income assumed to be determined outside of the model. This is one of the reasons we draw a distinction, labeling CGE models with a description of both relative prices and incomes as GE models and sorting as a model of multiple markets. Given the importance of the assumptions made about preferences (and especially the implied income elasticities) for the properties of welfare measures, this feature is another reason why we highlight the differences between modeling types.[16] This distinction can also be seen through the elements in the structure,

[16] One could also argue that any multi-market model reflects general equilibrium type effects in the sense that exchange of several markets interact in the joint determination of

information needs, and changes that arise when incorporating non-market influences in each type of model.

A. Non-market Effects in a CGE Framework

A computable general equilibrium model is a consistent description of individual and firm behavior that recognizes the joint determination of product and factor market prices. In a static competitive setting these models assure the conditions for budget constrained utility maximization by individuals and profit maximization of firms yields a price vector consistent with: equilibrium in all markets, budget exhaustion, and zero profits in all sectors. In the simplest cases production functions are restricted to constant returns to scale and preferences are often assumed to be homogenous of degree one. Both relationships are often described with constant elasticity of substitution (CES) functions.

CGE models are calibrated to match the observed baseline expenditures on final goods, payments to factors, taxes and government spending (if included in the model) as well as expenditures on any intermediate goods in a base year. Assuring a parameter calibration that realizes simultaneous consistency is greatly facilitated by the specification of homogenous CES functions. Rutherford [1997] has documented that establishing a consistent link is reasonably straightforward in this simple case. One of the few stumbling blocks in these models is the calibration of leisure and work time because time allocations that are not associated with hours worked are incompletely measured (see Fullerton et al. [1984]).

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prices. So this distinction is intended as a convenient simplification rather than to be treated as a universally accepted distinction.

Non-Market Calibration

When non-market resources are introduced into CGE models, the situation becomes more complex. The first difficulty arises with how the quantity of the non-market service is measured. In the case of marketed goods for the benchmark case; all prices are normalized to unity. As a result, quantities of the marketed goods can be measured by observed expenditures. The objective of the analysis is to evaluate how relative prices change, so this normalization does not compromise the models' relevance (given the assumption of homogeneity of degree one for preference and production functions).[17] As a result, after selecting substitution elasticities, the benchmark data can be assembled into a consistent social accounting matrix and a limited number of parameters calibrated to match the labor / leisure conditions.

When goods that are quasi-fixed (from the perspective of the agents in the model) are introduced, the calibration of the model can be more complex. This characterization is probably one that best fits social programs. They are either public goods or activities that reduce externalities. As a result, we might assume that one set of agents in the model produces them and the consumer receives them. However, the price paid for the amount received is usually not a per unit price. There may be no price. Costs may be a portion of taxes.[18] The consumer may not have a mechanism to choose how much is received.

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[17] Rutherford [2002] has demonstrated simple calibration strategies for the share parameters in CES functions.

[18] Epple, Romer, and Sieg[2001] discuss the prospects of developing models where voting determines the level of public goods and a budget balance condition, together with a specified production function for the public goods assures budget balance. This type of

What is especially important from the perspective of calibrating the model is how we measure the amounts of these goods, the nature of the relationships between them and the private goods (factors) entering preferences (production functions), and the information we have about the tradeoffs people would make to change the amounts of the non-market goods. Non-separability, together with the fixed level of these non-market goods *from the perspective of the individual,* implies that the preference (production) functions with non-market goods are non-homothetic.[19] This change alters all of Rutherford's conditions for calibrating the general equilibrium to match baseline conditions. They no longer hold. Calibration must match another set of conditions while producing the social accounting matrix and equilibrium prices.

Equally important, relative prices with linear homogeneity allowing the normalization discussed earlier assure we have sufficient information to calibrate preferences when the analysis considers only private goods. Without this information we must consider how to determine the marginal willingness to pay for the non-market good. There are a number of questions that have not been fully addressed for these cases. Smith and Carbone [2007] demonstrate for one special case how sensitive the PE / GE comparison is to the form of the function determining the amount of the non-market good. In their application the example involved linking emissions of pollutants to a characterization of air quality (or the health effects of pollution). When the preference information on non-market goods is an estimate of willingness to pay for an incremental

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structure has also been included in models by Nechyba[1999,2000] and Ferreyra[2007, 2009]

[19] See Carbone[2005,2007] for further discussion and Carbone and Smith[2008] for implementation of a model with these features.

change, the specification of these “production” or transfer functions underlie the implied tradeoffs between market and non-market goods.

Thus, two assumptions transform the calibration of CGE models and require much greater attention to the non-market sector than has been in the literature to date. The first is non-separability and the second is the assumption that the amount consumed is taken to be outside an agent’s control and unrelated to a price.

Calibration of these models exploits one or more envelop conditions to define a point where each non-homothetic function “appears” homothetic. Starting with a CES specification (and with one or more arguments fixed), the same Rutherford calibration strategy can be applied at the levels of consumption, input use, and values for the non-market good(s) consistent with satisfying the envelop condition(s). In practice, considering only the case of non-market goods influencing consumers, this process amounts to defining virtual income as a sum of expenditures on market goods plus expenditures on non-market goods that are implied by the virtual prices derived from the envelop condition linking the levels of the fixed goods to the other goods consumed for the benchmark solution. The levels for these goods are determined by the calibration. Parameters are set so that this amount of the non-market good, given the externally observed marginal willingness to pay, would be selected in the benchmark case. The calibration also needs to assure the benchmark reproduces the social accounting matrix for market goods, and any relationship defining how the amount of that non-market good is derived. These equations would be conditional to assumptions about substitution elasticities. As a result, the calibration strategy must include equations to solve for remaining free parameters and virtual prices so that they satisfy the conditions for a general equilibrium. The calibration conditions (i.e. envelop equations and definitions for the non-market valuation measure) are solved subject to the conditions for a competitive equilibrium defined in terms of the market goods so that it produces the levels of the non-market goods[20].

Examples

There is very little experience with introducing non-market goods within CGE models when they are treated as making non-separable contributions to preferences or production. Espinosa and Smith [1995] appear to offer the first treatment in a CGE framework. They resolved the calibration by assuming the non-market good had a private good serving as a perfect substitute. They also assumed a Stone Geary preference function. These two assumptions allowed them to adjust the translating (or subsistence) parameters so the level of each non-market good in the benchmark was consistent with its "production activities" and with external estimates for the marginal willingness to pay for each non-market good. This restriction directly affects the importance of the non-market sector for general equilibrium evaluations of policy.

De Mooij [2000] used a log-linear general equilibrium model (following the Jones [1965] format) to describe how non-separable externalities affect the impacts of an energy tax on employment, pollution and income. He does not discuss how the non-market component is calibrated and does not consider the consistency conditions we discussed – linking market and non-market sectors. While the welfare effects of taxes as

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[20] Perroni's [1992] demonstration that a homothetic function can be used to represent non-homothetic responses provides the underlying logic for the calibration.

measured with marginal excess burden are discussed for the separable case, they are not treated with non-separable effects.

Carbone and Smith [2008] appear to be the first to treat these issues in general terms. Their findings for a small CGE model lead to three direct conclusions:

(1) Even in cases with the non-market good having a small fraction of virtual income, the substitution or complementarity relationship between this good and a private good (leisure) have a large effect on the costs attributed to a tax in an economy with pre-existing distortions.

(2) The nature of the production relationship linking activities with private goods to the level of a non-market good is important for the measured effect of this good on measures of the welfare cost of a tax. Their comparison of different response functions held the share of the nonmarket resource in virtual income constant and there were large differences in the effects of the non-market sector on GE measures of excess burden. The shape of this response of non-market output to the production of private goods is important to determining the size of the GE feedback effect (Smith and Carbone [2007]).

(3) In a new analysis with several non-market goods, Carbone and Smith [2009] find that GE feedback effects may appear small based on substitution relationships to market goods. However, this judgment would be misleading. In their example feedback effects have larger effects in the interactions among the non-market goods themselves. Thus, changes in the virtual price of one of the non-markets goods was the best indicator of the importance of the changes

in feedbacks arising from different substitution or complementarity relationships between another non-market good and labor[21].

