THREE ESSAYS IN APPLIED ECONOMICS

By

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ABSTRACT

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This dissertation consists of three essays. Chapter 1 is "Charter School Location", Chapter 2 is "Are Urban Districts Inefficient?" and Chapter 3 is "Migration and Economic Growth".

Chapter 1: Charter schools represent one part of the larger movement toward parental choice in the U.S. school system. The intention of these programs is to use market mechanisms to improve school efficiency, innovation, and program variety. This study provides evidence on these issues using data on Michigan and California. We regress the number of charter schools in each school district on the characteristics of students and public schools in those same districts. The results indicate that more charter schools locate where populations are diverse in terms of race, income, and adult education levels. We interpret this as demand for horizontal differentiation, reflecting both preferences for homogeneous student populations and preferences for specific education programs. In both states, charter school location is negatively related with public school test scores. This implies that parents pay attention to test scores (vertical differentiation), even though these scores may be imperfect signals for school performance. Most differences in results across the two states can be attributed to

differences in state policies regarding the granting of charters and the funding of public schools.

Chapter 2: We use the stochastic production frontier model to estimate efficiency for public school districts in Michigan. Three different specifications for the efficiency term including the half-normal, truncated normal and exponential are used. We find that urban school districts are significantly less efficient than the non-urban school districts. Besides, the school districts with higher percentage of children in poverty, higher percentage of children who are black, larger enrollment (large districts), and larger total expenditure are less efficient. Moreover, the school districts with less schooling of the adult population are also less efficient. The by far biggest urban school district, Detroit, is relatively inefficient in the production of schooling in our model, especially for science test, however, it is not the worst one. The average measure of efficiency of Detroit is roughly twice as large as the least efficient one.

Chapter 3: We use the dynamic panel data model to explore the relationship between the migration rate and the economic growth. We find that high level income instead of high growth rate of income attracts people move in, and the inflow of migrants also contributes to the economic growth. In addition, the level of per capita income have significant dynamic properties, that is, its current level is significantly related with its previous value. However, we do not find significant dynamic property for the migration rate. We also find the urban population and the crime rate have significantly negative impact on the migration rate.

Dedicated to My Dearest Parents, Chien-Nan Lo and Ju-Hua Tsai,
for their love, encouragement, and all kinds of support.

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CHAPTER 1

CHARTER SCHOOL LOCATION[1]

I. Introduction

Before 1990, choice in the American education system was limited to assigned public schools and private schools. Since then, there has been a significant restructuring. Many states have allowed public school choice, allowing students to attend the public schools outside the districts in which they reside. Voucher plans in Milwaukee, Cleveland, San Antonio, and Florida have further expanded these choices to include private schools. These small-scale programs appear to be precursors to widespread choice programs, such as those proposed in Michigan, California, and other states.

A third instrument of providing greater school choice is the charter school system. Charter schools are publicly financed and often subject to less regulation than traditional public schools. Some oversight is usually administered by third parties, including universities or state government agencies, rather than local school boards. Charters receive a fixed amount per student enrolled. However, in contrast to public schools, they

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[1] We thank participants in association meetings of the AEA, Econometric Society, and Public Choice, as well as seminars at the Federal Reserve Bank of Chicago, Michigan State University, the University of Michigan, and the University of Kentucky. We especially thank Bih-Shiow Chen, Julie Cullen, Tom Downes, David Figlio, Larry Kenny, Bob Rasche, Peter Schmidt, and John Strauss for useful comments. Financial support for this project from the Business College at MSU is gratefully acknowledged.

do not receive a separate allotment for capital expenditures.[2] In addition, operating revenues in charter schools are sometimes as low as 50 percent of neighborhood public schools with an average of about also 80 percent (Finn, Manno, and Vanourek, 2000). Therefore, total spending per student is usually much lower in charter schools compared with nearby public schools.

The charter school movement is the most rapidly developing part of the U.S. school choice movement (Paris, 1998). By the end of 1994, eleven states had adopted charter programs. By 1999, thirty-three states had charter policies, yielding over 1,700 charter schools and 350,000 enrolled students (Finn et al, 2000). In Michigan, the charter school growth was similarly rapid, as indicated in Table 1.

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[2] Most public school districts can raise capital funding through local property tax levies. Arizona is a slight exception to the rule for charter policies, allowing charter start-up grants up to $100,000. However, this is quite small compared with total required capital costs for most schools.

Table 1: Charter School Growth in Michigan

Number of Charter Schools in District	YEAR				
	94-95	95-96	96-97	97-98	98-99
0	545	527	508	495	487
1	10	21	35	43	47
2	0	3	6	9	12
3	0	2	3	4	4
4	0	1	1	1	2
5	0	0	1	2	2
7	0	1	0	0	0
13	0	0	1	0	0
21	0	0	0	1	0
36	0	0	0	0	1
Total Charter Schools in MI	10	44	78	108	137
Total School District in MI	555	555	555	555	555

Perhaps the most compelling argument for school choice in general, and charter schools in particular, is that it will improve schooling by increased reliance on market mechanisms. One argument here is that students will "vote with their feet" for a better alternative school if charter school productivity is not sufficiently high. The market thus imposes discipline on the charter schools. Only good schools will survive. Peterson (1999) finds some support for this view in his review of research on recent, small-scale voucher programs. However, Bettinger (2000) finds that charter schools are not any more productive than public schools.

A second argument is that charter schools may improve productivity in the traditional public schools since they stand to lose enrollment, and hence state funding, to the charter schools. If this efficiency argument is valid, we expect to find a negative relationship between the number of charter schools and public school performance as measured by productive efficiency within each school district. Hoxby (1994, 1997) finds some evidence for this hypothesis in her studies of competition among private schools and public school districts.

A third aspect of efficiency relates to the Tiebout hypothesis, which roughly states that people will receive their optimal bundles of government-provided goods if there are many options to choose from and free mobility across jurisdictions. These bundles include the level of local taxation, private school tuition, school performance (vertical differentiation), the type of education being provided (horizontal differentiation), and other amenities. In the case of education, the less perfect is the sorting, the more likely it is that parents will seek other bundles when given alternatives.

There is anecdotal evidence that school choice produces schools with specialized curricula and homogeneous student bodies within schools. For instance, the El-Hajj Malik EL-Shabazz Academy in Lansing, Michigan describes its mission as to "serve students using a holistic, Afrocentric curriculum." More generally, 70 percent of all charter school students in Michigan are minority compared with 22 percent of public school enrollment.[3] In California, Grutzik, et al (1995) show that "the communities surrounding charter schools are primarily white and have income levels at or above the city and county averages." Wells et. al. (1996) comes to a similar conclusion, as do other survey-based studies. These outcomes are apparently similar in other countries that have implemented expansive school choice programs.[4]

In this paper, we address the question whether charter schools do indeed locate in those district where the lack of Tiebout sorting has provided for inefficient outcomes. What are the criteria which charter schools use to make their location decisions? Why might the demand for these schools be greater in some districts than others? For a given demand, what factors influence the supply of charter schools? Do charter schools indeed enter in districts where there are few existing alternatives and imperfect Tiebout sorting?

To help answer these questions, we assemble data for all charter schools in Michigan and California, and match each charter school with the public school districts in which they locate. We then regress the number of charter schools in a district on the student and public school characteristics of those same districts. The econometric methodology we use is similar to the one used by Downes and Greenstein (1996), using a statistical model of count data advanced by Hausman, Hall and Griliches (1984) and Cameron and Trivedi (1986).

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[3] These results come from a study commissioned by the State of Michigan: Public Sector Consultants and MAXIMUS (1999). The results are similar in Arizona, where the numbers are 6 percent and 4.3 percent respectively (Gifford, Ogle and Solmon, 1998).

[4] England, Chile, China, Sweden, New Zealand, South Africa, and the Czech Republic are a few examples. See Harris, Oliver, and Plank (2000) for discussion of these countries. For a description of differences across U.S. states, see Wohlstetter et. al (1995), Nathan (1996), and Mintrom (1998).

Downes and Greenstein study entry (location) by privately funded schools in California. Bettinger (2000) and Filer and Munich (2000) estimate regressions similar in form to those estimated here. The Bettinger paper also relates to charter schools in Michigan, but his main purpose is to obtain instruments for other regressions that study the impact of charter schools on public school performance. Most of the variables we find to be important are excluded in Bettinger's regressions. Filer and Munich's specification is more similar to those used here, but he studies new choice-based schools in the Czech Republic. These authors also exclude a large number of variables that we find to be important, but they do find that charter school location is negatively related with a measure of public school efficiency.

In Section II, we provide an informal theory of charter school location based on product differentiation. We describe our data in Section III. Empirical tests of our hypotheses are reported and discussed in Section IV.

II. An Informal Theory

The evidence above suggests that charter school entry is closely related to product differentiation, including both horizontal (h) and vertical (v) dimensions. Common examples of vertical differentiation (quality) in education include graduation rates, value-added, and the proportion of kids going on to college.

In most markets, inputs would not be considered an aspect of quality because more productive inputs are reflected in better outputs and higher prices. However, there are many reasons to believe that the price-quality relationship is rather weak in education.

First, dependence on the tax system means that non-consumers are paying most of the cost. Second, the movement toward state level funding may be weakening the connection between local taxation and local school funding. Third, information problems may prevent parents from being able to observe actual school quality. These three facts imply that it may be reasonable to interpret input levels as signals of public school quality. We consider student-teacher ratios, expenditure per student, teacher salaries, and special education expenditures.

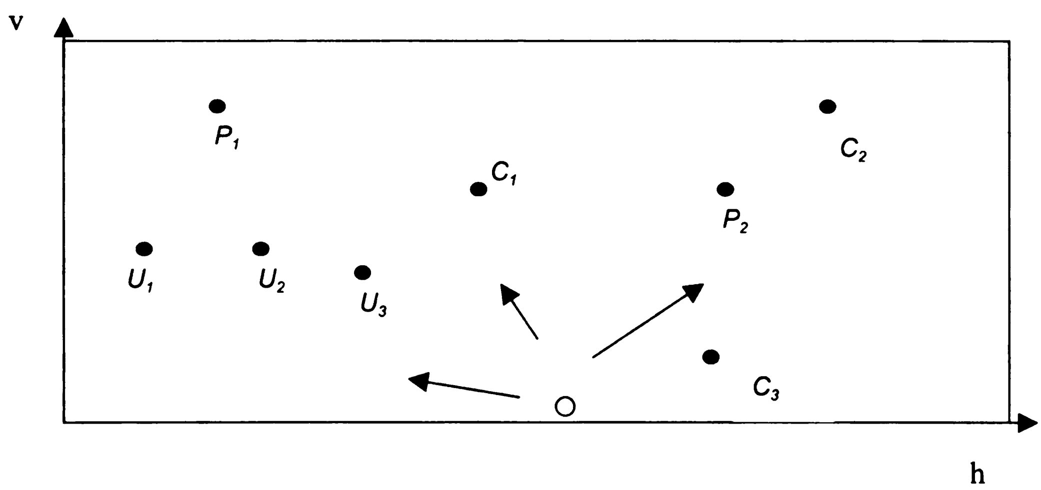
There are also various dimensions of horizontal product differentiation. These are dimensions along which preference heterogeneity generates disagreement among consumers over what is best. Some consumers may prefer an academic curriculum in high school, while others favor more vocational training. Other consumers may favor schools with racial and ethnic diversity, while others may favor homogeneity. Some favor authoritarian schooling by Catholic nuns, while others favor schooling in which children are free to determine their own rules of conduct.

Ideally, the location of schools ought to be considered as the outcome of a location game such as in Hotelling (1929) or Prescott and Visscher (1977). In these papers, location is an outcome of a game played by profit-maximizing firms. Unfortunately, the objective functions for public and private schools are controversial.[5] Instead of fully specifying such a location game and characterizing the equilibrium location, we only illustrate potential outcomes of such games.

[5] See, for example, Manski (1992) and Nechyba (1996).

In Figure 1, product differentiation is shown in *h*-*v* product space. This space is *n*-dimensional, where *n* is the number of product differentiation dimensions. Household preferences are distributed over the *h*-*v* space. The small open circle represents the preferred bundle of an individual person, assuming that person has to pay for the full cost of education. Small closed circles represent schools of which there are three types: public schools U_i, private schools P_i, and charter schools C_i.

Figure 1: Horizontal and Vertical Differentiation of Schools



The parent illustrated in Figure 1 can choose any school in the space, but C_1, P_2, and U_3 most closely match the parent's preferences. If all schools did charge full tuition, then we would expect the person to locate at the nearest school in the *h*-*v* space. However, the actual funding system includes tuition only at private schools. Therefore, if P_2 charged high tuition, this option would be eliminated from consideration, leaving C_1 and U_3, which would provide similar satisfaction at a much lower price.

While the above discussion is framed in the language of horizontal product differentiation, we will carry out our econometric work using heterogeneity of tastes. Actual measures of product differentiation, such as the amount of time spent teaching foreign languages, are not available. Therefore, we assume that variation in tastes will give rise to variation in education programs.

Public school education programs are chosen by school boards and superintendents for entire districts, therefore, we expect relatively minor variations in product differentiation across public schools within a district. Other models in which public and private schools co-exist, such as the one studied by Epple and Romano (1996), predict that private school quality is higher than public school quality. In addition, horizontal differentiation among the private schools is much greater than among the public schools, providing for the possibility of elite schools with high high-tuition and religious schools with low tuition.

As in Prescott and Visscher (1977), we assume that a charter school needs to attract a sufficient number of customers in order to cover fixed costs. It appears in Figure 1 that this is best accomplished by locating away from public and private schools in the *h-v* product space. However, if only private schools charge tuition, then charter schools may seek to provide education similar to private schools, but free of charge to consumers. Therefore, charter schools may instead try to locate very close to private schools in the product space. In any case, the location of charter schools in the *h-v* space is dependent upon the characteristics of both public and private schools in the district.

III. Data and Methodology

In this section we describe our data and the hypothesized relationships between the independent variables and charter school location. All of our data describing public school districts comes from the Departments of Education in Michigan and California. The data on charter schools in Michigan come from the Michigan Association of Public School Academies (MAPSA). The data on California charter schools comes from the California Department of Education. The data on demographic variables comes from the School District Data Book (SDDB), which includes U.S. Census Bureau data organized by school district.

The Michigan sample includes more than 500 observations in each regression specification, out of a total of 555 districts in the state. None of the missing district observations contains a charter school. However, our samples in California are in the range of 288-350 district observations, which is substantially lower than the total number of districts.[6] Approximately 60 of the 142 districts that contain charter schools are among the list of missing observations, though none of the missing observations contain more than one charter school. All missing observations for both states are due to missing data in the original sources listed above.

The unit of observation is the school district. In addition to simplifying the analysis, this approach is appropriate because school policies are set at the school district level. In addition, it is difficult to obtain data at the school level. We use the following

[6] The actual total number of districts in California varies from year to year, but is approximately 1,000.

variables: 1) wealth/income as measured by median household income and the poverty rate; 2) ethnic composition of the population; 3) adult (parent) educational attainment; 4) geographic characteristics, such as area and the enrollment density of the district; 5) performance of the public schools measured by outputs, such as test scores, graduation rates, and productive efficiency; 6) public school inputs, such as student-teacher ratios; 7) charter school revenue (state grants) and costs (teacher salaries); 8) the degree of competition from private schools.[7] Summary statistics are provided in appendices A and B. In Table 2 and Table 3 below, we exhibit public school characteristics by the number of charter schools per district.

[7] At least three of the variables discussed above are measured with error: teacher salaries, graduation rates, and the number of private schools. We tried various symmetric truncations, but found that the results were unaffected.