Using CGE for Policy Evaluation with Non-Market Goods

Several tentative lessons emerge from the work with CGE models that are relevant to using this strategy for evaluating the general equilibrium effects of social policies. First, the structure of the linkages between the non-market and market goods is important. Even for situations where the share of (virtual) national income attributed to the non-market sector is small, feedback effects can be very important to the difference between partial and general equilibrium welfare measures. Second, the strategy used to evaluate consumers' preferences for these goods also seems to be important. To date the evidence has been largely through the interaction of estimates of consumers' preferences and the shape of the "production relationship" for the non-market good (i.e. in the case of air pollution it would be the dose response function).

Third, most of these models use simple characterizations of the consumers and of the jurisdictions within which they select private goods. Carbone and Smith assumed a single aggregate consumer and abstracted from jurisdictions providing public goods. For many social programs, there are some opportunities' for people to adjust by changing locations.

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[21] In their example changes in marginal willingness to pay for habitat provided a better indicator of how the substitution relationship between recreational fishing and leisure influenced the net of benefits of pollution policies intended to improve both. This measure was superior to using a simple comparison of PE versus GE measures of the net benefits of the pollution policy.

Finally, benefit-cost analyses are increasingly being expected to include measures of the uncertainty in estimates. In the case of the CGE model, there has been limited work on how uncertainty in estimates would affect the results and what this implies for using these models.[22] We should draw a distinction between treating the parameters used in general equilibrium policy analyses as random variables and sensitivity analysis. The former attempts to develop distributions for the computed effects—whether price changes or measures of willingness to pay. The later recognizes a range of values for potential point estimates and considers the sensitivity of results to different values. It is not clear which strategy is most informative. Our point is that concerns about developing confidence intervals for benefit or cost estimates have often been raised as reasons for avoiding consideration of general equilibrium effects.

Many CGE analyses have used sensitivity analysis to judge robustness.[23] There is a need for research to evaluate how uncertainty in estimates of multiple key parameters can be used with CGE analyses.

B. Non-market Effects in a Locational Equilibrium Framework

Many services provided by local governments or simply available at different geographic locations have the characteristics of a local public good. The amounts available vary across different locations. For example, these differences could be due to variations in natural conditions for environmental amenities. For other goods they could

[22] A notable exception is Harrison and Vinod [1992] evaluate the sensitivity of CGE results to parameter values used in calibration in a statistical framework.
[23] See for example Goulder et. al. [1999], Parry, Williams and Goulder [1999], and West and Williams [2004].

be the result of decisions made by local communities. These locational differences are what lead Tiebout [1956] to suggest that for local public goods, communities were the "supermarket" allowing households to select the best match, given their preferences and abilities to pay.

A number of authors, in public and urban economics, have attempted to evaluate the analytical properties of Tiebout models.[24] This literature offers two approaches for discussing partial versus general equilibrium benefit measures. The ability to estimate these models has begun to change the orientation and for some applications, especially those related to environmental policies, the models have been used to compare partial and general equilibrium benefit measures. The first uses calibrated models such as Fernandez and Rogerson [1998] and the second directly estimates a sorting model, and is due to Epple and Sieg [1999] who demonstrated how a consistent description of a locational equilibrium could be used to estimate a model that: (a) recovered measures of heterogeneous households' preferences for housing and local public goods and (b) offered the means to describe how that equilibrium would change with exogenous changes affecting the amounts of those public goods. Several of the calibrated models have considered educational policy but the focus was primarily on accounting for the effects of general equilibrium adjustment or outcome measures rather than benefit measures.[25]

The models can be grouped depending upon how they characterize the heterogeneity in household preferences. The Epple-Sieg version assumes each household

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[24] A review of these studies is beyond the scope here. See Epple and Platt [1998] and Epple, Gordon, and Sieg [2009], and Klaiber and Smith [2009b], and Kuminoff, Smith and Timmins [2010].

[25] See Kuminoff, Smith and Timmins [2010] for further discussion.

(or each type of household) has a different taste parameter for the locationally differentiated good. However, the agents evaluate the locational attributes or services contributing to the amount of that good in the same way. This condition restricts the way preference parameters can vary. An alternative model, labeled the horizontal model, allows the parameters of location specific goods to vary more generally[26]. The first specification has also been labeled a pure characteristics model and the second a random utility model. Our example uses a vertical model, so we will focus the remaining discussion on estimating, interpreting, and using these models for policy evaluation.

Structure and Estimation

A key assumption allowing these models' to characterize the locational equilibrium in a way that facilitates estimation as well as the computation of a new equilibrium is the single crossing condition. The single crossing condition for income is a relaxation of the Willig [1978] condition often used in applications of weak complementarity in environmental economics. Suppose we can specify the price for a homogenous unit of housing in each location and the non-market good (or the index of non-market goods) a household acquires by locating in a specific community. If we use the indirect utility function given in (1), and treat p_1 as the annual price for a unit of this homogeneous housing in community one that also has the non market good designated by q_1, then the single crossing condition is given in equation (12).

[26] See Klaiber and Phaneuf[2009] for an example of a horizontal model that develops GE and PE welfare measures. Bayer et al [2007] also estimate a horizontal model but don not compute welfare measures or consider the PE/GE distinction.

$$\frac{\partial}{\partial m}\left(\frac{Vq_1}{Vp_1}\right) = \frac{\partial}{\partial m}\left(\frac{dp_1}{dq_1}\right) > 0 \qquad (12)$$

When this condition (for all communities) and an equivalent one for the relationship between p and q for all communities with variation in the taste parameter (β) are satisfied, then the sorting equilibrium displays three features: [27]

(1) Communities can be ranked by the public good index and by the equilibrium community specific housing price and the two rankings will be the same (this is called the ascending bundles condition).

(2) With a continuous array of different types of households, there will be a set of households indifferent between communities with adjoining ranks based on price and the index of public goods (this is called the boundary indifference condition).

(3) When we consider how households are ordered among communities, given a level of income, the equilibrium orders households with the greatest preference for the locational public good in the community with the largest amount of that good. Thus, conditional on income, households are stratified by their taste for the public good (this is called the stratification condition).

[27] This argument assumes that households are characterized by the joint distribution of income and an unobserved taste parameter for the public good and we assume the single crossing condition between p_1 and q_1 holds for all incomes given the taste parameter (as well as for all values of that taste parameter given an income level) then we can establish three properties for a locational equilibrium.

With the specification of a CES function to describe preferences, the three characteristics of the equilibrium allow the ordering of communities by price and the ordering of households by the unobservable taste parameter within each to be used to "predict" a distribution of income for each location. This feature provides the intuition for an estimator to recover the parameters of preferences (see Klaiber and Smith [2009b] for details). It is also the basis, given the parameter estimates and measures of the observed public good, to define a recursive index for housing prices across communities.

More specifically, the vertical model allows estimates for housing demand in each community, and the parameters describing the joint distribution of income and the taste parameters for a public good. This information, together with the properties of an equilibrium, implies that any exogenous change in the attributes entering q for one or more locations will induce households to re-sort. We can then use the model's structure to compute the new equilibrium prices resulting from the change and the re-location choices of households.

To simulate the equilibrium implies we select the price for the lowest ranked location, compute all other prices based on the estimated preference parameters and local public goods using the recursive structure linking prices to the community goods that are implied by the model. This relationship, together with the ordering of households, defines how the sorting will take place. Of course, the implied demands for housing must match the supply in each community, so price adjustment and re-sorting continue until the quantity of housing demanded in each community equals the supply, all households are located in a community and cannot improve upon their well-being by changing, and prices and public goods across communities satisfy the ordering implied by the equilibrium.

Examples

There are two published examples of the vertical model that discuss welfare measurement. The first by Sieg et al. [2004] uses the model to describe sorting among school districts in Southern California for educational quality and air quality. This paper demonstrates how the sorting framework can be used to estimate preference parameters and to compute the benefits for improvements in air quality in a framework that allows a comparison of partial and general equilibrium WTP measures. These measures were defined for an exogenous improvement in air quality.[28] The simulated results permit an assessment of the role of preference heterogeneity for measures of the differences in welfare across communities and income groups. This approach also allows the differences in PE versus GE measures to be considered using these same categories.

In this application the difference between PE and GE results are defined by how the change in air quality is treated and whether the housing price effect is taken into account. That is, each simulated household "controls" the air quality it ultimately experiences by moving. In other words, sorting together with other households' adjustments, along with the location specific supplies of housing, determine the equilibrium prices. To implement equations (2a) and (2b) we could consider how

[28] The actual simulation of the equilibrium is numerical. It draws two random variables to characterize each household (i.e. income and the taste parameter for the index of public goods in each community) and selects a large number of these pairs of random variables. Each is assumed to represent a "household".

households in a location in the baseline situation would evaluate an air quality improvement in that location, assuming prices don't change. This measure would be a partial equilibrium measure. Of course, in a model with no costs of adjustment the household would never actually experience that change even if the simulated agent stayed in the community, the adjustment of others would imply some price changes. Moreover the changes in the air quality that are actually realized depend on re-location. Both the realized air quality through adjustment and the price change contribute to the distinction between PE and GE measures in this case.

Several possible scenarios were considered and the sample computations illustrated that even though air quality might improve everywhere, some households might experience losses because housing prices increase more than the improved air quality was worth to them. This result may be partially due to the simulation's inability to capture exit. In the simulation a household must sort within the locations described by the model.

The second application by Walsh [2007] is similar in structure. The locational amenity in this case is open space and the sorting process is similar to what was used in the air quality application. There is however one important difference. Open space in Walsh's model is defined to be produced in part by the sorting. In the Sieg et al [2004] paper each household can select an air quality from a finite set so there is some endogeneity as part of the equilibrium amount realized. Nonetheless, these choices do not feedback and alter the amounts of air quality available in each community. They affect the prices of homes. For the Walsh model they affect both prices and the amount of open space! Open space is assumed to be a composite of protected land and undeveloped land.

As a result if policies to protect land attract households, it is possible for the equilibrium to lead to smaller amounts of open space by developing more of the unprotected land. In this situation both the prices of housing and the amount of the local public goods are equilibrium values.

Walsh's research illustrates how a Nash equilibrium can be computed for endogenous determination of prices and open space. Our example in the next section builds on this work and allows the level of the location specific good to be determined jointly with prices through the sorting process.

V. General Equilibrium Benefit Measures for Social Policy: Local Education

One way to illustrate the decisions that need to be made in developing a general equilibrium analysis of the benefits of a social policy is to use a tangible example. Our application involves local education in Maricopa County, Arizona. This section and the next describe how the model was estimated and used to evaluate the partial and general equilibrium benefits associated with changes in the number of teachers available in this county's school districts.

There is a large body of literature confirming the importance of school quality on housing prices. The magnitude of the effect is often debated, as illustrated by the contrast between Black's [1999] estimate and the more recent work by Bayer et al [2007]. These authors' findings suggest homeowners have a marginal willingness to pay that, on average, was about one quarter what Black found. The application we present here is not intended to contribute to this debate. It is simply an example. Nonetheless, our estimates of the marginal willingness to pay are consistent with the Bayer et al. estimates, as we discuss in more detail below. In this section we outline the model, describe the data, and show how the data are used to estimate the model's parameters. Section VI describes a policy analysis with the model.

Assume each household selects an amount of housing and a numeraire good. Homogenous housing is available in each of a finite number of communities with different amounts of local public goods. We assume for our application that public education is the primary public good and that the communities correspond to school districts. For simplicity assume the household decision process takes place in two stages. First, a household selects the best community (school district), considering the price of housing and the character of the public education available. Conditional on this decision, the amount of housing is selected. The numeraire is determined by default. Following Sieg et al. [2004], we use a variant of a CES function to describe preferences. This specification is given in equation (13). The subscript j indexes the school districts. We have omitted a subscript for households. As with Sieg et al, the model is estimated using moments based on the percentiles for the income and housing expenditure distributions predicted by the model in comparison to what is observed for each school district.

$$V_j = \left[\beta q_j^{\ \rho} + \left[e^{\frac{m^{1-\eta}}{1-\eta}} e^{\frac{-aP_j^{\varepsilon+1}-1}{1+\varepsilon}} \right]^{\rho} \right]^{1/\rho} \tag{13}$$

In our case the term, q_j, corresponds to a measure of public school quality and p_j the price of a standardized unit of housing in community *j*. η and ε correspond to the income (m) and price (P) elasticities respectively.

As we discussed in our summary of the features of a vertical sorting model, the locational equilibrium implies properties for how communities, prices and non-market services are ranked. It also provides a prediction for the distribution of income (and the distribution of housing expenditures) for each community. These relationships are functions of the parameters used to characterize preferences and to describe the unobserved heterogeneity in households' demands for local non-market services. An important insight from these models stems from the recognition that these properties of a multi-market equilibrium can be used to estimate the parameters for preferences. That is, instead of calibrating the models using estimates from related literature and simulating them under different policies, they could be used as structural models of an equilibrium process. To simulate different responses to policy the models had to provide a description of a data generating process that allowed each type of intervention to influence household responses and market outcomes.

Epple and Sieg [1999] were the first to recognize the potential to use the equilibrium to estimate preferences. Sieg et al. [2004] then proposed a generalized method of moments framework for seven moment conditions –three income quantiles (25^{th}, 50^{th}, and 75^{th}), three housing quantiles (25^{th}, 50^{th} and 75^{th}) and one expression to derive a measure for the public good index. In our case this condition assumes a linear function relating the public good index to a measure for the quality of public schooling defined below along with measures for the size of each community. The ascending bundle condition together with estimates for the housing prices can be used to derive the shares of all households in each community. The expressions for these equilibrium shares can be inverted (numerically) to derive estimates for the public good index that are a function of the model's other parameters. In summary we stack the seven moment conditions and use the ranks of the prices as instruments. We follow Kuminoff [2009] and use Chebyshev polynomials in ranks as instruments.[29]

Data Construction, Education Quality, and Housing Price

The study area is Maricopa County, Arizona and includes the Phoenix MSA. Our analysis considers the 46 school districts in this county containing a full set of school quality records and census data. These districts are highlighted in Figure 1 and comprise most of the Phoenix MSA excluding Indian Reservations and uninhabited mountain and desert preserves. At the time of the 2000 Census, the Phoenix MSA had a population of over 3.2 million and was growing rapidly. The population in 2008 was nearly 4.3 million people. Our study considers the period from 2003 through 2006 (largely before the collapse of the housing market in the area). Our data include all of the single family housing transactions for the years 2003 through 2006 as well as school quality data derived from annual school report cards for each school year between 2003 and 2006. Information on income and the population in each school district were developed using the block group SF3 file from the Census 2000 public data.

[29] Thanks are due Nicolai Kuminoff who developed the Matlab Code for the Sieg et al. estimator.

School quality is measured using the Arizona Department of Education School Report Cards. These reports are published for each school and are mandated by the No Child Left Behind Act. Test scores are available from Arizona's Instrument to Measure Standards (AIMS) test administered to students each spring. These reports have the test scores as well as the number of students in each school, the number of teachers, and teacher aids. The summary of the scores differentiate English versus non-English speaking students and are reported for grades 2 through 12 separately for categories of mathematics, language, and reading for 2003 through 2006. Our analysis considered the test results for grades 2 through 8 and was restricted to the scores for English speaking students.

We developed measures for the average number of students, teachers, and aids for each grade / district / year combination as well as a measure of the average math, reading, and language score for each grade / school / year combination. The individual school level data were aggregated based on the school's district, the test type, the grade, and the year. Using these averages, we constructed measures for average student / teacher ratio as well as average student / teacher-aide ratio. Considering only the cases with complete records our sample consists of 3,711 unique combinations of grade, district, year, and test score.