Table 2: Mean of Independent Variables Categorized by Number of Charter Schools in School Districts (Michigan)

Number of Charter Schools	0	1	2	3
Number of Observations	487	47	12	4
Med. House Value	54.4400	62.6596	53.1362	59.4318
Per Capita Income	12.4307	13.6903	12.8383	15.7198
Med. Household Income	29.2252	31.6506	27.7818	33.3838
Percentage of Children in Poverty	14.8747	13.1036	21.0569	16.3991
Percentage of Children Black	2.6253	4.9382	16.5913	34.9468
Percentage of Children Hispanic	2.2202	2.8294	4.9671	1.9740
Herfindahl Index for Race	88.5989	85.6163	74.4901	56.2649
Percentage of Adult with 12 Grade	23.6570	20.9840	23.1694	19.3347
Percentage of Adult with High School	38.1048	35.7185	30.1879	26.2820
Percentage of Adult with Some College	26.2057	28.5187	30.5313	31.5413
Percentage of Adult with Bachelor Degree or Higher	12.0325	14.7789	16.1115	22.8420
Average Years of Schooling	13.0095	13.2473	13.3456	13.8080
Herfindahl Index for Education	30.5036	29.2565	28.2192	27.2992
MEAP Math Score 4th Grade	43.2593	44.5915	38.8917	34.0250
Graduation Rate	90.2330	80.8489	83.6250	65.4500
Total Expenditure Per Student	4.3025	4.5489	4.9903	6.3618
Average Special Educational Expenditure Per Student	0.3162	0.3576	0.5576	0.4449
Pupil-Teacher Ratio	20.1948	19.5957	20.8333	17.7500
Average Teacher Salary	30.5072	33.1776	35.1267	39.1403
K-12 Enrollment Density	51.6359	45.5082	122.7717	189.7679
Number of Private Schools	1.4262	1.9574	5.5000	10.5000
Total K-12 Enrollment	2.2858	3.7169	7.5739	10.1568
Gr. Rate of K-12 Enrollment	-0.1121	0.5445	-0.9812	0.4128
Percentage of Public School located in City	3.3223	10.5910	36.4355	25.0000

Table 2 (cont'd)

Number of Charter Schools	4	5	36
Number of Observations	2	2	1
Med. House Value	77.1520	52.9955	25.2940
Per Capita Income	14.0100	12.2060	9.4430
Med. Household Income	26.7145	26.7460	18.7420
Percentage of Children in Poverty	24.3284	25.2006	44.2895
Percentage of Children Black	30.4542	25.9369	82.0884
Percentage of Children Hispanic	8.3750	9.6727	3.2848
Herfindahl Index for Race	47.8377	44.9284	69.2901
Percentage of Adult with 12 Grade	17.8227	21.7313	37.1489
Percentage of Adult with High School	23.0214	26.9645	28.3550
Percentage of Adult with Some College	27.9106	32.7880	25.5750
Percentage of Adult with Bachelor Degree or Higher	31.2453	18.5162	8.9211
Average Years of Schooling	14.2547	13.5494	12.6753
Herfindahl Index for Education	34.2620	26.2948	29.1771
MEAP Math Score 4th Grade	42.5500	30.3000	27.3000
Graduation Rate	69.6500	34.6000	71.6000
Total Expenditure Per Student	5.9510	5.0685	5.2930
Average Special Educational Expenditure Per Student	0.5234	0.7168	0.6109
Pupil-Teacher Ratio	18.5000	21.5000	22.0000
Average Teacher Salary	34.0570	31.7525	36.2440
K-12 Enrollment Density	114.6518	227.7712	510.1699
Number of Private Schools	14.0000	23.0000	98.0000
Total K-12 Enrollment	14.6515	26.4940	183.1510
Gr. Rate of K-12 Enrollment	-0.6721	-2.1684	-0.5748
Percentage of Public School located in City	98.3333	69.4444	94.5946

Table 3: Mean of Independent Variables Categorized by Number of Charter Schools in School Districts (California)

Number of Charter Schools	0	1	2	3	4	5
Number of Observations	683	73	11	7	2	2
Med. House Value	161.0317	155.5765	193.4620	166.0547	194.9715	143.8660
Per Capita Income	15.9204	15.1404	16.0471	14.9779	16.7700	14.0115
Med. Household Income	35.8001	33.1040	36.3837	34.8543	35.6245	35.3025
Percentage of Children in Poverty	16.5882	15.6422	12.5887	17.3796	13.0240	10.5404
Percentage of Children Black	2.8713	4.9998	3.4797	6.7075	1.8736	2.3503
Percentage of Children Hispanic	28.9470	24.3305	19.1421	26.8825	31.8585	34.0138
Herfindahl Index for Race	60.0797	56.1949	56.4036	59.4534	58.5670	51.6981
Percentage of Adult with 12 Grade	27.0420	23.9646	17.4619	24.5834	21.0595	23.3758
Percentage of Adult with High School	24.9958	25.5062	24.9778	25.4451	21.6060	28.4146
Percentage of Adult with Some College	29.9629	33.0880	36.8122	32.7108	34.1032	34.1096
Percentage of Adult with Bachelor Degree or Higher	17.9994	17.4412	20.7481	17.2607	23.2313	14.1000
Average Years of Schooling	13.4088	13.4686	13.8065	13.4440	13.8654	13.2944
Herfindahl Index for Education	31.5873	29.4507	28.2123	28.3918	27.2748	27.3166
MEAP Math Score 4th Grade	618.8822	615.2763	611.5000	614.1600	618.6500	616.9000
Graduation Rate	1.4072	2.3918	1.6143	3.4500	3.6000	1.9333
Total Expenditure Per Student	18.0109	42.8215	37.5880	33.2919	147.0195	37.8225
Average Special Educational Expenditure Per Student	0.0989	0.1128	0.0993	0.0950	0.1080	0.1164
Pupil-Teacher Ratio	22.9183	23.4600	24.8571	25.4125	23.3500	23.7000
Average Teacher Salary	25.1110	24.8379	24.5185	26.1930	23.9448	25.0770
K-12 Enrollment Density	81.5364	87.7917	40.9671	67.3475	146.1783	57.4615
Number of Private Schools	2.2568	5.5631	4.6667	4.7500	26.0000	45.0000
Total K-12 Enrollment	3.6456	8.9111	7.0964	6.9376	21.1140	27.6347
Gr. Rate of K-12 Enrollment	1.9272	2.0919	3.2202	6.0345	1.7747	3.3940
Percentage of Public School located in City	13.2095	20.2143	27.8592	18.5183	0.5814	6.2500

Table 3 (cont'd)

Number of Charter Schools	6	11	12	14	34
Number of Observations	2	1	1	1	1
Med. House Value	81.4525	87.0370	172.1070	183.2150	226.4900
Per Capita Income	11.5705	10.2930	14.6750	16.1970	15.3170
Med. Household Income	26.4850	22.7000	27.0900	31.9910	30.7950
Percentage of Children in Poverty	29.9362	32.0099	29.7194	20.9674	27.3885
Percentage of Children Black	4.9249	2.7295	51.2762	14.0586	13.6627
Percentage of Children Hispanic	39.1633	10.6700	17.7937	28.4801	59.1756
Herfindahl Index for Race	38.8973	76.2095	34.1082	29.1420	41.0275
Percentage of Adult with 12 Grade	31.3894	18.9516	25.4587	17.0489	35.6124
Percentage of Adult with High School	24.8657	20.3629	20.9801	21.4979	19.6746
Percentage of Adult with Some College	29.0823	39.7177	27.9328	35.0387	25.0559
Percentage of Adult with Bachelor Degree or Higher	14.6626	20.9677	25.6284	26.4145	19.6571
Average Years of Schooling	13.1475	13.8629	13.8418	14.1152	13.3244
Herfindahl Index for Education	26.8309	27.9096	25.2537	26.7826	26.6953
MEAP Math Score 4th Grade	614.1000	629.9000	594.0000	616.1000	601.3000
Graduation Rate	5.8500	0.0000	8.8000	4.4000	13.2000
Total Expenditure Per Student	158.5740	2.5060	231.5000	571.2540	3756.8060
Average Special Educational Expenditure Per Student	0.1160	0.1968	0.1056	0.1153	0.1081
Pupil-Teacher Ratio	24.7500	16.2000	22.6000	23.2000	24.5000
Average Teacher Salary	25.4180	23.8540	27.4040	24.8810	28.7040
K-12 Enrollment Density	203.8404	0.6787	350.9178	243.4163	430.8289
Number of Private Schools	16.5000	1.0000	54.0000	94.0000	593.0000
Total K-12 Enrollment	38.8115	0.3760	51.2340	125.1160	639.7810
Gr. Rate of K-12 Enrollment	1.4416	8.0251	0.4031	1.6966	1.2283
Percentage of Public School located in City	36.4706	0.0000	94.4444	100.0000	79.6825

The empirical analysis involves regressing the number of charter schools in each district on the characteristics of the schools and students in those same districts. Therefore, the dependent variable occurs in non-negative integer amounts and OLS is inconsistent. One of the methods created to deal with such issues is Poisson regression, developed by Hausman, Hall and Girliches (1984) and Cameron and Trivedi (1986). Poisson regressions have been used also by Papke (1991) in the context of manufacturing firm start-up and by Downes and Greenstein (1996) in the context of private school start-ups in California. Two of the potential weaknesses of this approach are: 1) violation of the independence assumption; and 2) "overdispersion" in the data. We use the Huber-White robust standard errors to correct for dispersion. [See Huber (1967), White (1982).]

There are two potential simultaneity problems in this framework. Charter schools, private schools, and public schools of choice are substitutes for each other. Entry of charter schools in a district is determined simultaneously with entry of private schools and/or public schools of choice within the same district. Moreover, public schools may respond to charter school entry by changing their behavior. We deal with both these problems by regressing the number of charter schools in 1998 on school district characteristics in 1992, the year before charter school policies began.[8]

The second simultaneity issue stems from the fact that students can cross district boundaries to attend charter schools.[9] This means that the number of charter schools in district i , C_i, depends not only on the characteristics of that district, X_i , but also on the

[8] See footnote 6 for information about specific years.

characteristics of neighboring districts, X_j, including the number of charter schools, C_j. This yields

$$C_i = f(X_i, X_j, C_j) \qquad (1)$$

District j may be a composite of information for many districts because there may be multiple districts nearby. This definition is important because it defines market size, or the geographic area over which it is possible to attract students. We start by excluding neighboring district data altogether, focusing only on home district characteristics. Next, we substitute in for C_j in (1) to obtain a reduced form that is a function only of X_i and X_j. In later parts of the paper, we expand the market definition to include nearby districts that do not border the home district.

In most cases where nearby districts are included, composite variables are created that account both for the number of students and physical distance of the border districts relative to the home district. For variables that are hypothesized to be positively (negatively) related to the number of charter schools, increasing the distance and decreasing the proportion of students in the border districts is expected to decrease (increase) the composite variable.

A common econometric issue is identifying the simultaneous equations of supply and demand. The usual simple model is not appropriate in this context because the price is exogenously fixed by the government, rather than being endogenously determined by

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[9] Kelejian and Prucha (1998) state that "cross-sectional spatial models frequently contain a spatial lag of the dependent variable as a regressor or a disturbance term that is *spatially autocorrelated.* The first of these topics is discussed here. We assume there is no spatial autocorrelation in our model.

markets. This yields two equations, but only one endogenous variable: the number of charter schools in a district. Therefore, we combine them into a single equation, which can be estimated consistently without additional changes to the estimation procedure.[10]

IV. Results

In this section, specific variables are introduced that relate to various aspects of horizontal and vertical product differentiation. We hypothesize specific relationships and interpret these results for both Michigan and California, which are presented below in Tables 4 through 7.

There are two reasons to expect that the results will be different across the two states. Both relate to state education policy. First, California education spending on traditional public schools is significantly constrained in wealthier school district to be below actual desired levels (Fernandez and Rogerson, 1999). Michigan also limits spending in high income districts; however, the limits appear to allow wealthier districts to come closer to their desired spending levels. In addition, Michigan has recently redistributed substantial funding to low income districts, resulting in a substantially higher average spending level (Papke, 2000).

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[10] Consider the following structural equations: and $C_d = \gamma_1 h + \gamma_2 v + \varepsilon_d$ and $C_s = \beta_1 p + \varepsilon_s$. The demand for charter schools C_d is a function of the variation in preferences for various horizontal characteristics h, the strength of preferences for quality v, and a disturbance ε_d. The supply of charter schools C_s is a function the price of inputs and output, and a disturbance ε_s. Again, prices do not show up on the demand side as they usually would because price is fixed at zero. After imposing the equilibrium condition $C = C_d = C_s$, it now appears that we have two separate equations trying to explain the same phenomenon. Therefore, we instead estimate $C = \pi_1 h + \pi_2 v + \pi_3 p + \varepsilon$.

A second key policy difference is that California's charter school policy limits chartering authority to local school districts, implying that charters cannot start without some support from the public schools. In Michigan, school districts may serve as chartering authorities, but this permission is also extended to universities and other organizations outside the district in which the charter schools reside.[11] The possible implications of these policy differences for our results are discussed below.

The demand for charter schooling is related to the size of the market. We measure the size of the market by the number of children enrolled in public schools or by the number of school-age children in the school district (ages 5-17). We would expect the number of charter schools to be positively related with this measure of "market-size," other things being equal. If entry decisions by charter schools are forward looking, trends in market size might matter as well. We therefore include the growth rate of enrollment as an independent variable. Many districts have been growing at a rapid rate, especially in California. In addition, the fact that only school districts can authorize charters in California implies that they are most likely to occur in growing districts that are adding schools. Building new charter schools, instead of traditional schools, allows the district to expand while decreasing regulatory burdens.

All of these hypotheses about market size are supported by the results in Table 4-1 (Michigan) and 4-2 (California). The coefficient on the number of students is consistently positive and significant in both states. Enrollment growth is positive and significant in California, but insignificant in Michigan. This provides support for the impact of differences in state charter policy.

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[11] The vast majority of schools are authorized by universities.

We use various measures of income.[12] Assuming education is a normal good, we might expect both median family income and median house value to be positively related with charter school entry.[13] This is especially true in California where state equalization policy has constrained public school spending in high-income districts. On the other hand, low income households may have fewer opportunities to move their residences, implying a negative relationship between income and charter entry. In other words, low-income households may demand less of a normal good, but they may also be further away from their most preferred bundle.

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[12] Chambers (1999) calculates school district-level cost indexes using a hedonic wage model. Many variables in our regressions are denominated in dollars, however, deflating them has very little impact on the results. All reported results are not deflated.

[13] The assumption that education is a normal good relates only to the vertical dimension of education characteristics. We have no theory about the relationship between income and any horizontal characteristic.

Table 4-1: Regression Results for Michigan

Dependent Variable: Number of Charter Schools for Each School District in Michigan, 1998-1999

(Robust standard errors in parentheses)

	(1)	(2)	(3)	(4)	(5)
Med. Household Income	-0.0329 (0.0123) **	-0.0182 (0.0182)	-0.0248 (0.0182)	-0.0413 (0.0199) **	-0.0276 (0.0212)
Percentage of Children in Poverty	--	0.0059 (0.0253)	-0.0004 (0.0241)	-0.0067 (0.0246)	-0.0028 (0.0247)
Average Yrs. of Schooling	1.1902 (0.1918) **	1.0257 (0.2398) **	0.9872 (0.2455) **	0.9954 (0.2438) **	0.9729 (0.2594) **
Herf. Index for Ad. Education	--	-0.1248 (0.0487) **	-0.1233 (0.0472) **	-0.0960 (0.0505) *	-0.1084 (0.0503) **
Herf. Index for Race	--	-0.0326 (0.0108) **	-0.0312 (0.0106) **	-0.0265 (0.0111) **	-0.0249 (0.0112) **
MEAP Math Score for 4th Grade	-0.0431 (0.0121) **	-0.0190 (0.0103) *	-0.0149 (0.0120)	-0.0176 (0.0128)	-0.0161 (0.0125)
Productive Efficiency	--	--	-3.9482 (4.5992)	-3.8725 (5.0275)	-3.9039 (4.8826)
Graduation Rate	-0.0065 (0.0044)	-0.0026 (0.0032)	-0.0024 (0.0030)	-0.0024 (0.0029)	-0.0021 (0.0029)
Tot. Exp. Per Student	0.1997 (0.0948) **	0.0326 (0.0899)	0.0886 (0.0931)	-0.0745 (0.1295)	0.0485 (0.1160)
Avg. Special Educational Expenditure Per Student	--	--	--	1.5656 (0.8082) *	1.5624 (0.8056) *
Pupil-Teacher Ratio	--	--	--	--	-0.0151 (0.0363)
Avg. Teacher Salary	--	--	--	0.0469 (0.0260) *	--
Expenditure minus Foundation Grant	--	--	--	--	--
Number of Priv. Schools	--	--	--	--	--
Total Enrollment	0.0267 (0.0010) **	0.0263 (0.0029) **	0.0274 (0.0030) **	0.0254 (0.0033) **	0.0264 (0.0032) **
Gr. Rate of Enrollment	-0.0379 (0.0608)	-0.0196 (0.0622)	-0.0201 (0.0632)	0.0202 (0.0700)	-0.0003 (0.0750)
City	--	--	--	--	--
Constant	-15.1547 (1.9957) **	-7.7136 (3.6071) **	-3.8374 (5.4191)	-5.8819 (5.6816)	-4.6103 (5.7761)

Note: One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Table 4-1 (cont'd)

Dependent Variable: Number of Charter Schools for Each School District in Michigan, 1998-1999

(Robust standard errors in parentheses)