The measure of school quality used in the estimation of the sorting model is based on predictions from a model of these test scores. It is an index of performance that is associated with observable factors contributing to test scores. We hypothesize that test scores are related to the type of test, the grade level, the year, and the average number of teachers and aids present in each school. The specific measures used in the model are the averages for the student / teacher and student / teacher-aide ratios.

Table 1 provides the results for the model used to construct our school quality index. The estimates are consistent with the literature and our prior hypotheses about the importance of small class sizes. Higher student teacher ratios are associated with lower performance after controlling for the grade, test subject, and year.[30] Increases in the ratio of students to teacher-aides increases test performance. While this finding may seem counter intuitive, there are a number of potential explanations. One would suggest that this result simply reflects the importance of teachers over aids. That is, the primary factor giving rise to improved test performance is the amount of teacher time devoted to students. If we assume there is a minimum number of staff required for class management and this threshold is met in all cases, then a lower number of aides for a given number of teachers, would be consistent with an increase in scores, because it implies that the class management threshold is more likely to be met with increased amounts of teacher time over that of aides.. This would imply increasing the number of aides at the cost of teachers would not enhance school quality. Our index of district quality uses the predicted test score for the language test during the 2003 school year for grade 2.

The price index for the homogenous unit of housing is developed following the framework outlined in Sieg et al. [2002], using the transaction database for residential housing sales. A log-linear price function is used to estimate district housing price

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[30] The fixed effects for 2003, grade 2, and language test were omitted in these specifications so the effects that are measured are relative to these reference points for each variable

indexes controlling for the attributes of each house sold and the year sold. The price indexes are derived from a set of fixed effect terms, one for each school district. We annualize housing prices (following Poterba [1981] and assume a rate of eleven percent). The sample of housing sales includes 406,556 transactions between 2003 and 2006. It has all the transaction records for single family homes falling in the 46 school districts. Table 2 reports the estimated price equation. All of the school district fixed effects are significant. Their rank generally agrees with the rank of the districts based on the index of school quality. This consistency is what would be expected based on the ascending bundles condition. The estimated coefficients for the district fixed effects are used to construct price indexes. These housing records also provide estimates for the housing quantities by school district.

The final components of our data are the measures for population in each school district and the income quantities for each school district. These are formed using the block group 100% sample from Census 2000 data reported in the SF3 series of tables. The primary variables are total population counts within each district and the income classified into one of 16 distinct categories with the lowest ranging from$0 to $10,000 and the top category unbounded above $200,000. To construct a spatially consistent measure by school district, the population counts for each block group are weighted based on the area falling within each school district. For example, a block group with half of the area falling in one school district and half the area falling in a second school district would be divided so that the population of people is split between the two districts. By using the total population in each district we construct the share of total population across all districts. This was also the approach used to allocate the count of households in each income bin. A map of the block groups overlaid on our school districts is shown in Figure 2.Interval censored regression was used to estimate the mean and variance of a log-normal distribution based on the Census income categories. Using the results from the estimated distribution, the estimates for the 25^{th}, 50^{th}, and 75^{th} income quantiles for each school district are recovered.

Summary statistics for the school quality, housing price, housing expenditure, household income, and demographic measures for the population are provided in Table 3.

Table 4 presents the GMM estimates for the preference parameters. The estimates for both the price and income elasticities for housing demand are consistent with the literature. The estimate for the rho (ρ) parameter is consistent with satisfying the single crossing property and school quality is a significant determinant of household's decisions about community location.

It is possible to develop some intuition about how our estimates compare with the literature by computing the marginal willingness to pay for a unit change in school quality. Our results imply a range of annual values from $40 to $83 a year (in 2003 dollars). Bayer et al. [2007] compare hedonic property value estimates and results for a horizontal sorting model applied to the 1990 PUMA data for the six counties in the San Francisco Bay Area (including Alameda, Contra Costa, Maria, San Mateo, San Francisco and Santa Clara counties). Two sets of estimates are reported in their study. The first of these estimates the effect of a one standard deviation change in average test scores using a hedonic price function using their boundary fixed effects to control for neighborhood effects (i.e. the demographic attributes of the neighbors such as education and race). Their estimates are about one-quarter the magnitude estimated by Black [1999] and range between $14 and $44 per month, with the variation based on the definition of the boundary and whether neighborhood socio-economic characteristics are included in the model. Their preferred estimate was $17 per month.

To compare this estimate with our results we need to adjust for price changes in residential housing, convert our measure to one in standard deviation units, and compute the monthly equivalent value.[31] After developing these adjustments, the range of estimates for the marginal willingness to pay implied by the parameter estimates of our model is $5.24 to $10.86. These estimates are in monthly 1990 dollars for a one standard deviation change in test scores. Given the differences in household incomes between the two areas, they are remarkably close to the Bayer et al. estimates. Overall it would appear our model yields consistent estimates for both the conventional parameters used to describe housing demand and the relative importance of school quality to households' selections of homes.

Context

There is extensive literature seeking to understand differences in public education programs and evaluate interventions to improve outcomes. The research most closely related to ours uses sorting models to evaluate neighborhood composition (see Fernandez and Rogerson [1998], Ferreyra [2009], Epple and Ferreyra [2008]) and to evaluate whether preferences for neighborhood attributes would be misinterpreted as estimates of

[31] The housing component of the CPI was 128.5 in 1990 and 184.0 in 2003. As Table 3 suggests the standard in test scores for our sample was 2.25. This scaling the endpoints of our range by 2.25 x (128.5/184.0) x (1/12) will provide comparable measures.

relative preferences for educational quality (Bayer et al. [2007]). One of these efforts by Ferreyra [2007] has also been used in separate research to evaluate a voucher program. This study does report estimates of the average welfare change (compensating variation) for different voucher programs. Her analysis includes budget balance at both the state and local levels so both tax rates and level of school funding are determined within the model. The quality of schooling is assumed to be determined by spending per student and a peer group effect measured by average income of households.

Our model was designed to illustrate the potential for non-market feedback that can result from households adjusting to exogenous changes in the support for education. A change in the resources available for local education can alter school quality. That is, as households adjust and move in response to changes in local public education, the number of students in a school district can change. If the number of teachers is fixed then school quality may change as a result of this household movement. Household sorting can also be expected to lead to price changes as part of the determination of a new equilibrium.

For our policy simulation we use a trivariate distribution with income, the taste parameter for schooling, and an assumed number of children per household. We allow for the fact that changes in resources can cause more children to be located in districts with greater resources and yet the ultimate educational outcomes may be inferior. That is, as households with children move to the districts with more resources the students per teacher increase and the school quality declines. To illustrate how recognition of these types of feedbacks can influence outcomes we compare a Nash equilibrium, where households move recognizing what others will do as well, with a case where households only consider the initial disruption to school quality and the effects it has on prices as households sort. In the Nash equilibrium both school quality and housing prices are jointly determined in equilibrium. For the second case only the prices change as a result of the equilibrium sorting. School quality is also a byproduct of movement but only the prices are recognized by households as they move.

VI. A Policy Simulation to Illustrate PE and GE Benefit Measures

To illustrate the effects of market and non-market feedbacks for PE versus GE measures of changes in resources for social programs we selected reductions in state support for local education in Maricopa County. Based on reports distributed through the Arizona Education Association in April 2009 over 1,600 teachers were fired in the county. These effects were unevenly distributed throughout the county's school districts. We use this policy to illustrate the welfare costs of budget cuts unevenly distributed across the Maricopa County school districts.

Two simulations were developed. The first considers market and non-market feedback effects. It introduces the reductions in the teachers for each district. Using our estimated school quality function given in Table 1 we then estimate, with existing students, the reduction in test scores. Recall increased student / teacher ratios reduce test scores. With no moving costs any reduction in school quality creates incentives for some households to move. These changes in turn alter housing prices and create more incentives for households to re-sort until housing price adjustments imply there are no further gains to movement.