	(6)	(7)	(8)	(9)	(10)
Med. Household Income	-0.0303 (0.0214)	-0.0374 (0.0213) *	-0.0208 (0.0188)	-0.0231 (0.0179)	-0.0134 (0.0175)
Percentage of Children in Poverty	-0.0042 (0.0243)	-0.0050 (0.0242)	-0.0001 (0.0242)	-0.0151 (0.0260)	-0.0064 (0.0245)
Average Yrs. of Schooling	0.9721 (0.2538) **	0.9543 (0.2624) **	1.0215 (0.2465) **	0.9105 (0.2430) **	0.7771 (0.2552) **
Herf. Index for Ad. Education	-0.1126 (0.0509) **	-0.1025 (0.0519) **	-0.1183 (0.0471) **	-0.1188 (0.0352) **	-0.1150 (0.0340) **
Herf. Index for Race	-0.0340 (0.0108) **	-0.0244 (0.0102) **	-0.0319 (0.0099) **	-0.0265 (0.0099) **	-0.0232 (0.0094) **
MEAP Math Score for 4th Grade	-0.0173 (0.0122)	-0.0174 (0.0127)	-0.0145 (0.0120)	-0.0148 (0.0121)	-0.0115 (0.0121)
Productive Efficiency	-3.3967 (4.8807)	-3.7854 (4.8789)	-3.9480 (4.6431)	-2.4928 (5.3160)	-1.6921 (5.4030)
Graduation Rate	-0.0027 (0.0030)	-0.0022 (0.0028)	-0.0029 (0.0031)	-0.0038 (0.0037)	-0.0012 (0.0022)
Tot. Exp. Per Student	-0.1275 (0.1596)	--	--	--	--
Avg. Special Educational Expenditure Per Student	--	1.5336 (0.8081) *	--	--	--
Pupil-Teacher Ratio	-0.0372 (0.0418)	-0.0175 (0.0310)	--	--	--
Avg. Teacher Salary	0.0526 (0.0268) **	0.0371 (0.0193) *	--	--	--
Expenditure minus Foundation Grant	--	--	0.1853 (0.2596)	0.2440 (0.2502)	0.3354 (0.2573)
Number of Priv. Schools	--	--	--	--	0.0461 (0.0054) **
Total Enrollment	0.0273 (0.0031) **	0.0255 (0.0033) **	0.0276 (0.0029) **	0.0253 (0.0030) **	--
Gr. Rate of Enrollment	-0.0436 (0.0768)	-0.0020 (0.0772)	-0.0141 (0.0632)	-0.0096 (0.0662)	-0.0157 (0.0689)
City	--	--	--	0.0093 (0.0031) **	0.0091 (0.0033) **
Constant	-3.8675 (5.4394)	-5.2281 (5.7439)	-3.9424 (5.3989)	-3.9508 (5.6821)	-4.0476 (5.7591)

Note: One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Table 4-2: Regression Results for California

Dependent Variable: Number of Charter Schools for Each School District in California, 1998-99

(Robust standard errors in parentheses)

	(1)	(2)	(3)	(4)	(5)
Med. Household Income	-0.0861 (0.0300) **	-0.0739 (0.0212) **	-0.0731 (0.0232) **	-0.0695 (0.0240) **	-0.0702 (0.0245) **
Percentage of Children in Poverty		0.0127 (0.0234)	0.0274 (0.0200)	0.0329 (0.0210)	0.0259 (0.0214)
Average Yrs. of Schooling	0.8558 (0.2737) **	0.7799 (0.3307) **	0.9871 (0.3707) **	0.9842 (0.4839) **	0.9486 (0.4117) **
Herf. Index for Ad. Education		-0.2144 (0.0698) **	-0.2137 (0.0646) **	-0.2031 (0.0784) **	-0.2159 (0.0728) **
Alternative Herf. Index for Race		0.0131 (0.0082)	0.0193 (0.0111) *	0.0146 (0.0112)	0.0196 (0.0113) *
STAR Math Score for 4th Grade	-0.0052 (0.0158)	-0.0083 (0.0177)	-0.0078 (0.0185)	-0.0071 (0.0184)	-0.0087 (0.0181)
Productive Efficiency			-3.3665 (1.1353) **	-2.9579 (3.7429)	-3.1755 (3.4613)
Dropout Rate	0.0176 (0.0328)	-0.0026 (0.0379)	-0.0042 (0.0370)	0.0038 (0.0350)	-0.0039 (0.0358)
Tot. Exp. Per Student	-0.0170 (0.0014) **	-0.0163 (0.0022) **	-0.0150 (0.0025) **	-0.0138 (0.0031) **	-0.0153 (0.0032) **
Avg. Special Educational Expenditure Per Student				-1.0158 (8.3636)	-0.6271 (7.1063)
Pupil-Teacher Ratio					-0.0262 (0.0671)
Min. Teacher Salary				-0.1276 (0.0969)	
Expenditure minus Foundation Grant					
Number of Priv. Schools					
Total Enrollment	0.1076 (0.0089) **	0.1028 (0.0131) **	0.0960 (0.0151) **	0.0894 (0.0182) **	0.0976 (0.0190) **
Gr. Rate of Enrollment	0.1276 (0.0557) **	0.1444 (0.0504) **	0.1325 (0.0486) **	0.1363 (0.0473) **	0.1297 (0.0482) **
City					
Constant	-7.4269 (7.9253)	0.4003 (9.4383)	-0.6781 (8.9617)	1.6724 (9.7679)	0.8964 (9.9190)

Note: One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Table 4-2 (cont'd)

Dependent Variable: Number of Charter Schools for Each School District in California, 1998-99

(Robust standard errors in parentheses)

	(6)	(7)	(8)	(9)	(10)
Med. Household Income	-0.0648 (0.0260) **	-0.0903 (0.0301) **	-0.0995 (0.0292) **	-0.0997 (0.0278) **	-0.0864 (0.0301) **
Percentage of Children in Poverty	0.0277 (0.0194)	0.0549 (0.0176) **	0.0191 (0.0195)	0.0191 (0.0194)	0.0330 (0.0191) *
Average Yrs. of Schooling	0.8936 (0.4198) **	1.4456 (0.4045) **	0.9530 (0.3109) **	0.9575 (0.2931) **	0.8956 (0.3394) **
Herf. Index for Ad. Education	-0.1994 (0.0656) **	-0.2582 (0.0697) **	-0.1864 (0.0565) **	-0.1865 (0.0568) **	-0.2127 (0.0572) **
Alternative Herf. Index for Race	0.0149 (0.0112)	-0.0045 (0.0138)	0.0018 (0.0151)	0.0017 (0.0143)	-0.0005 (0.0158)
STAR Math Score for 4th Grade	-0.0095 (0.0206)	0.0036 (0.0184)	0.0100 (0.0175)	0.0100 (0.0178)	0.0091 (0.0179)
Productive Efficiency	-1.7487 (1.7257)	-6.8301 (3.8641) *	-3.6933 (1.1975) **	-3.6840 (1.2445) **	-3.3845 (1.2546) **
Dropout Rate	0.0059 (0.0376)	0.0271 (0.0446)	-0.0703 (0.0607)	-0.0704 (0.0602)	-0.0105 (0.0498)
Tot. Exp. Per Student	-0.0146 (0.0028) **				
Avg. Special Educational Expenditure Per Student		-8.4139 (6.9365)			
Pupil-Teacher Ratio	-0.0452 (0.0671)	0.0619 (0.0644)			
Min. Teacher Salary	-0.1329 (0.0982)	-0.1528 (0.0800) *			
Expenditure minus Foundation Grant			-0.1037 (0.0204) **	-0.1044 (0.0205) **	-0.0574 (0.0243) **
Number of Priv. Schools					0.0237 (0.0071) **
Total Enrollment	0.0939 (0.0167) **	0.0080 (0.0012) **	0.0357 (0.0062) **	0.0359 (0.0060) **	
Gr. Rate of Enrollment	0.1316 (0.0459) **	0.1408 (0.0477) **	0.1228 (0.0434) **	0.1228 (0.0434) **	0.1278 (0.0443) **
City				-0.0003 (0.0042)	0.0032 (0.0049)
Constant	4.3352 (10.7343)	-5.0846 (10.4561)	-9.6069 (9.1573)	-9.6076 (9.1597)	-8.3214 (9.3238)

Note: One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

We use both median household income and median property values, but the results are unaffected by this choice. We use household income and find that the coefficient is negative for both states. It is occasionally significant for Michigan, and uniformly significant for California. The negative coefficients contradict the evidence for California from Grutzik et al (1995) who finds a positive relationship between income and charter location. However, Grutzik excludes adult education levels, which is highly correlated with income. The magnitude of the effect for California (Table 4-2, column 7) suggests that a one standard deviation increase in median income ($7,781) decreases the expected number of charter schools by 65 percent. In Michigan, the effect magnitude is smaller.

We include education of the adult population as an indicator of family preferences. Parents with higher education levels might receive greater utility from the education quality of their children, making them more eager to choose a charter school if traditional public schools perform below par. The measures we use are fractions of the population with: (i) high school degrees only, (ii) some college, and (iii) college degree. From these, we calculate a measure of average parent education level. The coefficient on this variable is consistently positive and significant in both states, which is consistent with the above hypothesis and the results of Downes and Greestein (1996). The magnitude for Michigan (Table 4-1, column 7) suggests that a one standard deviation increase in average years of schooling (0.6 years) raises the expected number of charter schools by 61 percent.

There are at least three ways in which population diversity may be associated with parents' demand for charter schools. First, diversity may imply greater dispersion of preferences and student needs. Second, parents may desire schools whose students have characteristics similar to those of their own children. Third, the median voter model suggests that if any group has greater than 50 percent of the population, then this group may be able to control schools through voting. Populations with less than 50 percent of the population may, therefore, seek to open schools that more closely match their preferences.

We include three measures of population diversity, based on race, income, and education of the adult population. Herfindahl indices are used both for race and education. A higher (lower) Herfindahl index implies a more (less) homogeneous population. Therefore, if diversity leads to more charter schools, then the coefficients on these variables should be negative. This hypothesis is generally supported by Tables 4-1 and 4-2, except that racial mix does not appear to be a factor in California. One reason for this may be the more restrictive charter-granting policies in California. If minority groups cannot affect school district polices, then these groups can seek charters on their own in Michigan. In California, they must work through the same school districts that have apparently already failed them. In Michigan, the magnitude of the effect suggests that a one standard deviation increase in either Herfindahl index yields a 29 percent decrease in the number of charter schools.

Available data does not allow for easy calculations of a Herfindahl index for income at the school district level. As an alternative, we include a measure of lower tail of the income distribution, in addition to median household income. Controlling for median income, a larger portion of the population in poverty implies a less equal income distribution. The coefficient on poverty in Tables 4-1 and 4-2 are generally positive, as expected, but they are usually insignificant.

The geographic size of the district may be important due to transportation costs. The number of students per square mile, controlling for the number of schools, indicates the average distance to school, which we would expect to be negatively related to charter school entry. Similarly, the number of public schools is expected to be negatively related with charter school location, since a large number of public schools would be associated with lower transportation costs and greater horizontal differentiation, controlling for the number of students.[14] It turns out that these variables are consistently insignificant, therefore, we omit them from the results reported here.[15] However, whether the schools are in cities, versus suburbs and rural areas, is important. The coefficient on the proportion of schools located in a central city is insignificant for California, but positive and significant in Michigan, regardless of whether density is included.

The intent of creating charter schools was to increase choice and competition in schooling. We expect charter schools to enter more frequently where school choice is limited. A larger number of private schools implies a larger number of substitutes to public schooling and, therefore, a higher degree of competition. We might expect then that the number of private schools (and public schools) will be negatively related with charter school entry.[16] However, charter schools could also locate near private schools and provide a similar type of education without charging tuition. In this case, charter

[14] It may also be the case that people prefer schools with few students.

[15] They were also highly correlated, therefore, we did not include both in any given specification.

[16] Cross-district schools-of-choice programs, which were described earlier, also measure choice, however, these do not have a significant impact.

school location might be an increasing function of the size of the private sector.[17] Our estimation results provide a test of which effect is dominant. The results in Table 4-1 and Table 4-2 indicate that more private schools are associated with more charter schools, providing support for the second hypothesis.

The quality of public schools might be an important determinant of charter school entry. If public school quality is low, dissatisfied parents might be more inclined to choose the charter school alternative. Two of our measures of public school quality are measures of output: graduation rates and student test scores.[18] Survey research suggests that when test scores are low, parents might consider alternatives to public education and we therefore expect these scores to be negatively related with charter school entry (Finn, 2000). The negative point estimates here support this hypothesis, but they are generally not significant.

Student and family characteristics vary widely across districts. Previous research indicates that these differences have an important impact on education outcomes.[19] Therefore, test scores and drop out rates alone will not accurately indicate the contribution to education made by the schools themselves. The ideal measure of school quality (vertical differentiation) is value-added. We calculate a measure of public school efficiency using frontier regressions of educational production functions in which the

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[17] Unfortunately, we do not have data on private school tuition and other private school characteristics.

[18] For Michigan, the student test is the 4th grade Michigan Educational Assessment Program (MEAP). For California, the student test is the 4th grade Standardized Testing and Reporting (STAR). We use the test scores for math since there is some evidence that math scores are more sensitive to school quality, whereas reading scores are more dependent on interaction with parents in the home. The results are unaffected by the choice of reading and math tests.

[19] See, for example, Coleman (1966) and Harris (2000a).

dependent variable is 7^{th} grade math scores.[20] The estimated functions are shown in appendix C. The best any district can do is produce on the production frontier. The further the actual test score is from the production frontier, the more inefficient is the district. If markets are relatively efficient, then we would expect a negative relationship between this measure of efficiency and the number of charter schools. However, we find just the opposite. As with the coefficients on test scores, the efficiency coefficients are consistently negative and insignificant. However, the low significance levels are at least partially caused by the high correlation between test scores and this measure of efficiency.[21]

Our data set includes many variables that measure the inputs of public school districts, including expenditure levels, student-teacher ratios, teacher salaries, and special education spending. To the extent that parents residing in a district do not pay the costs of education, we expect that fewer inputs will induce more charter schools to enter.

The interpretation of two input coefficients requires additional discussion. First, controlling for class size, teacher salaries, and special education spending, higher expenditures per pupil implies more spending on other inputs, such as after-school programs and administrators.[22] Second, variation in teacher salaries may reflect differences in compensating differentials across districts (e.g. crime) that are not accounted for by other included variables.

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[20] For Michigan, these scores are from 1993. For California, the scores are from 1998, which is the oldest available.

[21] The correlation range is 0.7-0.9, depending on the frontier specification.

[22] We use two measures of teacher salaries, namely average teacher salary and the contractual starting salary for a teacher with a bachelor's degree and zero teaching experience.

The results for school inputs are different across the two states. The positive relationship between charters and special education spending in Michigan is especially interesting, given the survey evidence that charter schools attract a disproportionate number of students with special needs compared with public schools.[23] The special education programs at traditional public schools often involve labeling kids and placing them in "pull-out" programs that separate kids from the mainstream. Also, Cullen (1999) finds that fiscal incentives lead traditional public schools to include more students in special programs. Charter schools, in contrast, have far lower funding levels and rarely offer pull-out programs. Therefore, one interpretation is that many parents prefer to keep their kids in mainstream classrooms and programs.

In Michigan, the coefficient magnitude for special education expenditures suggests that a one standard deviation increase in this category ($156 per pupil) increases the expected number of charter schools by 24 percent. For teacher salaries, a one standard deviation increase ($6,079) raises the number of charter schools by 23 percent. A similar increase in class size decreases the number by 6 percent.

The discussion of coefficient magnitudes above focuses on Michigan. In California, the effect magnitudes are larger for the demographic variables. For example, a one standard deviation increase in median household income is associated with an 88 percent drop in the number of charter schools. This may be due to differences in state equalization policy, as discussed earlier. The one demographic variable that has a

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One possible exception is teacher salaries, as indicated earlier.

smaller impact in California is the Herfindahl index for race, which here implies only a 12 percent decrease in the number of charters, compared with 30 percent in Michigan. The effects of most other variables are quite similar across the two states.

On the supply side, revenue will be a key factor regardless of a school's objective function. In both states, schools receive the per pupil foundation grant for the district in which the school is located. This grant also indicates the districts' minimum total spending for public schools, as guaranteed by the state government. Without going into detail about how this is calculated, the important characteristic of the funding system is that public school districts with a low foundation grant also tend to have total spending that is exactly equal or slightly above the foundation grant. This means that charter schools will have an easier time competing with public schools in low-spending districts.[24] We incorporate the revenue effect by including a variable that measures expenditures minus foundation grant, which should reveal a negative relationship with the number of charters. For California, the coefficient is negative and significant, as expected. The same coefficients for Michigan are positive and insignificant.

In many ways, Detroit is an unusual school district in Michigan. It is by far the largest district in Michigan with an enrollment of about 180,000, which exceeds mean enrollment by a factor of 60! The ethnic composition of Detroit is much different from

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[23] Finn (2000, p.79) states that "many charter schools attract youngsters with more problems and deficits than the conventional schools to which they are compared." Also, 20 percent of their survey respondents indicated that they chose a charter school because "my child's special needs [were] not met at [the] previous school."

[24] The overall advantage/disadvantage is somewhat difficult to establish for two other reasons: 1) charter schools do not receive capital funds from the government; 2) the foundation grant does not account for grade level, allowing charter schools to focus on "cheaper" student populations. However, these differences should affect all districts in relatively equal ways.

the rest of Michigan, the poverty rate is much higher and test scores are much lower. Perhaps most importantly, a very large proportion of all charter schools is located in Detroit. In order to check to what extent our results are driven by this single observation, we re-run the regression from Table 4-1 column 7, omitting Detroit. We also run regressions omitting some other potential outliers, namely the very small school districts. The results are shown in Table 5 and are fairly robust to these changes.