Three aspects of the development of our policy scenarios should be noted before turning to our results. The first concerns replicating the benchmark equilibrium. Our index of educational quality relies on the estimates for test scores as reported in Table 1. To assure they are consistent with the benchmark equilibrium and with our estimates for equilibrium housing prices we begin our analysis by simulating the benchmark case and adjusting the intercept of the education function so we exactly match the population shares in each school district. The second issue concerns the assumed family size. Here we rely on Census estimates for the mean and variance of family sizes.[32] Finally, our analysis generated one million values for income, the taste parameter for education, and family size using a trivariate normal distribution based on the estimates for these parameters. The initial benchmark solution used to establish the corrections to the intercepts for the school quality equation assigns each to a school district.

The first simulation considers the Nash equilibrium where households recognize the effects of sorting on both price and school quality through the children assigned to each simulated household. When households move the student / teacher ratio changes and school quality adjusts accordingly. In our analysis, the only exogenous change is the cuts in teachers in each district. Table 5 presents our results for this simulation. The first two columns provide the school district id and name. Column three is the percentage

[32] The mean for family size was 3.116. We subtracted 2 to reflect parents and restricted the children to be a positive value or zero. The variance was .0326. Family size was assumed to be negatively correlated with income and independent of taste for education.

reduction in teachers implied by these cuts. Twelve of the forty-six districts lost teachers with cuts ranging from three to twenty-seven percent of the teaching staff.

The next two columns report the results that are the primary reason for developing the model. The first is the general equilibrium measure for the loss of teachers and the second is the partial equilibrium measure. These are estimates for the annual loss. The GE measure considers both the reduction in school quality and the price change resulting from household moving.

Our analysis follows the Smith et al. [2004] convention and treats households as renters, so the capitalization effects due to price changes from the initial housing assignment accrue to absentee land owners. Considering the last two columns of the table, dq and dp provide the proportionate change in school quality and housing price comparing the benchmark solution to the new equilibrium. Several important results emerge from this comparison. First, averaging across households in a school district, it appears that everyone loses from cuts in teachers in about one-quarter of the districts. Households attempt to adapt and the result is a spreading of the "pain" through price increases in those districts where school quality increases slightly. When quality declines housing prices may decline. Equilibrium schooling quality declines in most places. The losses range from about \$41 to \$91 a month. Comparing the GE estimates to the partial equilibrium findings in the fifth column we have dramatic support for the importance of a GE perspective.

The PE results consider only the change in school quality. They include districts that would appear to have small annual gains and others with large losses, amounting to over \$160 per month. These gains can be traced to situations where school quality increased slightly and the housing price increases are ignored. (See school districts 16 and 46 as examples). The columns labeled MWTP_old and MWTP_new report the marginal willingness to pay measures for improvements in school quality, evaluated at the benchmark and new equilibrium values for school quality and prices.

Table 6 repeats the exercise but computes the equilibrium allowing households to move based on price alone. As a result, the non-market feedback does not influence the market equilibrium. It does influence the computation of GE and PE welfare measures. As expected, the general equilibrium measures of the loss due to the policy are about the same order of magnitude as with the Nash equilibrium. In general, GE losses are smaller, as might be expected when households are assumed to anticipate how their own and others' behavior will affect school quality. The ascending bundle conditions yield the same ordering of school districts.

Larger differences arise with the PE willingness to pay measures. Consider for example Palo Verde school district or Roosevelt Elementary. The PE measures derived from the Nash equilibrium are positive while they are negative when adjustment is based on price. In these cases Nash adjustment leads to an increase in school quality whereas sorting based on price alone implies a very small decline in school quality in one case and no change in another.

Overall, our sorting example illustrates three features of the comparison of GE and PE measures of the willingness to pay to avoid declines in school quality. First, it is possible to exploit revealed preference logic to develop models capable of reflecting multi-market adjustment in response to policies affecting social programs. Second, when the programs exist in different jurisdictions both market and non-market adjustments are possible. The non-market feedbacks are likely to be more important to discrepancies between PE and GE measures than between models with different GE measures based on the information households might have about the consequences of moving. Finally, measures of marginal willingness to pay were not as sensitive to the point of evaluation as comparisons of PE versus GE willingness to pay might lead an analyst to speculate would be the case.

VII. Summary and Research Ahead

This paper has summarized definitions for partial and general equilibrium welfare measures when policy is assumed to affect only market goods. We generalized these definitions to consider market and non-market goods and outlined two modeling strategies for measuring the importance of GE effects. Finally, we developed an example of how one of these frameworks, a locational equilibrium model, could be used to estimate PE and GE welfare measures for local public education policies as an example of a social policy. While our estimates closely match the literature relevant to the application, they are intended here simply as an example. A more complete analysis would require consideration of other determinants of educational quality, especially peer group effects. In addition, other determinants of locational choices would need to be considered such as local views, air quality, crime and a variety of other spatially delineated factors that influence neighborhood choices.

There are also several research issues “buried” in the details of model implementation that should be considered in future research. We highlight three here: measures for the “amounts” of social programs; revealed preference and the nonuse values for changes in social programs; and the extent of the market for social programs. We close with a short discussion of each issue.

A. Quantity Measures for Social Program Outputs

Our example of education policies as a social program focused on one measure of the output-school quality measured by test scores. If the objective of public education is to assure an informed electorate so that a democracy provides “better” decisions, then the relationship between test scores and an “informed electorate” is certainly not clear. If we believe education helps to avoid other social problems or enhances the chance for good social outcomes on a number of dimensions (i.e. crime, teenage pregnancy, childhood poverty, etc), then it seems reasonable to assume these effects are unlikely to be captured by the gains realized by individual households who seek to enhance the private skills of their children. How these individual choices add up to transform the collective outcome may well not be adequately considered.

The task becomes more complex as the nature of the social program has limited private benefits. These issues must be addressed to quantitatively “scale” the output in a CGE setting and make them ill equipped to fit frameworks that rely on revealed preference methods to measure how people evaluate the resources they would be willing to give up to obtain more of a specific program.[33]

B. Non Use Values for Social Programs

Environmental economists have been concerned about people who care about environmental resources that they may never want to "use." These preferences need not stem from an altruistic motive directed at the current or some future generation. It is certainly possible to consider preferences for a society that sustains social programs. It may be the case that individuals would make decisions (if they were available) to give up resources for these outcomes. We simply don't observe them. Once again this raises issues about how we measure the tradeoffs to calibrate preferences. In most CGE models for market goods we assume these marginal tradeoffs are revealed through ideal markets. In these cases they are not.

C. Extent of the Market

At an aggregate level, judging the importance of GE effects will depend on these tradeoff measures *and* the extent of the market. That is, how many people have them? Such questions don't come up for market transactions because expenditure flows allow the analyst to scale up consumption levels and create the representative consumer. A comparable process can be used for user values for non-market goods on the revealed

[33] See Carbone and Smith [2009] for further discussion of the first point.

preference logic. Neither is available for social programs that largely resemble the concepts classified as non-use services. Both the characterization of the tradeoffs with market goods and "the extent of the market" (or the aggregate resources that would be made available by people who would make these tradeoffs) determine the importance of the GE effects of policies influencing these non-market goods.

These issues can be addressed. Some progress has been made for policies that are intended to change environmental resources. However, the record is much more limited with social programs. It would seem then – a prudent starting point would be to begin with social policies that can be addressed with some variant of the revealed preference logic, such as illustrated here with our sorting model for education.

Table 1. School Quality Regression Model

Variable	Estimate	Std Err	t-stat
Student/Teacher	-0.2493	0.1074	-2.32
Student/Teacher Aide	0.0598	0.0061	9.81
Grade 3	-0.6073	0.8297	-0.73
Grade 4	0.3291	0.8293	0.40
Grade 5	0.1127	0.8285	0.14
Grade 6	1.1122	0.8293	1.34
Grade 7	2.7064	0.8317	3.25
Grade 8	2.1403	0.8333	2.57
Math	5.0642	0.5442	9.31
Reading	1.2624	0.5444	2.32
Year 2004	-0.3870	0.6327	-0.61
Year 2005	-1.5289	0.6308	-2.42
Year 2006	-2.6884	0.6290	-4.27
Constant	48.4230	2.0401	23.74

R-square= .0594
N=3711

Table 2. Fixed Effect Hedonic Property Model for Maricopa County School Districts 2003-2006

Variable	Estimate	Std Err	t-stat	Variable	Estimate	Std Err	t-stat
Lot Acres	0.3020	0.0030	100.66	District 18	8.9333	0.0053	1676.05
Square Feet (100s)	0.0569	0.0003	182.24	District 19	8.7462	0.0078	1114.49
Stories	-0.1452	0.0013	-109.92	District 20	9.1150	0.0055	1665.36
Bathrooms	0.0670	0.0012	57.27	District 21	8.7727	0.0055	1585.03
Age	-0.0083	0.0001	-71.06	District 22	8.8561	0.0065	1372.61
Lot Acres Sq	-0.0234	0.0006	-39.19	District 23	8.8902	0.0053	1677.99
Square Feet (100s) Sq	-0.0005	0.0000	-90.50	District 24	8.8079	0.0056	1585.03
Age Sq	0.0001	0.0000	31.56	District 25	9.3861	0.0074	1267.62
Garage	0.0411	0.0020	20.41	District 26	8.9157	0.0049	1804.82
Pool	0.0758	0.0011	67.55	District 27	9.6041	0.0604	159.01
Year 2004	0.1116	0.0019	59.03	District 28	8.2523	0.0282	292.52
Year 2005	0.3936	0.0019	209.71	District 29	8.5662	0.0136	630.22
Year 2006	0.5521	0.0020	281.73	District 30	8.3126	0.0116	717.23
District 1	8.2976	0.0353	235.27	District 31	9.1222	0.0086	1066.71
District 2	8.8099	0.0067	1322.38	District 32	8.2997	0.0226	367.28
District 3	7.9440	0.0279	285.09	District 33	9.1620	0.0051	1789.31
District 4	8.7445	0.0057	1534.37	District 34	8.8030	0.0056	1574.50
District 5	9.0810	0.0114	798.06	District 35	8.9441	0.0050	1801.12
District 6	8.6239	0.0055	1556.11	District 36	9.0546	0.0076	1196.21
District 7	8.7563	0.0057	1545.80	District 37	8.7389	0.0065	1343.83
District 8	9.2811	0.0058	1606.96	District 38	8.7416	0.0098	889.23
District 9	8.9473	0.0049	1826.41	District 39	8.7555	0.0052	1683.18
District 10	9.1132	0.0072	1258.24	District 40	8.9351	0.0121	737.79
District 11	8.9726	0.0049	1833.24	District 41	9.4296	0.0054	1741.63
District 12	8.8057	0.0047	1866.59	District 42	9.0172	0.0061	1467.58
District 13	9.3064	0.0074	1264.40	District 43	8.7829	0.0079	1112.95
District 14	8.7443	0.0065	1339.52	District 44	8.9009	0.0055	1633.04
District 15	7.9725	0.0290	274.85	District 45	8.6870	0.0110	791.37
District 16	8.9419	0.0050	1781.48	District 46	8.3221	0.0305	273.00
District 17	8.7980	0.0058	1504.79				

R-square=.999

N=406,556

Table 3. Summary Statistics for Characteristics of Maricopa County School Districts Used in Sorting Model

Variable	Mean	Std Dev	Min	Max
Price Index Rank	23.5	13.4	1.0	46.0
Population Share	0.0217	0.0290	0.0003	0.1437
Test Score	48.43	2.25	43.21	56.26
Price Index	8.83	0.35	7.94	9.60
Income 25th Pct	23,307	8,133	11,526	44,099
Income 50th Pct	39,307	12,882	21,056	77,497
Income 75th Pct	66,501	21,190	36,960	136,189
House Price 25th Pct	18,772	9,221	4,950	58,300
House Price 50th Pct	25,169	11,019	7,810	59,400
House Price 75th Pct	34,428	16,003	9,900	85,250
Household Size	3.12	0.89	2.06	6.90
Students	12,562	13,972	21	59,701
Teachers	678	749	3	3,051
Teacher Aides	212	363	1	2,174
# Schools	14	16	1	77

Number of districts=46

Table 4: GMM Estimation Results for Household Preferences*

Variable	Estimate	Std Error	t-stat
std dev for Ln(inc)	0.4332	0.0029	148.8200
mean for Ln(inc)	10.5296	0.3154	
mean for taste par.	0.9092	0.0764	11.9080
std dev for taste par	0.1806	0.0079	22.8610
lambda	-0.2758	0.0025	-112.4700
income elasticity	0.9214	0.0015	630.6300
price elasticity	-0.4781	0.0370	-12.9280
beta	1.3215	0.0254	52.0960
rho	-0.0438	0.0005	-88.6630
q_initial	46.4400	0.1412	328.8600

*** Standard errors are generated from bootstraps using 5 iterations,**
std deviation for mean income based on census data
N=1,000,000for simulation

Table 5: General and Partial Equilibrium Measures of Willingness to Pay: Nash Equilibrium for Teacher Cuts