Table 5: Regression Results Omitting Potential Outliers for Michigan

Dependent Variable: Number of Charter Schools for Each School District in Michigan, 1998-1999

	With Detroit	Delete Detroit	Delete 5% smallest Districts (with Detroit)	Delete 10% smallest Districts (with Detroit)
Number of Observations	517	516	492	466
Med. Household Income	-0.0374 (0.0213) *	-0.0447 (0.0216) **	-0.0485 (0.0220) **	-0.0493 (0.0219) **
Poverty Rate	-0.0050 (0.0242)	-0.0074 (0.0244)	-0.0121 (0.0262)	-0.0161 (0.0262)
Average Yrs. of Schooling	0.9543 (0.2624) **	0.8418 (0.2511) **	0.9494 (0.2642) **	0.9164 (0.2630) **
Herf. Index for Ad. Education	-0.1025 (0.0519) **	-0.0826 (0.0451) *	-0.1140 (0.0523) **	-0.1095 (0.0510) **
Herf. Index for Race	-0.0244 (0.0102) **	-0.0186 (0.0096) *	-0.0264 (0.0107) **	-0.0280 (0.0109) **
MEAP Math Score 4th Grade	-0.0174 (0.0127)	-0.0169 (0.0130)	-0.0111 (0.0118)	-0.0101 (0.0123)
Production Efficiency	-3.7854 (4.8789)	-1.2361 (5.5450)	-5.8932 (4.8209)	-6.3623 (4.9279)
Graduation Rate	-0.0022 (0.0028)	-0.0004 (0.0010)	-0.0020 (0.0029)	-0.0019 (0.0027)
Avg. Special Educational Expenditure Per Student	1.5336 (0.8081) *	1.2851 (0.9139)	1.5302 (0.8325) *	1.4613 (0.8321) *
Pupil-Teacher Ratio	-0.0175 (0.0310)	-0.0457 (0.0321)	-0.0237 (0.0340)	-0.0258 (0.0338)
Average Teacher Salary	0.0371 (0.0193) *	0.0399 (0.0198) **	0.0396 (0.0200) **	0.0350 (0.0202) *
Total Enrollment	0.0255 (0.0033) **	0.0704 (0.0207) **	0.0267 (0.0035) **	0.0272 (0.0035) **
Gr. Rate of Enrollment	-0.0020 (0.0772)	0.0108 (0.0802)	0.0138 (0.0826)	0.0083 (0.0841)
Constant	-5.2281 (5.7439)	-6.7197 (5.9850)	-2.5142 (5.6140)	-1.3709 (5.6048)

Note: One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Many charter schools attract students not only from the district in which they are located but also from neighboring districts. In order to account for this, we regress the number of charter schools not only on characteristics of the district in which the charter school is located, but also on characteristics of neighboring (contiguous) districts. There are two possible effects of neighboring districts: First, the parents may send their children to charter schools in other districts. If this were the only effect, then we would expect the neighboring coefficients to be of the same sign as the home district coefficients. Furthermore, if the charter schools expected most of their students to come from the home district, then the border-district coefficients should have lower magnitudes.

The home district coefficients in Table 6 reveal results quite similar to those in Table 4-1. Also, unlike Downes and Greenstein (1996), we find that some characteristics of neighboring districts have a significant impact on the number of charter schools.

Table 6: Regression Result with Border Districts for Michigan

Dependent Variable: Number of Charter Schools for Each School District in Michigan, 1998-1999

(With Contiguous Districts and with Detroit)

	Home	Contiguous
Number of Observations	516	
Med. Household Income	-0.0376 (0.0279)	0.0158 (0.0639)
Poverty Rate	0.0110 (0.0247)	-0.0833 (0.0535)
Average Yrs. of Schooling	1.0497 (0.2887) **	0.2305 (0.4131)
Herf. Index for Ad. Education	-0.1187 (0.0438) **	-0.1243 (0.1224)
Herf. Index for Race	-0.0238 (0.0110) **	0.0409 (0.0253)
MEAP Math Score 4th Grade	-0.0076 (0.0135)	-0.0914 (0.0375) **
Production Efficiency	-1.2660 (5.7479)	-9.3094 (4.8134) *
Graduation Rate	-0.0032 (0.0034)	-0.0043 (0.0066)
Avg. Special Educational Expenditure Per Student	0.3621 (0.8689)	5.7005 (1.6936) **
Pupil-Teacher Ratio	-0.1105 (0.0381) **	0.4073 (0.0956) **
Average Teacher Salary	0.0157 (0.0217)	-0.0783 (0.0526)
Total Enrollment	0.0194 (0.0036) **	0.0088 (0.0071)
Gr. Rate of Enrollment	-0.0985 (0.0878)	0.3104 (0.1903) *
Constant	-3.9033 (4.9852)	--

Note: One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

V. Conclusion

This paper provides evidence about the equity and efficiency effects of charter schools by studying their location patterns. The results reinforce the conclusions of existing research that finds a significant impact of racial diversity. However, we clarify this result by including variables that measure other forms of diversity, including income and adult education levels. The effect of population diversity on the demand for charter schools may reflect differences in preferences for education programs, not just preferences for homogeneous student populations.

We find mixed support for the effect that charter schools have on school efficiency. Charter schools do appear to locate in more school districts with less efficient public schools. However, they also locate in districts that should already be competitive by way of private school entry. Therefore, instead of providing competition, charters may simply shift resources to students who previously went to private schools.

The results here also suggest that state policies toward charter and public schools do impact the location of charter schools. This means that state education policy at least partially determines the effects that charter schools have on equity and efficiency. Several other issues are left for future research. One is the impact that charter schools have on public school performance. Also, Table 6 here indicates that the characteristics of border districts seem to impact charter location. While this specification does not seem to alter the general role of home district characteristics, the general issue of geography and market size warrants further attention.

APPENDICES

Appendix A: Summary Statistics (Michigan)

Table A: Summary Statistics (Michigan)

Variable	Mean	Std. Dev.	Min	Max
Med. House Value	55.1641	23.5722	19.0000	230.3750
Per Capita Income	12.5686	3.9566	6.2200	48.3400
Med. Household Income	29.3916	9.3980	9.8050	88.9180
Percentage of Children in Poverty	14.9930	9.6126	0.0000	51.7051
Percentage of Children in Black	3.6778	11.6971	0.0000	97.0390
Percentage of Children in Hispanic	2.3795	3.2701	0.0000	35.2941
Herfindahl Index for Race	87.4753	12.4457	37.7571	100.0000
Percentage of Adult with 12 Grade	23.3867	7.5265	2.5726	51.0638
Percentage of Adult with High School	37.5373	7.1426	6.6098	60.1852
Percentage of Adult with Some College	26.5604	5.9011	3.1915	50.7564
Percentage of Adult with Bachelor Degree or Higher	12.5156	8.4886	0.0000	60.1718
Average Years of Schooling	13.0483	0.6371	11.9362	16.1119
Herfindahl Index for Education	30.3224	2.7340	25.3326	44.4370
MEAP Math Score 4th Grade	43.1317	13.5106	4.3000	100.0000
Graduation Rate	88.7272	115.0292	0.0000	2570.4000
Total Expenditure Per Student	4.3633	1.1428	0.0000	14.4420
Average Special Educational Expenditure Per Student	0.3286	0.1559	0.0000	0.8590
Pupil-Teacher Ratio	20.1391	3.6000	8.0000	41.0000
Average Teacher Salary	30.9208	6.0789	0.0000	51.4430
K-12 Enrollment Density	55.3187	124.0824	0.0194	1068.5000
Number of Private Schools	1.9209	5.0483	0.0000	98.0000
Total K-12 Enrollment	3.0317	8.3631	0.0040	183.1510
Gr. Rate of K-12 Enrollment	-0.0817	2.4367	-11.9489	15.0722
Percentage of Public School located in City	5.5431	21.7519	0.0000	100.0000

Appendix B: Summary Statistics (California)

Table B: Summary Statistics (California)

Variable	Mean	Std. Dev.	Min	Max
Med. House Value	160.8949	99.4099	0.0000	490.9770
Per Capita Income	15.8181	7.7811	4.0510	64.9930
Med. Household Income	35.4842	13.5953	11.4060	122.9080
Percentage of Children in Poverty	16.5164	12.6396	0.0000	76.1134
Percentage of Children in Black	3.2033	6.3613	0.0000	71.5090
Percentage of Children in Hispanic	28.4079	23.7525	0.0000	100.0000
Herfindahl Index for Race	59.5052	18.2437	25.9773	100.0000
Percentage of Adult with 12 Grade	26.5714	16.1165	2.1212	90.1883
Percentage of Adult with High School	25.0245	7.2968	0.0000	87.5000
Percentage of Adult with Some College	30.4035	7.8658	0.0000	47.8919
Percentage of Adult with Bachelor Degree or Higher	18.0006	13.0581	0.0000	70.5273
Average Years of Schooling	13.4224	0.9858	11.1992	16.6736
Herfindahl Index for Education	31.2533	6.7032	25.2537	81.8317
STAR Math Score	618.2699	19.6486	555.2000	681.9000
Drop-Out Rate	1.7616	4.2021	0.0000	68.5000
Total Expenditure Per Student	27.1975	139.5741	0.0000	3756.8060
Average Special Educational Expenditure Per Student	0.2453	0.8829	0.0021	16.3793
Pupil-Teacher Ratio	22.1008	5.3378	0.0000	60.6000
Entry Teacher Salary	25.0853	2.4229	15.9120	44.3570
K-12 Enrollment Density	81.4625	149.2684	0.0000	1450.7500
Number of Private Schools	3.4679	19.2437	0.0000	593.0000
Total K-12 Enrollment	4.8513	21.1820	0.0000	639.7810
Gr. Rate of K-12 Enrollment	2.3278	4.9000	-14.4514	67.1028
Percentage of Public School located in City	14.4063	33.1666	0.0000	100.0000

Appendix C: The Educational Production Frontier Function (Michigan)

Table C: The Educational Production Frontier Function (Michigan)

Dependent Variable: MEAP Math Test Score in 7th, 1993

Variable	MLE Estimates
Per Capita Income (Deflated by Teacher Cost Index)	0.1762 (0.1126)
Percentage of Children in Poverty	-0.3925 (0.1509) **
Percentage of Children in Black	0.0219 (0.0442)
Percentage of Children in Hispanic	0.0015 (0.0040)
Herfindahl Index for Race	-0.4558 (0.1338) **
Average Years of Schooling	-0.2908 (0.0379) **
Pupil-Teacher Ratio	0.2453 (0.0384) **
Total Expenditure Per Student (Deflated by Teacher Cost Index)	2.0855 (3.1521)
Total K-12 Enrollment	0.2079 (0.0357) **
K-12 Enrollment Density	-2.1753 (2.7757)
Average Teacher Salary (Deflated by Teacher Cost Index)	0.0051 (0.0032) *
Average Special Educational Expenditure Per Student (Deflated by Teacher Cost Index)	0.2974 (0.2445)
Constant	60.1321 (9.6782) **

Note: One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

REFERENCES

REFERENCES

Armor, D.J., & Peiser, B.M. (1998). "Interdistrict Choice in Massachusetts," In *Learning From School Choice*, Peterson and Hassel, editors. Washington, DC: The Brookings Institution, pp. 157-186.

Bettinger, E. (2000). "The Effect of Charter Schools on Public Schools," *Working Paper*, Massachusetts Institute of Technology.

Cameron, A.C. & Trivedi, P.K. (1986). "Econometric Models Based on Count Data: Comparisons and Applications of Some Estimators and Tests." *Journal of Applied Econometrics*, pp. 29-53.

Chambers, J. (1999). "Differences Across the United States: Introduction to a Teacher Cost Index," *American Institutes for Research.*

Chubb, J.E. & Moe, T.M. (1990). *Politics, Markets and America's Schools*, Washington, DC: The Brookings Institution.

Coleman, J.S., Campbell, E.Q., Hobson, C.J., McPartland, J., Mood, A.M., Weinfield, F.D., & York, R.L. (1966). *Equality of Educational Opportunity.* Washington, DC: U.S. Government Printing Office.

Coons, J.E. and S.O. Sugarman. (1978). *Education by Choice: The Case for Family Control.* Berkeley: University of California Press.

Cullen, J. (1999). "The Impact of Fiscal Incentives on Student Disability Rates," *NBER Working Paper No. 7173.*

Downes, T.A., & Greenstein, S.M. (1996). "Understanding the Supply of Non-Profits: Modeling the Location of Private Schools," *Rand Journal of Economics,* Vol. 27, pp. 365-390.

Epple, D. & Romano, R. (1996). "Ends Against the Middle: Determining Public Sector Provision When There are Private Alternatives," *Journal of Public Economics.*

Fernandez, R., & Rogerson, R. (1999). "Education Finance Reform and Investment in Human Capital: Lessons from California," *Journal of Public Economics*, Vol. 79, No. 3, pp. 327-50.

Filer, R.K. and D. Munich (2000). "Education Reform in the Post-Communist Czech Republic," *Manuscript*.

Finn, C.E., Manno, B.V., & Vanourek, G. (2000) *Charter Schools in Action*. Princeton, NJ: Princeton University Press.

Fitz, J., D. Halpin, & Power, S. (1993). *Grant Maintained Schools Education in the Market Place*. London: Kogan Page.

Friedman, M. (1962). *Capitalism and Freedom*. Chicago: University of Chicago Press.

Gifford, M., M. Ogle, and L. Solmon. (1998). "Who is Choosing Charter Schools? A Snapshot of Geography and Ethnicity of Charter School Students," *Manuscript*.

Glomm, G., D. Harris, and T. Lo (2000). "Are Urban School Districts Inefficient?" *Working Paper*, Michigan State University.

Grutzik, C., D. Bernal, D. Hirschberger, and A. S. Wells. (1995). "Resources and Access in California Charter Schools." Paper presented at the *American Educational Research Association Meetings*, San Francisco, 1995.

Harris, D. (2000). "New Approaches to Meta-Analysis with Applications to Education Production Functions," *Doctoral Dissertation*, Michigan State University.

Harris, D., S. Oliver, and D. Plank (2000). "International Lessons from School Choice," *Education Policy Center at Michigan State University*.

Hassel, B.C. (1998). "The Case for Charter Schools," In *Learning From School Choice*, Peterson and Hassel, editors. Washington, DC: The Brookings Institution, pp. 30-45.

Hausman, J., Hall, B.H., & Griliches, Z. (1984). "Econometric Models for Count Data with an Application to the Patents-R&D Relationship." *Econometrica*, Vol. 52, pp. 909-38.

Hotelling, H. (1929). "Stability in Competition." *Economic Journal*, Vol. 39, pp. 41-57.

Hoxby, C. (1997). "Does Competition Among Public Schools Benefit Students and Taxpayers? Evidence from Natural Variation in School Districting," *NBER Working Paper No. 4979.*

Hoxby, C. (1994). "Do Private Schools Provide Competition for Public Schools?" *NBER Working Paper No. 4978.*

Huber, P.J. (1967). "The Behavior of Maximum Likelihood Estimates under Non-Standard Conditions." In Proceedings of the Fifth Berkeley Symposium in Mathematical Statistics, Vol. 1, University of California, Berkeley.

Keljian, H., & Prucha, I. (1998). "A Generalized Spatial Two-Stage Least Squares Procedure for Estimating a Spatial Autoregressive Model with Autoregressive Disturbances," *Journal of Real Estate Finance and Economics*, Vol. 17, No. 1, pp. 99-121.

Manski, Ch. (1992). "Educational Choice (Vouchers) and Social Mobility." *Economics of Education Review*, vol.11, pp. 351-69.

Mintrom. M. (1998). "Michigan's Charter School Movement." *Manuscript.*

Nathan, J. (1996). Charter School Creating Hope and Opportunity for American Education, San Francisco: Tossey-Bass Publishers.

Nechyba, T. (1996). "Public School Finance in a General Equilibrium Tiebout World: Equalization Programs, Peer Effects and Private School Vouchers," *NBER Working Paper No. 5642.*

Papke, L. (1991). "Interstate Business Tax Differentials and New Firm Location. Evidence from Panel Data. " *Journal of Public Economics*, Vol. 45, pp. 47-68.

Papke, L. (2000). "Michigan Applied Public Policy Research Project on K-12 Education," *Manuscript.*

Paris, D.C. (1998). "Standards and Charters: Horace Mann Meets Tinker Bell." *Educational Policy*, Vol. 12, pp. 380-396.

Peterson, P. E. (1999). "Vouchers and Test Scores," *Policy Review*, No. 93, pp. 10-15

Prescott, E. and M. Visscher. (1977). "Sequential Location Among Firms with Foresight." *Bell Journal of Economics*, Vol. 8, pp. 378-393.

Public Sector Consultants, Inc. and MAXIMUS, Inc. (1999) "Michigan's Charter School Initiative: From Theory to Practice." *Final Report.*

Vergari, S. and M. Mintrom. (1996). "Charter School Laws Across the United States." *Manuscript.*

Weinschrott, D.J., & Kilgore, S.B., (1998), "Evidence from the Indianapolis Voucher Program." In *Learning From School Choice*, Peterson and Hassel, editors. Washington, DC: The Brookings Institution, pp. 307-334.