schoold	district	loss	gewtp	pewtp	mwtpold	mwtpnew	dq	dp
1	ARLINGTON ELEMENTARY DISTRICT	0	-490.38943	-13.527759	40.259444	40.230033	-.0004018	.0067556
2	GILA BEND DIST.	0	-504.76866	-7.306073	44.433164	44.390347	-.0001492	.006866
3	MORRISTOWN ELEM. DIST.	0	-491.40097	-22.798008	40.803003	40.780765	-.0002999	.0066339
4	AGUILA ELEM. DIST.	0	-510.08132	-69.735639	43.456627	43.493236	-.0015271	.0059797
5	PALO VERDE ELEMENTARY DISTRICT	0	-490.16196	6.3026169	40.641551	40.585726	.0001972	.0068686
6	NADABURG DIST.	0	-490.89503	-21.185502	41.68903	41.666205	-.000534	.0064792
7	WILSON ELEMENTARY DISTRICT	0	-502.50206	-5.4290461	43.831858	43.787035	-.0001104	.0067001
8	MURPHY ELEMENTARY DISTRICT	0	-500.87852	-102.44376	42.3859	42.458013	-.0060759	.0033984
9	BUCKEYE ELEMENTARY DISTRICT	0	-498.98996	-410.17369	41.890434	42.31981	-.0119292	.0000544
10	WICKENBURG DIST.	0	-508.8757	-538.0534	42.644868	43.219903	-.0130557	-.0005925
11	QUEEN CREEK DIST.	27	-501.36401	-455.44873	40.875015	41.341651	-.0109218	.000619
12	RIVERSIDE ELEMENTARY DISTRICT	0	-495.7499	-265.46507	39.959439	40.208151	-.0060156	.0034135
13	FOWLER ELEMENTARY DISTRICT	0	-515.35501	-281.65795	42.6209	42.89145	-.0003772	.0066804
14	AVONDALE ELEMENTARY DISTRICT	5	-517.90611	-104.60041	43.281137	43.347715	.0002133	.0070217
15	ISAAC ELEMENTARY DISTRICT	0	-517.63118	-.5061104	44.289605	44.235534	-.0000109	.00689
16	ROOSEVELT ELEMENTARY DISTRICT	0	-514.47881	4.2486439	45.352614	45.291817	.0001032	.0069537
17	CARTWRIGHT ELEMENTARY DISTRICT	0	-511.40305	-.95035779	46.591663	46.535288	-.0000201	.0068764
18	LAVEEN ELEMENTARY DISTRICT	0	-507.40299	-78.414726	46.8302	46.86207	-.0015017	.0059092
19	TOLLESON ELEMENTARY DISTRICT	0	-512.15242	-158.53226	47.488125	47.611333	-.0018939	.0056541
20	GLENDALE ELEMENTARY DISTRICT	0	-511.37385	-58.746621	47.645785	47.653667	-.0026111	.0051872
21	PENDERGAST ELEMENTARY DISTRICT	0	-512.96333	-48.290093	48.692144	48.687146	-.0009761	.0062443
22	DYSART DIST.	0	-514.61709	-68.425549	49.535268	49.552494	-.0013299	.0060052
23	LITTLETON ELEMENTARY DISTRICT	0	-513.22004	-85.572521	49.769886	49.806584	-.001277	.0060482
24	ALHAMBRA ELEMENTARY DISTRICT	0	-512.75566	-103.13234	49.794211	49.850256	-.0008173	.0063849
25	LIBERTY ELEMENTARY DISTRICT	0	-512.04251	-491.54559	49.42409	49.918331	-.0082804	.0011682
26	LITCHFIELD ELEMENTARY DISTRICT	18	-518.4737	-786.97677	50.071393	50.900916	-.0134275	-.0024214
27	WASHINGTON ELEMENTARY DISTRICT	0	-534.86717	-841.59576	50.607628	51.492398	-.0145812	-.0031869
28	MESA UNIFIED DIST.	7	-582.19313	-975.10337	52.884543	53.910709	-.0165885	-.0046419
29	HIGLEY UNIFIED DISTRICT	21	-612.95549	-1108.7067	54.217491	55.386593	-.0137122	-.0023404
30	SADDLE MOUNTAIN UNIFIED DISTRICT	0	-607.46621	-1112.5434	53.263926	54.428495	-.0115285	-.0006144
31	GILBERT DIST.	18	-622.49038	-802.51034	54.648602	55.468738	-.011095	-.0002633
32	PEORIA DIST.	15	-631.55101	-356.86198	55.824382	56.142021	-.0060616	.0037086
33	CHANDLER DIST.	0	-636.70084	-163.521	56.888237	56.984643	-.0021709	.0068742
34	DEER VALLEY DIST.	4	-643.29688	-248.6952	58.135862	58.326143	-.0046049	.0048577
35	TEMPE ELEMENTARY DISTRICT	0	-643.33356	-206.41051	58.357359	58.496803	-.0092786	.0008754
36	PHOENIX ELEMENTARY DISTRICT	0	-642.99049	-308.76799	58.668589	58.921068	-.0128077	-.0021962
37	BALSZ ELEMENTARY DISTRICT	0	-649.43834	-503.58203	59.452283	59.922008	-.0083008	.0015706
38	CREIGHTON ELEMENTARY DISTRICT	3	-654.92593	-773.52231	59.562762	60.329983	-.0119121	-.001586
39	KYRENE ELEMENTARY DISTRICT	0	-670.03012	-742.27325	60.604916	61.333758	-.0074373	.0024637
40	OSBORN ELEMENTARY DISTRICT	0	-680.54862	-550.46333	61.456541	61.968451	-.0079016	.0020439
41	PARADISE VALLEY DIST.	9	-698.19829	-553.27627	62.808903	63.316734	-.0093285	.0007782
42	CAVE CREEK DIST.	18	-719.20999	-1344.3497	64.026544	65.392575	-.019143	-.0087977
43	FOUNTAIN HILLS DIST.	19	-721.75168	-1519.4717	63.066454	64.609226	-.0210388	-.0106322
44	MADISON ELEMENTARY DISTRICT	0	-749.74946	-1909.1	63.810503	65.762463	-.0256822	-.0150985
45	SCOTTSDALE DIST.	13	-919.3232	-1925.9011	69.035853	70.970869	-.0071384	.0059341
46	MOBILE ELEM. DIST.	0	-1093.2008	6.6730281	83.561564	83.312242	.0000683	.0155473

Table 6: General and Partial Equilibrium Measures of Willingness to Pay: Equilibrium for Teacher Cuts Based on Prices Only

schoold	district	loss	gewtp	pewtp	dq	dp
1	ARLINGTON ELEMENTARY DISTRICT	0	-494.98017	0	3.06e-16	.0070134
2	GILA BEND DIST.	0	-508.76134	-1.7742719	-1.52e-16	.0069965
3	MORRISTOWN ELEM. DIST.	0	-495.02173	-11.855071	1.42e-16	.0068362
4	AGUILA ELEM. DIST.	0	-513.44588	-12.164209	0	.0068111
5	PALO VERDE ELEMENTARY DISTRICT	0	-493.35632	-.23503178	0	.00681
6	NADABURG DIST.	0	-493.89379	-1.0731877	-1.40e-16	.0068029
7	WILSON ELEMENTARY DISTRICT	0	-505.34552	-.86583073	-4.19e-16	.0067977
8	MURPHY ELEMENTARY DISTRICT	0	-503.76719	-107.64579	-.0061744	.0033826
9	BUCKEYE ELEMENTARY DISTRICT	0	-501.9955	-414.89058	-.0120764	.0000119
10	WICKENBURG DIST.	0	-511.91192	-535.3155	-.0129999	-.0005208
11	QUEEN CREEK DIST.	27	-504.22877	-441.4307	-.0105893	.0008467
12	RIVERSIDE ELEMENTARY DISTRICT	0	-498.50061	-255.71386	-.0057885	.0035806
13	FOWLER ELEMENTARY DISTRICT	0	-518.13883	-271.86577	-.0005601	.0066102
14	AVONDALE ELEMENTARY DISTRICT	5	-520.623	-107.1448	-.0000282	.0069177
15	ISAAC ELEMENTARY DISTRICT	0	-520.3991	-.07489656	1.53e-15	.0069332
16	ROOSEVELT ELEMENTARY DISTRICT	0	-517.31574	-.41510836	-1.27e-16	.0069282
17	CARTWRIGHT ELEMENTARY DISTRICT	0	-514.27833	-.03808399	3.81e-15	.0069278
18	LAVEEN ELEMENTARY DISTRICT	0	-510.1121	-28.644659	-.000335	.0067026
19	TOLLESON ELEMENTARY DISTRICT	0	-514.72394	-102.32895	-.0017937	.0057524
20	GLENDALE ELEMENTARY DISTRICT	0	-514.18766	-90.189852	-.0026468	.0051965
21	PENDERGAST ELEMENTARY DISTRICT	0	-516.64294	-97.890529	-.0019764	.0056231
22	DYSART DIST.	0	-518.97509	-117.57657	-.0013022	.006086
23	LITTLETON ELEMENTARY DISTRICT	0	-517.82753	-84.172384	-.0013037	.0060884
24	ALHAMBRA ELEMENTARY DISTRICT	0	-517.32671	-98.864273	-.0011445	.0062108
25	LIBERTY ELEMENTARY DISTRICT	0	-516.49586	-471.28208	-.0082161	.0012754
26	LITCHFIELD ELEMENTARY DISTRICT	18	-522.89931	-766.35249	-.0136382	-.002515
27	WASHINGTON ELEMENTARY DISTRICT	0	-539.33404	-846.08607	-.0150543	-.0034856
28	MESA UNIFIED DIST.	7	-587.15817	-988.04729	-.0169885	-.0048837
29	HIGLEY UNIFIED DISTRICT	21	-618.3816	-1132.4287	-.0126912	-.0014594
30	SADDLE MOUNTAIN UNIFIED DISTRICT	0	-612.85236	-1136.0491	-.012318	-.0011626
31	GILBERT DIST.	18	-628.01804	-810.71504	-.0100883	.0006059
32	PEORIA DIST.	15	-637.38064	-376.51179	-.0063927	.0035208
33	CHANDLER DIST.	0	-642.98338	-185.23855	-.0025399	.0066567
34	DEER VALLEY DIST.	4	-649.94682	-256.48348	-.0051659	.0044801
35	TEMPE ELEMENTARY DISTRICT	0	-649.84502	-198.31366	-.0092975	.0009487
36	PHOENIX ELEMENTARY DISTRICT	0	-649.34187	-302.56993	-.0125817	-.0019153
37	BALSZ ELEMENTARY DISTRICT	0	-655.82645	-507.61753	-.0081807	.0017603
38	CREIGHTON ELEMENTARY DISTRICT	3	-661.34439	-777.61402	-.0119741	-.0015548
39	KYRENE ELEMENTARY DISTRICT	0	-676.53374	-748.35132	-.0076589	.0023512
40	OSBORN ELEMENTARY DISTRICT	0	-687.2344	-567.67416	-.0082762	.0017916
41	PARADISE VALLEY DIST.	9	-705.34113	-560.92684	-.0099518	.0002959
42	CAVE CREEK DIST.	18	-726.23899	-1337.8835	-.0190385	-.0086028
43	FOUNTAIN HILLS DIST.	19	-728.64363	-1513.999	-.0209653	-.0104676
44	MADISON ELEMENTARY DISTRICT	0	-756.73894	-1916.1204	-.0257835	-.0151063
45	SCOTTSDALE DIST.	13	-923.51859	-1878.0036	-.0047263	.0086774
46	MOBILE ELEM. DIST.	0	-1055.411	0	0	.0149221