Wells, A. S., Grutzik, C., & Carnochan, S. (1996). "The Multiple Meanings of US Charter School Reforms: Exploring the Politics of Deregulation." Paper presented at the British Educational Research Association Annual Conference, Lancaster, UK, 1996.

White, H. (1982). "Maximum Likelihood Estimation of Misspecified Models," *Econometrica*, Vol. 50, 1-26.

Whitty, G., Power, S., & Halpin, D. (1998). *Devolution and Choice in Education.*

Wohlstetter, P., Wenning, R., Briggs, K.L. (1995). "Charter Schools in the United States: The Question of Autonomy." *Educational Policy*, Vol. 9, December, 331-358.

Wooldridge, J.M. (1992). "Quasi Likelihood Methods for Count Data." *Journal of Economics*, pp. 352-406.

CHAPTER 2

ARE URBAN DISTRICTS INEFFICIENT?

I. Introduction

> "In a move virtually unprecedented in American education, the state of Missouri is stripping away the accreditation of all [Kansas City] schools because of poor academic performance."[25]
>
> "The children failed the test. There are arguments about the way in which standards are imposed, but I suppose those kinds of arguments could go on forever about any test. The fact is, it's a statewide test."

Many people believe American schools are failing. In the case of urban districts, the public perception is one of complete disaster. Chicago, Detroit, Cleveland, Baltimore, Kansas City, and Los Angeles school districts have all seen serious attempts by city or state governments to impose special controls, reforms, or outright takeover. For instance, the state of Ohio has implemented an audit program that applies only to urban districts. In Michigan, Wisconsin, Florida, and Ohio, recent proposals have sought to fund school vouchers targeted almost exclusively to school children in large urban districts like Cleveland, Milwaukee or Detroit.

Such proposals are certainly not new. Local governments have often been subject to special provisions and controls, usually due to extreme financial crisis or mismanagement. What is new is that the controls are now being justified based on

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[25] Christian Science Monitor.

general performance measures – i.e. student test scores. Table 1 below provides a summary of average district test scores for Michigan along several dimensions.

Table 1: Average Test Score along Different Dimensions

	Difference	Mean	
		Urban[26]	Non-Urban
Math Grade 11 High School Test, 1999	-11.3457 (2.6300) **	54.0688	65.4144
Math Grade 11 High School Test, 1998	-14.0979 (2.8332) **	49.0750	63.1729
Science Grade 11 High School Test, 1999	-12.5547 (2.6348) **	41.3844	53.9390
Science Grade 11 High School Test, 1998	-11.6276 (2.7693) **	42.7281	54.3557
		Rich[27]	Poor
Math Grade 11 High School Test, 1999	10.1151 (1.2176) **	69.7714	59.6523
Math Grade 11 High School Test, 1998	8.7049 (1.3519) **	66.6510	57.9461
Science Grade 11 High School Test, 1999	9.3811 (1.2369) **	57.8526	48.4715
Science Grade 11 High School Test, 1998	8.5954 (1.3107) **	57.9337	49.3383
		Nonblack[28]	Black
Math Grade 11 High School Test, 1999	3.1358 (1.2900) **	66.2749	63.1391
Math Grade 11 High School Test, 1998	4.2681 (1.3931) **	64.4282	60.1602
Science Grade 11 High School Test, 1999	2.9967 (1.2981) **	54.6541	51.6574
Science Grade 11 High School Test, 1998	4.2988 (1.3516) **	55.7812	51.4824

Note: Number in parenthesis presents standard error.

Two asterisks (**) indicates significance at the 95 percent confidence level.

[26] Public school districts are defined as urban districts in Table 1 when half of the public schools in this district locate in large and mid-size central cities.

[27] Public school districts are defined as rich districts in Table 1 when the percentage of children in poverty in a specific school district is less than 12.88 percent. We also define rich districts when the per capita income (deflated by the teacher cost index) in a specific school district is greater than 12406 dollars. The result is similar as the first definition of rich districts.

[28] Public school districts are defined as black districts in Table 1 when the percentage of children in a specific school district is greater than 0.348 percent.

In Table 1, the difference between rich and poor districts is about 8~10 percentage points[29], the difference between non-black and black districts is about 3~4 percentage points, and finally the difference between urban districts and non-urban districts is about 11~14 percentage points. Those differences are statistically significant. The distribution of scores in Table 1 comes as little surprise. The relatively low level of scores in urban districts is well known. What appears to be unknown, however, is the degree to which this is caused by low school inputs (e.g. large classes), student characteristics, or low efficiency of teachers and/or administrators. Existing research provides little, if any, evidence, even though the distinction is fundamental to evaluating and reforming schools. If the distribution of student ability or background is not equal across schools, as appears to be the case, then test scores should vary even if school performance/efficiency is identical in every school. If different schooling outcomes are caused by differential school inputs, changing the amount of school inputs might be the desired policy. In neither case is institutional reform such as a state take over called for.

The above discussion implies a need for some type of "value-added" measure of school performance that indicates the contribution of the school to each child's learning. Ideally, this would involve students taking comparable tests on the first and last days of class. However, few districts actually collect such data. Another option is using student demographic data to form a proxy for student ability, and using funding levels to control for the other resources that schools have to work with. The objective is to determine how close districts are to being efficient – i.e. how close they are to the production frontier.

[29] The MEAP and HSP results are reported in percentage of meeting some requirements. See Section III. Data and Model for detailed description.

There are at least three ways to implement the above approach. The first is to regress test scores on student characteristics and funding levels, using the error terms as measures of productive efficiency. However, this approach is inconsistent with economic theory because this allows schools to be above the production frontier. Two general approaches to fixing this problem are: data envelopment analysis and frontier regression. The former uses mathematical optimization to find the frontier. Frontier regression, as the name suggests, relies on statistical estimation of the same function.

This paper uses frontier regression to estimate the productive efficiency of schools using data on Michigan school districts. The methodology is described in Section II. Estimation results are presented in Section III, yielding a measure of efficiency for each district. Besides, Section III also includes comparisons of these efficiency measures across district types. While comparisons are possible on various dimensions, the primary issue is whether large urban districts, such as Detroit, are indeed less efficient than other school districts and, therefore, whether governments are justified in targeting those districts with special controls/institutional reform to improve school performance.

II. Methodology

The production frontier methodology has been developed fairly recently. Its application is increasingly widespread in many different fields, such as air force maintenance units [Charnes, Clark Cooper, and Golany (1985), Bowlin (1987)], education [McCarty and Yaisawarng (1990, 1992), Ray (1991), Wyckoff and Lavigne (1991)], national parks [Rhodes (1986)], employment offices [Cavin and Stafford (1985)], and health clinics [Huang and McLaughlin (1989), Johnson and Lahiri (1992)]. The first empirical estimation of production functions begins with the papers of Cobb and Douglas (1928). However, it was largely used to study the functional distribution of income between capital and labor at the macroeconomic level. The production frontier model in disaggregated level hasn't drawn much empirical attention until recent decades.

The analysis of productive efficiency is a branch of the production frontier model because deviations from a production frontier have a natural interpretation as a measure of the efficiency with which economic units pursue their technical or behavioral objectives. Greene (1993) has a short definition for "productive efficient" that producers will be characterized as efficient if they have produced as much as possible with the inputs they have actually employed or they have produced that output at minimum inputs. Lovell (1993) defined the efficiency of a production unit as a comparison between observed and optimal values of its output and input.

Koopmans (1951) provides a formal definition of technical efficiency. A producer is technically efficient if an increase in any output requires reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output. Thus a technically inefficient producer could produce the same outputs with less of at least one input, or could use the same inputs to produce more of at least one output.

Debreu (1951) and Farrell (1957) introduced a measure of technical efficiency. Their measure is defined as one minus the maximum equiproportionate reduction in all inputs that still allows continued production of given outputs. A score of unity indicates technical efficiency because no equiproportionate input reduction is feasible, and a score less than unity indicates the severity of technical inefficiency.

There are two competing paradigms on how to construct the frontier efficiency model. One uses mathematical programming techniques, the other employs econometric techniques. The mathematical programming techniques is also called "Data Envelopment Analysis" (DEA), which is a body of techniques for analyzing production, cost, revenue, and profit data without parameterizing the technology. By wrapping a hull around the observed data, we can calculate the distance of each observed producer to that frontier. Presumably, the larger is the sample, the more precisely this information will be revealed. The major advantage of "Data Envelopment Analysis" approach is that no explicit functional form need be imposed on the data. However, since it lumps noise and inefficiency together, the calculated frontier may be warped if the data are contaminated by statistical noise. The econometric approach can handle statistical noise, but it imposes an explicit, and possibly overly restrictive, functional form for technology. This kind of parametric approach is likely to confound the effects of misspecification of functional form (of both technology and inefficiency) with inefficiency estimation. However, the more structure we impose on a model the better our estimates – provided the structure we impose is correct. This is a trade-off between structure and flexibility.

For the econometric approach, let us construct a single production equation cross-sectional model to illustrate the basic concepts. Suppose producers use inputs $x \in R_+^n$ to produce scalar output $y \in R_+$ with technology

$$y_i = f(x_i;\beta)\exp\{v_i + u_i\}. \tag{2.1}$$

The econometric version of the Debreu-Farrell output-oriented technical efficiency (TE) measure is written

$$TE_i = \frac{y_i}{[f(x_i;\beta)\exp\{v_i\}]} = \exp\{u_i\}, \tag{2.2}$$

where β is a vector of technology parameters to be estimated and i =1, …, I indexes producers. The random disturbance term v_i is intended to capture the effects of statistical noise and is assumed to be independently and identically distributed as $N(0,\sigma_v^2)$. The disturbance term u_i is assumed to be distributed independently of v_i and to satisfy $u_i \leq 0$.

Early studies adopted the deterministic frontier model, that is, assume $v_i = 0$. Then the frontier becomes $f(x_i;\beta)$. The residual is also adjusted to make sure that $0 < TE_i \leq 1$. Winsten (1957) proposed corrected ordinary least squares (COLS), which corrects the downward bias in the estimated OLS intercept by shifting it up until all corrected residuals are nonpositive and at least one is zero. Richmond (1974) introduced modified ordinary least squares (MOLS), which makes an assumption about the functional form of the nonpositive efficiency component u_i. The most popular assumption is half normal and exponential. Two-parameter distributions, including the truncated normal and the gamma distribution, are also proposed by Stevenson (1980) and Greene (1980), respectively. Finally, MLE is an implemented method that simultaneously estimates all the technology parameters and the parameters of the distribution of u_i.

Recent econometric approaches usually select the stochastic frontier model because it allows for statistical noise resulting from events outside the firm's control, such as luck and weather. Employing a stochastic frontier can also be seen as allowing for some types of specification error and for omitted variables uncorrelated with the included regressors. In equation (2.1), the stochastic production frontier is $f(x_i;\beta)\exp\{v_i\}$ and the nonpositive error component u_i represents technical inefficiency. The degree of technical efficiency of a producer is given by the ratio of observed to maximum feasible output, where maximum feasible output is given by the stochastic production frontier.

To calculate TE in equation (2.2), we need to estimate equation (2.1). Moreover, we need to decompose the residuals into separate estimates of noise and technical inefficiency, which is a difficult task. COLS is no longer a feasible technique. MOLS and MLE proceed roughly as in the deterministic frontier strategy, however, the resulting residuals contain both noise and inefficiency, and they adjusts the OLS intercept by minus the mean of u_i, which is extracted from the moments of the OLS residuals. The distribution of the compound error term $\varepsilon_i = v_i + u_i$ has been derived by Weinstein (1964) and is discussed in Aigner, Lovell, and Schmidt (1977). Jondrow, Lovell, Materov, and Schmidt (1982) suggested a technique to decompose the noise term and inefficiency term.

For half-normally distributed inefficiency term, the log-likelihood function for the model is

$$Log(\alpha,\beta,\sigma,\lambda) = -N\ln\sigma - \text{constant} + \sum\left[\ln\Phi\left(\frac{-\varepsilon_i\lambda}{\sigma}\right) - \frac{1}{2}\left(\frac{\varepsilon_i}{\sigma}\right)^2\right], \qquad (2.3)$$

and the explicit form of the estimated inefficiency component u_i is

$$E[u_i \mid \varepsilon_i] = \left[\frac{\sigma\lambda}{1+\lambda^2}\right]\left[z_i + \frac{\phi(z_i)}{\Phi(z_i)}\right], \tag{2.4}$$

where $\lambda = \sigma_u/\sigma_v$, $\sigma^2 = \sigma_v^2 + \sigma_u^2$, $z_i = \frac{-\varepsilon_i\lambda}{\sigma}$, $\phi(\cdot)$ is the density of the standard normal distribution, and $\Phi(\cdot)$ is the cumulative density function of the standard normal distribution.

Meeusen and van den Broeck (1977) and Aigner, et. Al. (1977) presented the log-likelihood function for an exponentially distributed disturbance,

$$Log(\beta,\sigma_v,\theta) = N\left[\ln\theta + \frac{1}{2}(\theta\sigma_v)^2\right] + \sum_{i=1}^{N}\left[\ln\Phi\left(\frac{-\varepsilon_i}{\sigma_v} - \theta\sigma_v\right) + \theta\varepsilon_i\right], \tag{2.5}$$

and the expression of the estimated inefficiency term u_i is

$$E[u_i \mid \varepsilon_i] = z_i + \sigma_v \frac{\phi(z_i/\sigma_v)}{\Phi(z_i/\sigma_v)}, \tag{2.6}$$

where $z_i = \varepsilon_i - \theta\sigma_v^2$.

Stevenson (1980) argued that the zero mean assumed in the Aigner, Lovell, and Schmidt (1977) model was an unnecessary restriction. Therefore, he proposed a truncated normal distribution. The log-likelihood function is

$$Log(\alpha,\beta,\sigma,\lambda,\mu^0) = -N\left[\ln\sigma + \frac{1}{2}\ln 2\pi + \ln\Phi(\mu^0)\right] - \sum_{i=1}^{N}\left[\frac{1}{2}\left(\frac{\varepsilon_i}{\sigma}\right)^2 - \ln\Phi\left(\mu^0 - \frac{\varepsilon_i\lambda}{\sigma}\right)\right],$$

(2.7)

and the explicit form of the inefficient term u_i is similar with the equation (2.4), however, replace z_i with $z_i - \mu^0$.

The above three approaches are employed in our model to estimate efficiency for public school production in Michigan.

III. Result

Our analysis is mainly based on the Michigan public school students' academic achievement on mathematics and science, which is measured by MEAP (Michigan Educational Assessment Program) satisfaction percentage. A cross-sectional data set of 511 public school districts in Michigan is used in our estimation[30]. Selected data statistics are summarized in Table 2. To investigate the relationship between the student's performance, the school inputs and the characteristic of the specific public school district, we employ the following linear stochastic frontier model to estimate the efficiency level for individual public school district.

$$\text{MEAP HST Score} = \alpha + \beta X_i + \gamma Z_i + (v_i + u_i)\,. \qquad (3.1)$$

[30] There are 555 public school districts in Michigan, however, 44 public school districts are removed from our dataset because of missing data. These 44 public school districts were listed in Appendix A.

The educational achievement is measured by the MEAP (Michigan Educational Assessment Program) and HST[31] (High School Test) results on Mathematics and Science for the public school students in Michigan. MEAP tested students of 4th and 7th grade in Mathematics, and the result is reported in percentage of students achieving a satisfactory performance. MEAP also tested students of 5th and 8th grade in Science, and the result is reported in percentage of satisfaction.

[31] The result of HST for 11th grade in both Mathematics and Science is reported in percentage of students achieving level 1 or 2, which was adopted begins from 1998 academic year, replacing the original MEAP test for 10th graders. Level 1 implies that students exceed Michigan standard, and level 2 implies that students meet Michigan standard. We sum up the percentage of level 1 and 2 to construct a comparable measure to the original MEAP result for 10th grade.

Table 2: Data Statistics Summary

Observation: 511 public school districts in Michigan

Variable	Mean	Std. Dev.	Min	Max
Math Grade 11 High School Test, 1999[32]	64.7039	14.6509	0.0000	100.1000
Math Grade 11 High School Test, 1998[10]	62.2900	15.8744	0.0000	93.8000
Science Grade 11 High School Test, 1999[10]	53.1528	14.7343	2.9000	96.9000
Science Grade 11 High School Test, 1998[10]	53.6276	15.4124	0.0000	88.7000
Math Grade 4 MEAP result, 1992[10]	43.0955	12.8369	4.3000	89.0000
Science Grade 5 MEAP result, 1993[10]	75.3025	11.0131	25.6000	100.0000
Per Capita Income[33]	12.9272	3.2200	6.3981	41.1796
Percentage of Children in Poverty	14.7225	9.2616	0.8441	51.7051
Percentage of Children in Black	3.9806	12.1739	0.0000	97.0390
Percentage of Children in Hispanic	2.4143	2.9180	0.0000	26.5808
Racial Herf. Index	87.0414	12.4616	37.7571	100.0000
Average Schooling Years	13.0717	0.6385	12.0772	16.1119
Educational Herf. Index	30.1435	2.4663	25.3326	44.4370
Enrollment Density, 1998[34]	53.9974	101.9657	0.1466	758.5000
Average Enrollment Density, 1990-1998[12]	55.6475	110.7128	0.1405	868.1875
K-12 Enrollment, 1998[35]	3.2188	8.3143	0.0930	174.7300
Average K-12 Enrollment, 1990-1998[13]	3.2061	8.4432	0.0878	177.9384
Total Expenditure, 1998[10]	6.3248	1.0456	4.4017	17.0296
Average Total Expenditure, 1990-1998[10]	5.3944	0.8739	3.2534	11.2415
Average Teacher Salary, 1998[10]	46.1317	4.8170	32.6905	62.0232
Average Teacher Salary, 1990-1998[10]	38.9330	3.6639	28.3104	50.6924
Special Educational Expenditure per student, 1998[10]	0.4193	0.1534	0.0000	1.0793
Average Special Educational Expenditure per student, 1990-1998[10]	0.3859	0.1391	0.0000	0.8993
Pupil-Teacher Ratio, 1998[36]	21.1898	2.4926	10.0000	29.0000
Average Pupil-Teacher Ratio, 1990-1998[14]	21.3116	2.4068	9.7500	28.3750

[32] In percentage points.

[33] In thousand dollars, and deflated by Teacher Cost Index.

[34] In persons per square kilometers.

[35] In thousand persons.

[36] In number of students per teacher.

Here, X_i is a vector of characteristics of public school districts, including per capita income, percentage of children in poverty, percentage of children in Black, percentage of children in Hispanic, educational Herfindahl index[37], average schooling years, K-12 enrollment, and student density,...etc[38]. In equation (3.1), Z_i is a vector of school input variables, includes pupil-teacher ratio, total expenditure, average teacher salary, and special educational expenditure per pupil..etc. The random disturbance term is v_i, which captures the effects of statistical noise, is assumed to be independently and identically distributed as $N(0,\sigma_v^2)$. The other disturbance term u_i is assumed to be distributed independently of v_i and to satisfy $u_i \leq 0$.

Three different functional specifications are used. The output variable is MEAP satisfaction percentage for all models, however, we change the characteristic variables and school input variables for different models. In Model 1, the characteristics variables includes per capita income, percentage of children in poverty, percentage of children which are Black, percentage of children which are Hispanic, educational Herfindahl index, average schooling years, K-12 enrollment, and student density. The school input variables includes pupil-teacher ratio, total expenditure, average teacher salary, and special educational expenditure per pupil. In Model 2, we use racial Herfindahl index instead of percentage of children in Black and percentage of children in Hispanic in the

[37] The educational Herfindahl index is constituted by summing up the square term of the percentage of adult educational attainment including 12 grade, high school, some college, and bachelor or higher. When the adult educational attainment is homogenous, say all are with high school education, the value of index is at its maximum, which equals 1. The smaller the value of educational Herfindahl index, the more heterogenous the adult educational attainment is in that school district.

[38] Per capita income, average teacher salary, total expenditure, and special educational expenditure per pupil are deflated by teaching cost index (TCI).

characteristic variables. In Model 3, we add square term of school input variables based on Model 2's specification.

Ordinary least squares estimates of the education production of Model 1, 2, and 3 appear in Table 3. Greene (1993) suggested that although the OLS coefficients themselves are of somewhat limited usefulness in the frontier model, it is worthwhile to note how different assumptions and estimators sometimes only produce minor variation from the OLS estimates. We will also show MLE estimates for different specification for the efficiency term later for comparison. The consistency of the OLS estimates does not require the normal distribution of the compound error term, instead, the only requirement is the zero mean of the error term. Therefore, we can always get the consistent OLS estimates by subtracting the mean of compound error term from both of the constant term and the compound error term. Since the OLS estimates are consistent here, exploring the impacts of each input variable on the educational performance for the public school districts in Table 3 is a good starting point. The MLE results reported in Appendix B are remarkably similar to the OLS results for all those specifications.

Table 3 shows that the lower the socioeconomic status (higher percentage of children in poverty, higher percentage of children who are minority, and fewer years of adult's schooling) and the poorer the characteristics of school districts (higher enrollment density), the lower the HST test result is.

Table 3: OLS Estimates for Different Models

Observation: 511 public school districts in Michigan

Dependent Variable: Math Grade 11 High School Test, 1999

	Model 1	Model 2	Model 3
Per Capita Income, 1989	-0.1659 (0.3003)	-0.2769 (0.3067)	-0.2790 (0.3017)
Percentage of Children in Poverty, 1989	-0.1889** (0.0923)	-0.3397** (0.0876)	-0.2483** (0.0919)
Percentage of Children Black, 1989	-0.3395** (0.0600)	-- --	-- --
Percentage of Children Hispanic, 1989	-0.3649** (0.1724)	-- --	-- --
Racial Herf. Index, 1989	-- --	0.2021** (0.0526)	0.2006** (0.0520)
Educational Herf. Index, 1989	-0.2552 (0.2191)	-0.1994 (0.2236)	-0.2220 (0.2204)
Avg. Schooling Years, 1989	8.5937** (1.3783)	8.7564** (1.4343)	9.3384** (1.4253)
K-12 Enrollment, 1998	0.0581 (0.0645)	-0.0224 (0.0641)	0.0150 (0.0636)
Enrollment Density, 1998	-0.0114** (0.0055)	-0.0155** (0.0055)	-0.0176** (0.0055)
Pupil-Teacher Ratio, 1998	-1.0099** (0.3246)	-1.3681** (0.3198)	-9.7294** (2.2359)
Pupil-Teacher ratio (Square), 1998	-- --	-- --	0.1908** (0.0516)
Total Expenditure, 1998	-1.0312 (0.8337)	-1.5417* (0.8413)	-3.7346 (2.4016)
Total Expenditure (Square), 1998	-- --	-- --	0.0225 (0.1271)
Average Teacher Salary, 1998	0.6634** (0.1337)	0.7850** (0.1330)	5.4527** (1.4488)
Average Teacher Salary (Square), 1998	-- --	-- --	-0.0484** (0.0153)
Special Educational Expenditure, 1998	-0.8303 (3.5165)	-0.2903 (3.5926)	5.1694 (12.3680)
Special Educational Expenditure (Square), 1998	-- --	-- --	-4.9503 (12.5879)
Constant	-34.6820* (20.2290)	-49.2028** (22.5234)	-66.6397 (43.0470)

Note: Number in parenthesis presents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level. Two asterisks (**) indicates significance at the 95 percent confidence level.

In addition to regressing Math High School Test in 1999 on the characteristic and school input variables in 1998 (Type 1 showed in Table 3), there are four more alternative specifications for each model. We regress Math High School Test in 1999 on the average characteristic and school input variables from 1990 to 1998. We also regress Math High School Test in 1998 on the characteristic and school input variables in 1998. Moreover, we regress Math High School Test in 1998 on the average characteristic and school input variables from 1990 to 1998. Finally, we regress Math High School Test in 1999 on the Math MEAP in which grade results in 1992, and average characteristic and school input variables from 1992 to 1998[39]. Table 4 summarizes all of five types of regressions as follows:

Table 4: Summary of Five Types of Regressions for Model 1, 2, and 3

	Type				
	1	2	3	4	5
	Dependent Variable				
Math / Science Grade 11 High School Test, 1999	x	x			x
Math / Science Grade 11 High School Test, 1998			x	x	
	Explanatory Variables				
Socioeconomic Status of the Students, 1989	x	x	x	x	x
Characteristics of Public School Districts, 1998	x		x		x
Characteristics of Public School Districts, Average 1991-98		x		x	
Schools' Inputs, 1998	x		x		x
Schools' Inputs, Average 1991-98		x		x	
MEAP Math 4th Grade, 1992 / Science 5th Grade, 1993					x

[39] This is analogous to the value-added approach in Fox and Taylor (1991) and Grosskopf, Hayes, and Weber (1991).

We found the regression results are robust across all these different specifications within the same model.

Table 5 presents method of moments estimators for the parameters of our stochastic frontier models. The basis for the calculations appears in equation (2.3) – (2.7). All the analysis in Table 5 is carried out using the LIMDEP (Greene, 1991) computer program. However, it did not automatically calculate the efficiency measure defined in equation (2.2), which limits the value of efficiency between 0 and 1. The estimated outcomes by LIMDEP includes observed Y, predicted Y, residual (efficiency term u_i), $x_i\hat{\beta}$, and $y - x_i\hat{\beta}$. In order to calculate the measure of efficiency defined in equation (2.2), we adopt Coelli's (1996) definition as follows:

$$EFF_i = E(y_i^* \mid u_i, x_i) / E(y_i^* \mid u_i = 0, x_i) = (x_i\hat{\beta} + \hat{u}_i) / x_i\hat{\beta} . \qquad (3.2)$$

Comparing equation (3.2) to equation (2.2)

$$TE_i = \frac{y_i}{[f(x_i;\beta)\exp\{v_i\}]} = \frac{f(x_i;\beta)\exp\{v_i + u_i)}{[f(x_i;\beta)\exp\{v_i\}]} = \exp\{u_i\}, \qquad (2.2)$$

we obtain $$\hat{TE}_i = \frac{\hat{y}_i}{f(x_i;\beta)} = \frac{f(x_i;\hat{\beta})\exp(\hat{u}_i)}{f(x_i;\hat{\beta})} = \exp\{\hat{u}_i\}, \qquad (2.2')$$

where the numerator in equation (3.2) presents the sum of the predicted HST result and the efficiency residual term (negative in our model), which is similar to the numerator in equation (2.2'), except that equation (2.2') adopts a Cobb-Douglas production form. Remember $y_i = f(x_i;\beta)\exp\{v_i + u_i)$, and predicted value of y_i becomes

$\hat{y}_i = f(x_i;\hat{\beta})\exp\{\hat{u}_i\}$. The denominator presents the predicted test score excluding the efficiency residual term, which is the optimal test score when no inefficiency occurred, and which is similar to the denominator in equation (2.2'). Table 5 shows that the estimated average efficiency are similar across different specification of the functional form for efficiency term (half-normal, truncated-normal, and exponential).

Table 5: Estimated Efficiency Distribution for Different Models

	Model 1	Model 2	Model 3
	Half-Normal		
λ	1.0140	1.0345	1.0154
σ	12.9528	13.2754	12.9215
$E(u_i)$	7.3173	7.5740	7.3107
$E(TE_i)$	0.8953	0.8925	0.8956
	Truncated-Normal[40]		
μ / σ_u	0.0218	0.0170	0.0091
λ	1.1161	1.1366	1.0869
σ	13.5568	13.7876	13.3317
$E(u_i)$	7.9558	8.1465	7.7472
$E(TE_i)$	0.8873	0.8852	0.8901
	Exponential		
θ	0.1833	0.1757	0.1804
σ_v	8.9961	9.1237	8.9572
$E(u_i)$	5.4544	5.6928	5.5424
$E(TE_i)$	0.9196	0.9166	0.9185

[40] Greene (1993) claimed that although truncated-normal benefits by relaxation of a possibly erroneous restriction (μ =0), the cost appears to be that the log-likelihood is relatively flat in the dimension of μ.. Therefore, estimation of a nonzero μ often inflates the standard errors of the other parameters considerably, and quite frequently impedes or prevents convergence. We also encounter the same problem when estimating the individual value of efficiency, which is assumed as truncated-normally distributed. The results produced by LIMDEP for truncated normal model routinely denied convergence and, as often as not, produced nonsense estimates according to the warning message showed by program. Therefore, we also run the same estimation by using the FRONTIER 4.1 (Coelli, 1995) computer software. It did not produce any error message for the truncated normal model. Besides, we found that the values of the individual efficiencies are the same in the result carried out by LIMDEP and FRONT 4.1 (accurate to 4 decimal points). Hence we still report the truncated normal result for our model.

There are totally 45 regressions for Mathematics and Science, respectively[41]. However, only 18 regression results for Science are reported since OLS residuals do not pass the skewness check. This implies the model is probably not well specified or the data are inconsistent with the model.

Average efficiency is calculated by summing up all the efficiency calculated from each of the regressions, then divided by total number of regressions estimated. We rank all the public school districts from least efficient to most efficient according to the value of average efficiency, and report the 20 least efficient public school districts in Table 6. Table 6A is for Mathematics, and Table 6B is for Science. Besides, Hanushek (1986) discussed the drawbacks of test scores as a single measure of educational output and claimed that the perceived importance of schooling is to affect the ability of students to perform in and cope with society after they leave school. Therefore, the percentage of continuation of schooling (graduation rate) would be a better measure for school performance in some extent. We also use the graduation rate as the dependent variable in our production model for comparison, and the estimated result for efficiency measure is reported in Table 6C. Finally, the 20 most efficient school districts are also reported in Appendix C.

[41] There are 5 types of regressions for each of three models, moreover, each of them has three alternative functional form of efficiency term

Table 6A: 20 Least Efficient Public School Districts for Math

School District Name	Avg. Efficiency[42]	Relative District Size[43]	Percent of Schl. In City	Relative Math Test Score[44]
Engadine Consolidated Schs	0.4150	0.1053	0.00	0.0000
Burr Oak Comm School Dist	0.5192	0.1084	0.00	0.2922
Waldron Area Schools	0.5501	0.1345	0.00	0.7192
City Of Muskegon Heights Sd	0.5657	0.7695	0.00	0.1445
Highland Park City Schools	0.6039	1.1274	0.00	0.2312
Benton Harbor Area Schools	0.6149	1.8050	100.00	0.1589
Fulton Schools	0.6217	0.3007	0.00	0.3211
Buena Vista School District	0.6273	0.5120	100.00	0.1445
River Rouge City Schools	0.6935	0.7910	0.00	0.2504
Deerfield Public Schools	0.6951	0.1277	0.00	0.3211
Arenac Eastern School Dist	0.6997	0.1488	0.00	0.5940
Dearborn Hgts Sch Dist No. 7	0.7065	0.7528	0.00	0.2569
Baldwin Community Schools	0.7092	0.2461	0.00	0.3773
Ecorse Public School Dist	0.7128	0.3902	0.00	0.4495
Britton Macon Area Sch Dist	0.7371	0.1516	0.00	0.5153
Oak Park City School Dist	0.7446	1.1231	0.00	0.4013
Pontiac City School District	0.7569	3.9676	93.55	0.3757
Memphis Community Schools	0.7633	0.3116	0.00	1.0708
Springport Public Schools	0.7656	0.3389	0.00	0.4913
Westwood Community Schools	0.7659	0.6822	0.00	0.4880

[42] The mean of average efficiency for math test is 0.9001, and with 10% percentile of 0.8099, 25% percentile of 0.8627.

[43] Numbers are reported as K-12 enrollment in 1998 of each district divided by average K-12 enrollment in 1998.

[44] Numbers are reported as HST Math test score in 1998 of each district divided by average HST Math test score in 1998.

Table 6B: 20 Least Efficient Public School Districts for Science

School District Name	Avg. Efficiency[45]	Relative District Size[46]	Percent of Schl. In City	Relative Science Test Score[47]
Highland Park City Schools	0.0000	1.1274	0.00	0.0000
Burr Oak Comm School Dist	0.3099	0.1084	0.00	0.0000
Engadine Consolidated Schs	0.3100	0.1053	0.00	0.0000
City Of Muskegon Heights Sd	0.4163	0.7695	0.00	0.0839
Inkster City School District	0.4343	0.5589	0.00	0.1175
Godfrey Lee Public Sch Dist	0.4498	0.3871	0.00	0.1548
Coloma Community Schools	0.4928	0.7298	0.00	0.2667
Marenisco School District	0.4937	0.0367	0.00	0.2667
Willow Run Community Schools	0.5347	1.0361	0.00	0.2387
Webberville Community Schs	0.5448	0.2426	0.00	0.3897
Fulton Schools	0.5471	0.3007	0.00	0.3729
Buena Vista School District	0.5542	0.5120	100.00	0.1883
Akron Fairgrove Schools	0.5775	0.1553	0.00	0.4084
Benton Harbor Area Schools	0.5902	1.8050	100.00	0.2200
Mason Cons School District	0.5928	0.4837	0.00	0.3767
Detroit City School District	0.6160	54.2843	94.59	0.2461
Kingsley Area School	0.6230	0.3974	0.00	0.4662
Oak Park City School Dist	0.6254	1.1231	0.00	0.2816
Tahquamenon Area Schools	0.6429	0.3821	0.00	0.4736
Dearborn City School Dist	0.6475	4.9329	96.30	0.5128

[45] The mean of average efficiency for science test is 0.8771, and with 10% percentile of 0.7462, 25% percentile of 0.8292.

[46] Numbers are reported as K-12 enrollment in 1998 of each district divided by average K-12 enrollment in 1998.