Figure 1: School Districts in Maricopa County, Arizona

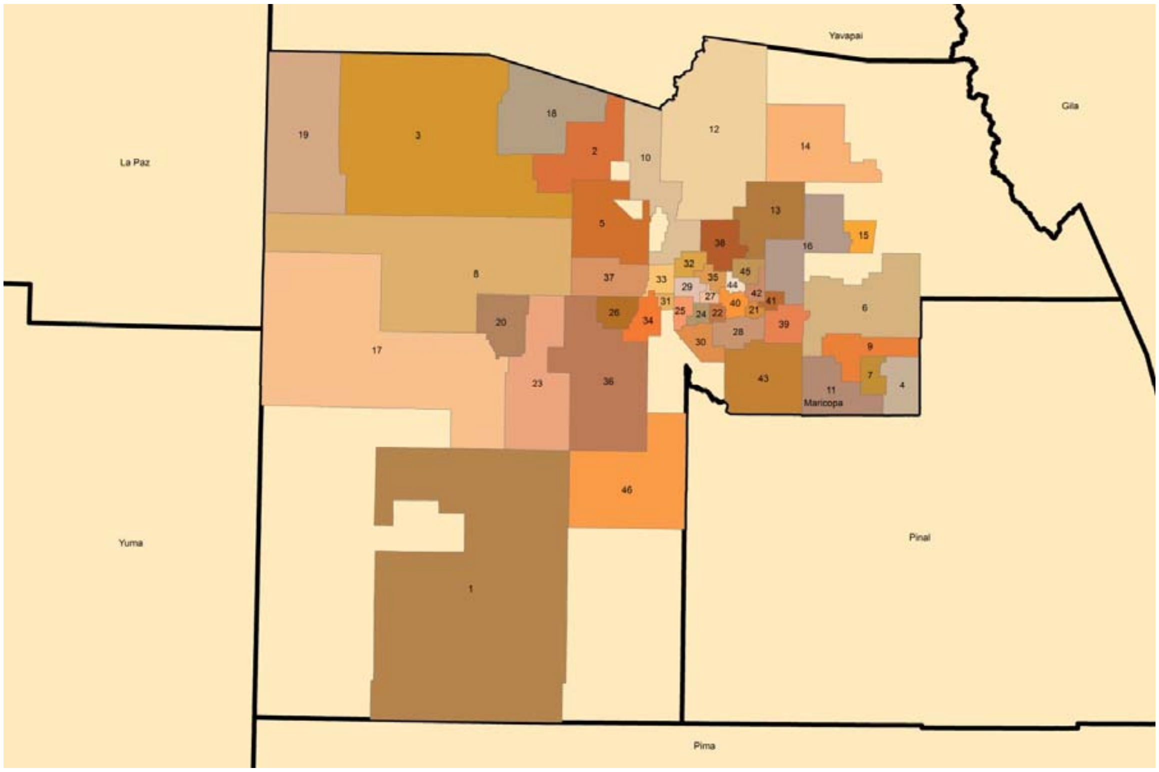
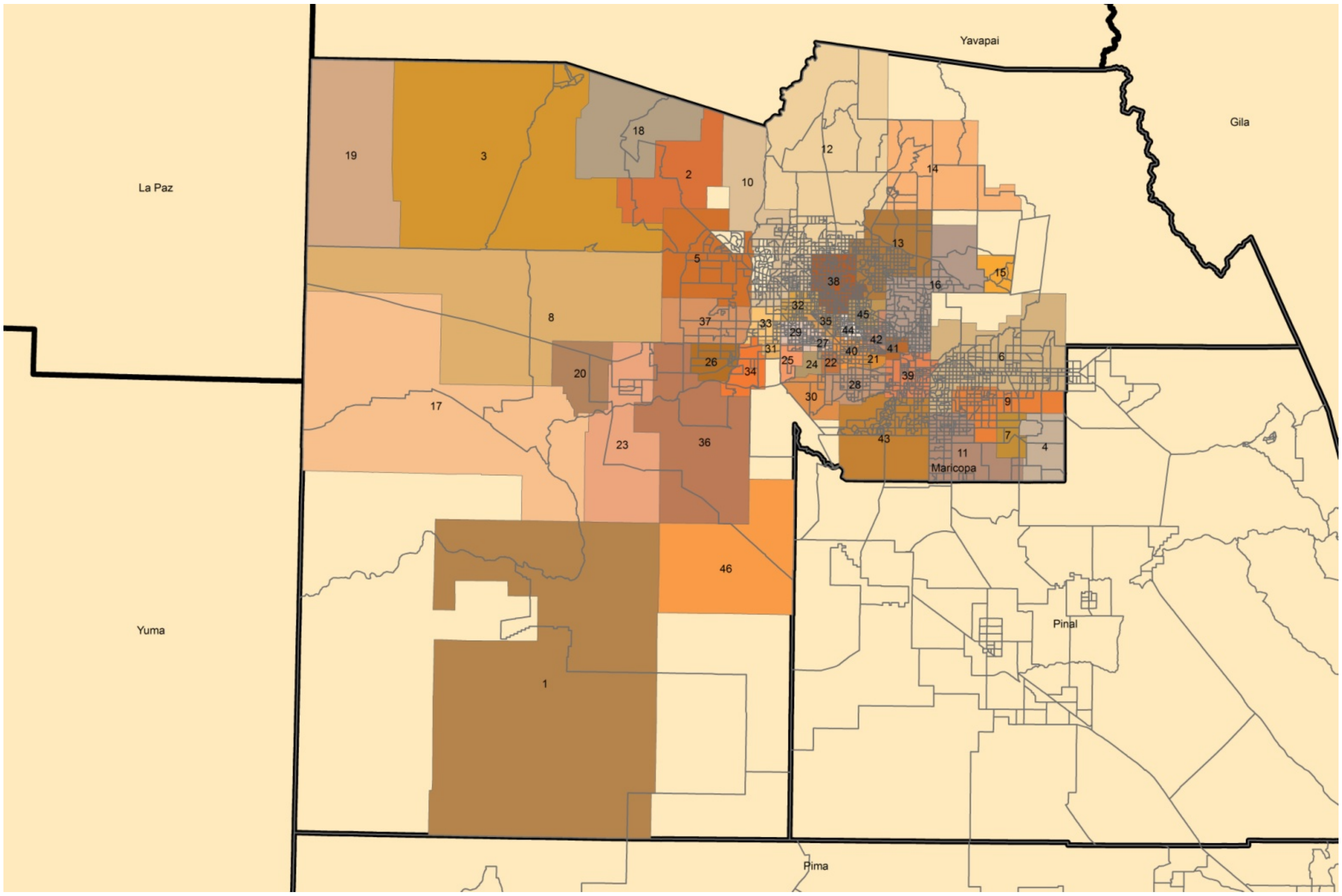


Figure 2: Census Block Groups Overlaid with Maricopa School Districts



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