[47] Numbers are reported as HST Science test score in 1998 of each district divided by average HST Science test score in 1998.

Table 6C: 20 Least Efficient Public School Districts for Graduation Rate

School District Name	Avg. Efficiency[48]	Relative District Size[49]	Percent of Schl. In City	Relative Graduation Rate[50]
Lansing Public School Dist	0.4569	5.9181	100.00	0.4305
Inkster City School District	0.5022	0.5589	0.00	0.4590
Galien Township School Dist	0.5930	0.1417	0.00	0.6428
Colon Community School Dist	0.6030	0.2986	0.00	0.6475
Eau Claire Public Schools	0.6348	0.2774	0.00	0.6760
Ecorse Public School Dist	0.6357	0.3902	0.00	0.6025
Mancelona Public Schools	0.6360	0.3408	0.00	0.6819
Jackson Public Schools	0.6600	2.3788	100.00	0.6736
River Rouge City Schools	0.6615	0.7910	0.00	0.6392
Fennville Public Schools	0.6784	0.5008	0.00	0.7009
River Valley School District	0.6805	0.4110	0.00	0.7507
Lakeville Comm School Dist	0.6871	0.7105	0.00	0.7353
Hale Area Schools	0.6971	0.2554	0.00	0.7566
Grand Haven City School Dist	0.7046	1.8836	0.00	0.7673
Alcona Community Schools	0.7060	0.3287	0.00	0.7732
Onaway Area Comm School Dist	0.7081	0.2973	0.00	0.7626
Bellevue Comm Sch Dist	0.7121	0.3203	0.00	0.7768
Huron School District	0.7181	0.6036	0.00	0.7697
Saranac Community Schools	0.7187	0.3821	0.00	0.7780
South Haven Public Schools	0.7217	0.8727	0.00	0.7448

[48] The mean of average efficiency for graduation rate is 0.9135, and with 10% percentile of 0.7965, 25% percentile of 0.8555.

[49] Numbers are reported as K-12 enrollment in 1998 of each district divided by average K-12 enrollment in 1998.

[50] Numbers are reported as graduation rate in 1998 of each district divided by average graduation rate in 1998.

Detroit is the largest urban school district in Michigan and has been the focus of much policy debate, hence it may worth our additional attention. Departing from the common perception that Detroit is in a complete disaster for education, Detroit does not show up in the list of 20 least efficient public school for HST math result. The average efficiency measure of Detroit for Mathematics is 0.7898, and with the rank of 33. For science test score, Detroit performs much worse with an average efficiency measure of 0.6160, and a rank of 16. For both the HST math and science results, Detroit's measure of efficiency is roughly twice as large as the least efficient one. Besides, when we measure district performance by using graduation rate, Detroit even performs very well, the average efficiency measure for graduation rate is 0.9450, and with a rank of 357. Besides, from Appendix D we see that Detroit enter the list of 20 least efficient school districts for HST math result only once in total 45 regressions. However, it shows up most of time in the list of 20 least efficient school districts for HST science result (17 out of 18 regressions). Finally, Detroit show good performance in graduation rate again. It did not enter the list of 20 least efficient school districts for graduation rate, and with an average ranking of 343.74. We report the relative measure of efficiency for Detroit in Table 7.

Table 7: Relative Measure of Efficiency for Detroit

Regression	Half Normal	Truncated-Normal	Exponential
	HST Mathematics, 1998		
Model 1			
Type 3	0.8399	0.8385	0.8747
Type 4	0.8396	0.8349	0.8694
Model 2			
Type 3	0.8222	0.8208	0.8690
Type 4	0.8243	0.8234	0.8656
Model 3			
Type 3	0.8300	0.8299	0.8705
Type 4	0.8288	0.8162	0.8679
	HST Science, 1998		
Model 1			
Type 3	0.6903	0.6994	0.7405
Type 4	0.6756	-4.8621	0.7441
Model 2			
Type 3	0.7110	0.7100	0.7735
Type 4	0.7030	0.6992	0.7680
Model 3			
Type 3	0.7049	0.7019	0.7660
Type 4	0.7080	0.7045	0.7706
	Graduation Rate, 1998		
Model 1			
Type 3	1.0665	1.0668	1.0336
Type 4	1.0682	1.0688	1.0361
Model 2			
Type 3	1.0714	1.0721	1.0310
Type 4	1.0720	1.0710	1.0345
Model 3			
Type 3	1.0666	1.0710	1.0296
Type 4	1.0728	1.0786	1.0342

Note: Number reported as measure of efficiency divided by average measure of efficiency in each regression.

Roughly speaking, Detroit is relatively inefficient in the production function of schooling in our model, however, it did not perform as bad as people think. The difference between the regression result and the common knowledge maybe comes from the different measure of academic performance. Usually, people use the test score to justify whether a specific school district performs well or bad. However, as we mentioned in section I, if the characteristics of students are different, then the performance of test score may not only result from the school inputs. We examine the correlation coefficient between the test result and the efficiency measure, as well as the correlation coefficient between the graduation rate and the efficiency measure. Table 8 shows the correlation coefficient between the HST mathematics result in 1998 and the estimated efficiency is around 90 percent when we use half-normal or truncated normal model. However, the correlation coefficient decreases when an exponential model is used (up to 12 percentage points). This is also the case for HST mathematics result in 1998, and for most of the HST science result. On the other hand, we found the correlation coefficient is roughly 95 percent between the graduation rate and efficiency measure, and this highly correlated property may suggest that graduation rate is a better index for district's academic performance then test score.

Table 8: Correlation Coefficients between Educational Achievement and Efficiency

Efficiency	Half Normal	Truncated-Normal	Exponential
		HST Mathematics, 1998	
Model 1			
Type 3	0.9120 *	0.9100 *	0.6908 *
Type 4	0.9136 *	0.9125 *	0.8428 *
Model 2			
Type 3	0.9087 *	0.9061 *	0.8454 *
Type 4	0.9108 *	0.9075 *	0.8526 *
Model 3			
Type 3	0.9061 *	0.9034 *	0.8438 *
Type 4	0.9084 *	0.9085 *	0.8517 *
		HST Science, 1998	
Model 1			
Type 3	0.4939 *	0.5483 *	0.7398 *
Type 4	0.0370	0.1352 *	0.6995 *
Model 2			
Type 3	0.9106 *	0.9094 *	0.8394 *
Type 4	0.9195 *	0.9149 *	0.8427 *
Model 3			
Type 3	0.9104 *	0.9105 *	0.8366 *
Type 4	0.9105 *	0.9109 *	0.8412 *
		Graduation Rate, 1998	
Model 1			
Type 3	0.9436 *	0.9425 *	0.9099 *
Type 4	0.9441	0.9423 *	0.9125 *
Model 2			
Type 3	0.9554 *	0.9541 *	0.9460 *
Type 4	0.9560 *	0.9543 *	0.9207 *
Model 3			
Type 3 (1998)	0.9535*	0.9548 *	0.9144 *
Type 4 (1998)	0.9560 *	0.9574 *	0.9202 *

Note: Asterisk (*) indicates significance at the 95 percent confident level.

Table 9 reports the comparison of estimated efficiency in different dimensions. Except the category of city (urban district is defined as when at least half of schools are located in city), all other categories divide 511 school districts into two even parts by ordering from least to best and cutting right in half. We make the dummy variables for all categories, and run OLS regression on those dummy variables in each dimension once a time. Although the efficiency measure is estimated by assuming they are distributed half-normally, truncated normally or exponentially, the OLS estimates are still the best unbiased estimates because our sample size is large enough (511 observations).

We found that urban districts always have lower estimated efficiency. The difference of estimated efficiency between urban districts and non-urban districts are significant, and with the value of 3.65 percent. Besides, the poorer district (no matter measured by per capita income or the percentage of children in poverty) tends to have lower efficiency and the difference of 2.16 percentage points is significant. The adult educational level is also an important factor of efficiency in our model. The districts with higher-educated parents are more efficiency for Mathematics. The difference of estimated efficiency is significantly large, which is 3.18 percentage points. The other factors, which caused significant difference of efficiency, are K-12 enrollment, percentage of children who are black and total expenditure. Larger districts, the districts with higher percentage of black children, and the districts with more total expenditure tend to be more inefficient, and the decreased efficiency is around 1 percentage point.

Table 9: Comparison of Estimated Efficiency (HST Math)

Variable	Estimated Efficiency		Difference (Std. Dev.)
City	Urban	Rural	0.0365**
	0.8506	0.8855	(0.0115)
K-12 Enrollment, 1998	Large	Small	0.0098*
	0.8882	0.8784	(0.0056)
Enrollment Density, 1998	High Density	Low Density	0.0025
	0.8845	0.8820	(0.0056)
Percentage of Children in Poverty	Poor	Rich	0.0216**
	0.8725	0.8941	(0.0055)
Percentage of Children in Black	Black	Non-Black	0.0101*
	0.8782	0.8884	(0.0056)
Percentage of Children in Hispanic	Hispanic	Non-Hispanic	0.0056
	0.8861	0.8805	(0.0056)
Average Schooling Years	High Education	Low Education	0.0318**
	0.8992	0.8673	(0.0054)
Per Capita Income, 1989	Poor	Rich	0.0227**
	0.8719	0.8946	(0.0055)
Pupil-Teacher Ratio, 1998	Large Class	Small Class	0.0034
	0.8850	0.8816	(0.0056)
Total Expenditure, 1998	High Exp.	Low Exp.	0.0103*
	0.8781	0.8885	(0.0056)

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Other than comparing the mean of efficiency measure for each categories, we can also specify the efficiency measure as the function of some explanatory variables. That is, instead of treating efficiency measure as an independent random variable, we doubt it is correlated with some of the explanatory variables. FRONT41 provides this function, and the result is reported in Table 10. In Table 10, we specify city, total expenditure, poverty rate, and K-12 enrollment may explain the efficiency measure, and we found that none of them have significant impact on efficiency measure. Moreover, the coefficients lose their significance when they simultaneously explain both test score and efficiency measure.

Table10: MLE Estimates for Technical Efficiency Models for Math Test

	Model 1	
	Math Score	Efficiency
City	--	0.0432 (0.0520)
Per Capita Income, 1989	-0.2074 (0.2955)	--
Percentage of Children in Poverty, 1989	-0.0712 (0.1436)	0.2841 (0.2572)
Percentage of Children Black, 1989	-0.3540** (0.0602)	--
Percentage of Children Hispanic, 1989	-0.3560** (0.1761)	--
Educational Herf. Index, 1989	-0.1499 (0.2169)	--
Avg. Schooling Years, 1989	8.5617** (0.8745)	--
K-12 Enrollment, 1998	-0.0210** (0.0617)	-0.5284 (0.4998)
Enrollment Density, 1998	-0.0130** (0.0055)	--
Pupil-Teacher Ratio, 1998	-1.0672** (0.2801)	--
Total Expenditure, 1998	-0.9931 (0.8429)	-0.2425 (0.7367)
Average Teacher Salary, 1998	0.6251** (0.1399)	--
Special Educational Expenditure, 1998	-0.8340 (0.9993)	--
Constant	-27.5924** (1.0000)	-0.0595 (1.0076)

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

IV. Conclusion

In our model, we use the stochastic production frontier models to estimate efficiency for public school districts in Michigan. Three different specifications for the efficiency term including the half-normal, truncated-normal, and exponential are used. By estimating the measure of individual efficiency for HST math and science achievement, we find that urban school districts are significantly less efficient than non-urban school districts. Besides, the school districts with higher percentage of children in poverty, higher percentage of children who are black, larger enrollment (large districts), parents who are lower-educated, and larger total expenditure are less efficient.

We also found that the correlation coefficient between the test score and the efficiency measure for HST math result is relatively high, however, it is not so high between the test score and some of the efficiency measures for HST science result. According to the test score, Detroit is pretty inefficient in both math and science, with rank of 6 to 10. Nevertheless, according to the measure of efficiency, although Detroit is relatively inefficient in the production of schooling, especially for HST science result, it is not the worst one. Moreover, the average measure of efficiency of Detroit is roughly twice as large as the least efficient one.

In the face of the evidence presented in this paper, it seems inappropriate to single out the school district of Detroit for special institutional reform. If special institutional reforms are applied to any district they should be applied to those districts who have the lower score in our measure of efficiency.

APPENDICES

Appendix A: Public School Districts with Missing Data

Table A: Public School Districts with Missing Data

Public School District Name	Relative District Size[51]	Public School District Name	Relative District Size[28]
Autrain-Onota Public Schools	0.0149	Bloomfield Twp S D 7f	0.0075
Burt Township School Dist	0.0236	Colfax Twp Sch Dist 1f	0.0047
Saugatuck Public Schools	0.2153	Sigel Twp School District 3	0.0062
Ganges School District No.4	0.0081	Sigel Twp School District 4	0.0062
Arvon Township School Dist	0.0084	Sigel Twp School District 6	0.0050
Hagar Township School Dist 6	0.0168	Verona Twp Sch Dist No 1f	0.0068
Sodus Twp Sch Dist 5	0.0245	Stockbridge Comm Schools	0.5577
Mar Lee School District	0.0811	Palo Comm School District	0.0612
Beaver Island Comm Schools	0.0283	Berlin Twp School District 3	0.0056
Whitefish Schools	0.0286	Easton Twp School District 6	0.0099
Crawford Ausable Schools	0.7046	Ionia Twp School District 2	0.0093
Breitung Twp School District	0.6940	Excelsior District #1	0.0115
Maple Valley School District	0.5052	Grant Township Schools	0.0031
Oneida Twp School District 3	0.0059	Bois Blanc Pines Sch Dist	0.0016
Loucks School-Roxand #12 S/D	0.0025	Moran Township School Dist	0.0401
Littlefield Public Sch Dist	0.1491	Powell Township School Dist	0.0245
Genesee School District	0.3014	Wells Township School Dist.	0.0143
Wakefield Twp School Dist	0.1106	Holton Public Schools	0.3936
Litchfield Community Schools	0.2038	Pineview School District	NA[52]
Elm River Twp School Dist	0.0056	Big Jackson School District	0.0118
Stanton Twp School District	0.0572	Ferry Community School Dist	NA[29]
Church School District	0.0075	Nottawa Community School	0.0522
Bloomfield #1 School District	0.0000	Bangor Twp School District 8	0.0065

[51] Numbers are reported as K-12 enrollment in 1998 of each district divided by average K-12 enrollment in 1998.

[52] Missing Data.

Appendix B: MLE Estimates for Different Models for Math Test

Table B: MLE Estimates for Different Models for Math Test

Observation: 511 public school districts in Michigan

Output Variable: Math Grade 11 High School Test, 1999

	Model 1	Model 2	Model 3
Per Capita Income, 1989	-0.1613 (0.3816)	-0.2564 (0.3970)	-0.2760 (0.4015)
Percentage of Children in Poverty, 1989	-0.1951 (0.0937) **	-0.3419 (0.0933) **	-0.2534 (0.0967) **
Percentage of Children in Black, 1989	-0.3334 (0.0485) **	-- --	-- --
Percentage of Children in Hispanic, 1989	-0.3618 (0.1678) **	-- --	-- --
Racial Herf. Index, 1989	-- --	0.1911 (0.0516) **	0.1970 (0.0515) **
Educational Herf. Index, 1989	-0.2206 (0.2561)	-0.1629 (0.2585)	-0.1667 (0.2578)
Avg. Schooling Years, 1989	8.2446 (1.7712) **	8.3192 (1.8434) **	8.9857 (1.9701) **
K-12 Enrollment, 1998	0.0514 (0.1832)	-0.0305 (0.2654)	0.0047 (0.2499)
Enrollment Density, 1998	-0.0116 (0.0067) *	-0.0154 (0.0060) **	-0.0176 (0.0059) **
Pupil-Teacher Ratio, 1998	-1.0593 (0.3296) **	-1.4308 (0.3457) **	-10.0091 (2.2744) **
Pupil-Teacher ratio (Square), 1998	-- --	-- --	0.1967 (0.0508) **
Total Expenditure, 1998	-0.9703 (0.7824)	-1.5360 (0.9631)	-3.4421 (4.6889)
Total Expenditure (Square), 1998	-- --	-- --	0.0018 (0.3255)
Average Teacher Salary, 1998	0.6469 (0.1318) **	0.7695 (0.1330) **	4.9325 (1.1341) **
Average Teacher Salary (Square), 1998	-- --	-- --	-0.0430 (0.0122) **
Special Educational Expenditure, 1998	-1.0690 (3.5811)	-0.4224 (3.5664)	1.8380 (10.6519)
Special Educational Expenditure (Square), 1998	-- --	-- --	-1.4590 (10.6194)
Constant	-22.2901 (25.7425)	-34.2018 (27.4516)	-40.6176 (41.2992)

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Appendix C: 20 Most Efficient Public School Districts

Table C.1: 20 Most Efficient Public School Districts for Math

School District Name	Avg. Efficiency[53]	Relative District Size[54]	Percent of Schl. In City	Relative Math Test Score[55]
Osceola Twp School District	0.9458	0.0935	0.00	1.2843
Croswell Lexington Comm Sd	0.9485	0.7876	0.00	1.1286
Holland City School District	0.9488	1.7634	0.00	1.2522
New Lothrop Area Public Sd	0.9502	0.2666	0.00	1.2667
Cadillac Area Public Schools	0.9502	1.2188	0.00	1.2442
Pickford Public Schools	0.9509	0.1563	0.00	1.4721
Brown City Comm School Dist	0.9518	0.3492	0.00	1.3228
Fowler Public Schools	0.9520	0.1553	0.00	1.3277
Alba Public Schools	0.9532	0.0584	0.00	1.1238
Ludington Area School Dist	0.9537	0.8572	0.00	1.4208
Rapid River Public Schools	0.9539	0.1637	0.00	1.2667
Charlevoix Public Schools	0.9542	0.4182	0.00	1.4095
Public Schools Of Calumet	0.9544	0.5412	0.00	1.3100
Dowagiac Union Schools	0.9544	0.9550	0.00	1.2795
Hamilton Community Schools	0.9545	0.6894	0.00	1.4079
Onekama Consolidated Schools	0.9546	0.1612	0.00	1.2618
N.I.C.E. Community Schools	0.9555	0.4384	0.00	1.4593
Saranac Community Schools	0.9575	0.3821	0.00	1.3453
Peck Community School Dist	0.9597	0.1793	0.00	1.4111
Zeeland Public Schools	0.9608	1.3160	0.00	1.3373

[53] The mean of average efficiency for graduation rate is 0.9001, and with 10% percentile of 0.8099, 25% percentile of 0.8627.

[54] Numbers are reported as K-12 enrollment in 1998 of each district divided by average K-12 enrollment in 1998.

[55] Numbers are reported as HST Math test score in 1998 of each district divided by average HST Math test score in 1998.

Table C.2: 20 Most Efficient Public School Districts for Science

School District Name	Avg. Efficiency[56]	Relative District Size[57]	Percent of Schl. In City	Relative Science Test Score[58]
Wyoming Public Schools	0.9439	1.7637	0.00	1.3836
Kaleva Norman Dickson Schs	0.9440	0.2874	0.00	1.3463
North Central Area Schools	0.9445	0.1855	0.00	1.3855
White Pine School District	0.9447	0.0510	0.00	1.4657
Rapid River Public Schools	0.9470	0.1637	0.00	1.4507
Gladwin Community Schools	0.9473	0.6633	0.00	1.3985
Saranac Community Schools	0.9477	0.3821	0.00	1.4433
Mid Peninsula School Dist.	0.9489	0.1109	0.00	1.4433
Brown City Comm School Dist	0.9490	0.3492	0.00	1.4153
Caseville Public Schools	0.9492	0.0935	0.00	1.4918
Charlevoix Public Schools	0.9496	0.4182	0.00	1.5570
Pentwater Public School Dist	0.9501	0.1156	0.00	1.5104
Public Schools Of Calumet	0.9509	0.5412	0.00	1.4582
Watersmeet Twp School Dist	0.9510	0.0596	0.00	1.5533
Mio Au Sable Schools	0.9513	0.2936	0.00	1.4414
Marlette Community Schools	0.9550	0.4499	0.00	1.5197
Onekama Consolidated Schools	0.9551	0.1612	0.00	1.5981
Pickford Public Schools	0.9581	0.1563	0.00	1.5533
Freeland Comm School Dist	0.9592	0.4595	0.00	1.6279
Bark River Harris Sch Dist	0.9600	0.1796	0.00	1.6447

[56] The mean of average efficiency for science test is 0.8771, and with 10% percentile of 0.7462, 25% percentile of 0.8292.

[57] Numbers are reported as K-12 enrollment in 1998 of each district divided by average K-12 enrollment in 1998.

[58] Numbers are reported as HST Science test score in 1998 of each district divided by average HST Science test score in 1998.

Table C.3: 20 Most Efficient Public School Districts for Graduation Rate

School District Name	Avg. Efficiency[59]	Relative District Size[60]	Percent of Schl. In City	Relative Graduation Rate[61]
Grant Public School District	0.9763	0.7652	0.00	1.1409
Suttons Bay Public Sch Dist	0.9765	0.3330	0.00	1.1717
Glen Lake Community Sch Dist	0.9766	0.2805	0.00	1.1860
Bear Lake School District	0.9770	0.1025	0.00	1.1860
North Central Area Schools	0.9771	0.1855	0.00	1.1860
Posen Cons School District	0.9773	0.1202	0.00	1.1860
Coloma Community Schools	0.9775	0.7298	0.00	1.1634
Climax Scotts Comm Schools	0.9776	0.2203	0.00	1.1860
Atlanta Community Schools	0.9779	0.1789	0.00	1.1611
Beal City School	0.9780	0.1839	0.00	1.1860
Chippewa Valley Schools	0.9781	3.3537	0.00	1.1622
Pellston Public School Dist	0.9783	0.2308	0.00	1.1860
Sandusky Comm School Dist	0.9786	0.4579	0.00	1.1860
Adams Twp School District	0.9787	0.1656	0.00	1.1860
Godfrey Lee Public Sch Dist	0.9790	0.3871	0.00	1.1373
Akron Fairgrove Schools	0.9800	0.1553	0.00	1.1860
Vanderbilt Area School	0.9801	0.1031	0.00	1.1860
Caro Community Schools	0.9802	0.7456	0.00	1.1765
Westwood Heights Sch Dist	0.9852	0.3725	100.00	1.1717
Walkerville Rural Comm Sd	0.9857	0.1274	0.00	1.1860

[59] The mean of average efficiency for graduation rate is 0.9135, and with 10% percentile of 0.7965, 25% percentile of 0.8555.

[60] Numbers are reported as K-12 enrollment in 1998 of each district divided by average K-12 enrollment in 1998.

[61] Numbers are reported as graduation rate in 1998 of each district divided by average graduation rate in 1998.

Appendix D: Counts for Appearing in the 20 Least Public School Districts

Table D: Counts for Appearing in the 20 Least Public School Districts

School District Name	Counts of Appearing in the 20 Least Efficient Public School Districts for Math Test					
	Math	(efficiency rank)[62]	Science	(efficiency rank)	Grad. rate	(efficiency rank)
Addison Comm Schools	8	(147, 18, 67.51)	0	(241, 214, 228.44)	0	(277, 253, 265.70)
Akron Fairgrove Schools	0	(431, 82, 287.58)	18	(16, 10, 13.17)	0	(509, 503, 507.30)
Alcona Community Schools	0	(368, 241, 299.91)	0	(475, 443, 456.33)	27	(17, 13, 14.96)
Arenac Eastern School Dist	36	(23, 5, 13.80)	0	(173, 145, 158.50)	0	(146, 129, 138.33)
Ashley Community Schools	9	(147, 12, 62.67)	0	(278, 232, 258.94)	0	(203, 172, 188.04)
Atlanta Community Schools	0	(111, 24, 64.24)	5	(25, 17, 21.78)	0	(505, 493, 499.07)
Bad Axe Public Schools	13	(304, 17, 177.13)	0	(168, 142, 156.56)	0	(344, 318, 334.26)
Baldwin Comm Schools	40	(25, 9, 14.44)	0	(46, 21, 29.44)	0	(401, 329, 363.52)
Beecher Comm Sch Dist.	19	(112, 10, 41.18)	0	(129, 74, 85.56)	0	(150, 71, 113.78)
Bellevue Comm Sch Dist	0	(461, 131, 279.29)	0	(431, 400, 419.83)	27	(18, 16, 16.78)
Benton Harbor Area Schools	45	(13, 4, 6.84)	17	(21, 11, 13.78)	0	(116, 44, 69.44)
Britton Macon Area Sd	18	(73, 8, 37.69)	0	(115, 83, 98.00)	0	(345, 305, 323.89)
Buckley Comm Sch Dist.	4	(507, 16, 217.07)	0	(251, 202, 227.50)	0	(267, 217, 236.30)
Buena Vista School Dist.	42	(25, 2, 8.84)	18	(18, 8, 10.83)	0	(371, 154, 236.44)
Burr Oak Comm Sch Dist	45	(8, 2, 3.82)	18	(4, 1, 1.61)	0	(40, 26, 33.26)
Capac Comm Sch District	18	(263, 16, 154.11)	0	(56, 45, 50.06)	0	(312, 291, 300.70)
Carrollton School District	16	(185, 15, 72.38)	0	(177, 116, 151.50)	0	(415, 378, 398.56)
Muskegon Heights Sd	45	(12, 2, 4.91)	18	(7, 1, 3.56)	0	(265, 86, 147.70)
Coleman Community Sd	18	(294, 10, 169.51)	0	(64, 52, 58.06)	0	(268, 249, 256.85)
Coloma Community Schools	0	(348, 172, 249.96)	18	(9, 3, 7.00)	0	(508, 487, 497.37)
Colon Comm School Dist	0	(393, 126, 286.33)	3	(25, 19, 22.11)	27	(4, 4, 4.00)
Dearborn City School Dist	0	(223, 27, 128.98)	15	(23, 14, 19.17)	0	(336, 249, 293.63)
Dearborn Hgts Sd No. 7	18	(126, 4, 56.33)	0	(30, 21, 25.17)	0	(229, 171, 190.63)
Deerfield Public Schools	18	(176, 2, 67.13)	0	(60, 27, 44.50)	0	(164, 111, 141.59)
Detroit City School District	1	(56, 16, 41.42)	17	(21, 14, 16.33)	0	(380, 277, 343.74)
Eau Claire Public Schools	17	(150, 13, 56.04)	0	(163, 85, 109.39)	27	(7, 5, 5.85)
Ecorse Public School Dist	27	(62, 5, 24.53)	0	(147, 103, 117.39)	27	(8, 5, 6.15)
Engadine Consolidated Schs	45	(2, 1, 1.62)	18	(3, 1, 1.83)	0	(279, 193, 222.37)

Table D (cont'd)

School District Name	Counts of Appearing in the 20 Least Efficient Public School Districts for Math Test					
	Math (efficiency rank)		Science (efficiency rank)		Grad. rate (efficiency rank)	
Fairview Area Sd.	9	(88, 14, 44.33)	1	(28, 20, 24.78)	0	(436, 396, 413.93)
Fennville Public Sch	0	(464, 45, 193.51)	0	(68, 24, 42.72)	27	(12, 10, 10.70)
Fulton Schools	45	(12, 3, 8.49)	18	(14, 8, 10.78)	0	(472, 454, 463.67)
Galien Twp Sd	0	(307, 54, 188.04)	0	(162, 108, 134.61)	27	(3, 3, 3.00)
Godfrey Lee Public Sch Dist	0	(400, 174, 271.76)	18	(6, 3, 4.83)	0	(508, 495, 503.41)
Grand Haven City Sd	0	(443, 410, 424.53)	0	(319, 306, 312.67)	27	(16, 14, 14.67)
Hale Area Schools	0	(63, 38, 51.04)	0	(196, 153, 176.28)	27	(15, 12, 13.26)
Hamtramck Public Schools	0	(300, 65, 180.38)	0	(64, 49, 57.89)	5	(35, 16, 22.56)
Hanover Horton Schools	6	(76, 16, 41.47)	0	(139, 96, 118.00)	0	(268, 232, 249.85)
Highland Park City Schools	45	(20, 1, 8.58)	13	(511, 1, 147.72)	0	(226, 41, 102.37)
Huron School District	0	(260, 49, 131.78)	0	(172, 135, 151.17)	26	(21, 18, 18.67)
Inkster City School District	12	(201, 10, 69.76)	18	(6, 4, 4.28)	27	(2, 2, 2.00)
Jackson Public Schools	0	(241, 133, 177.07)	0	(178, 138, 159.28)	27	(9, 7, 8.41)
Kingsley Area School	0	(424, 165, 279.91)	18	(18, 13, 16.67)	0	(361, 337, 350.52)
Lakeville Comm School Dist	0	(311, 116, 225.11)	0	(182, 147, 166.94)	27	(13, 9, 11.48)
Lansing Public School Dist	0	(176, 87, 127.36)	0	(82, 42, 64.72)	27	(1, 1, 1.00)
Lincoln Park Public Schools	8	(84, 15, 38.64)	0	(69, 47, 57.33)	0	(82, 54, 63.00)
Mackinac Island Pub Sch	3	(511, 17, 315.47)	0	(79, 27, 48.78)	0	(233, 138, 174.59)
Mancelona Public Schools	0	(101, 54, 71.56)	0	(146, 130, 135.22)	27	(7, 5, 6.04)
Marenisco School District	0	(447, 165, 313.29)	18	(9, 3, 6.39)	0	(227, 159, 189.30)
Mason Cons School District	0	(99, 22, 58.44)	18	(17, 12, 14.83)	0	(47, 41, 43.56)
Memphis Comm Schools	27	(346, 4, 126.84)	0	(346, 285, 314.00)	0	(228, 199, 212.33)
Mendon Comm Sch Dist	11	(43, 17, 28.29)	0	(183, 139, 164.11)	0	(32, 24, 29.19)
Morenci Area Schools	1	(46, 20, 33.62)	0	(90, 76, 83.83)	0	(104, 94, 98.59)
Oak Park City School Dist	23	(70, 12, 24.71)	15	(29, 13, 17.94)	0	(491, 397, 444.41)
Onaway Area Comm Sd	0	(447, 176, 309.02)	0	(276, 198, 235.28)	27	(17, 13, 15.41)
Onsted Community Schools	18	(411, 13, 230.62)	0	(76, 54, 66.33)	0	(240, 210, 225.56)
Pellston Public School Dist	3	(342, 17, 147.56)	0	(453, 441, 446.61)	0	(508, 495, 501.59)
Pontiac City School District	12	(48, 14, 26.07)	0	(60, 34, 47.28)	0	(51, 36, 41.44)

[62] The first number in parenthesis represents maximum rank, the second one represents minimum rank, and the last one represents average rank.

Table D (cont'd)

School District Name	**Counts of Appearing in the 20 Least Efficient Public School Districts for Math Test**					
	Math (efficiency rank)		**Science** (efficiency rank)		**Grad. rate** (efficiency rank)	
River Rouge City Schools	22	(35, 7, 18.87)	0	(45, 26, 33.22)	27	(10, 8, 8.59)
River Valley School District	22	(192, 11, 76.44)	0	(338, 272, 303.22)	27	(12, 10, 10.85)
Saranac Community Schools	0	(506, 490, 500.60)	0	(501, 496, 497.94)	25	(21, 18, 18.93)
South Haven Public Schools	0	(331, 42, 195.40)	0	(133, 101, 119.39)	20	(22, 19, 20.15)
Southfield Public Sch Dist	5	(104, 13, 49.20)	5	(33, 17, 23.94)	0	(339, 266, 300.67)
Springport Public Schools	18	(179, 7, 103.22)	1	(29, 20, 25.78)	0	(33, 26, 29.78)
Tahquamenon Area Schools	0	(129, 67, 102.18)	16	(23, 13, 18.39)	0	(123, 87, 108.85)
Vanderbilt Area School	26	(72, 10, 34.67)	0	(104, 82, 91.50)	0	(509, 505, 507.44)
Waldron Area Schools	27	(79, 1, 26.13)	0	(89, 64, 73.50)	0	(143, 122, 129.70)
Warren Woods Public Schs	7	(118, 18, 61.89)	0	(69, 60, 66.06)	0	(486, 460, 473.04)
Webberville Comm Schs	18	(383, 14, 230.16)	18	(13, 7, 10.44)	5	(22, 20, 21.33)
Westwood Community Schs	20	(74, 14, 29.02)	0	(46, 23, 30.94)	0	(498, 472, 483.59)
Willow Run Comm Schs	0	(113, 25, 67.33)	18	(12, 8, 9.50)	0	(214, 170, 198.48)

REFERENCES

REFERENCES

Aigner, D., K. Lovell, and P. Schmidt, (1977) "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, 6, pp. 21-37.

Bauer, Paul W., (1990) "Recent Developments in the Econometric Estimation of Frontiers", *Journal of Econometrics*, 46, pp. 39-56.

Bowlin, W. F., (1987) "Evaluating the Efficiency of U.S. Air Force Real-Property Maintenance Activities", *Journal of the Operational Research Society*, 38(2), pp. 127-135.

Cavin, E. S., and F. P. Stafford, (1985) "Efficient Provision of Employment Service Outputs: A Production Function Analysis", *Journal of Humna resources*, 20, pp. 484-503.

Charnes, A., C. T. Clark, W. W. Cooper, and B. Golany, (1985) "A Development Study of Data Envelopment Analysis in Measuring the Efficiency of Maintenance Units in the U.S. Air Forces", *Annals of Operations Research*, 2, pp. 95-112.

Cobb, S. and P. Douglas, (1928) "A Theory of Production", *American Economic Review*, 18, pp. 139-165.

Coelli, Tim, (1996) "A Guide to Frontier Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation", *Center for Efficiency and Productivity Analysis* Working Paper.

Debreu, G. (1951) "The Coefficient of Resource Utilization", *Econometrica*, 19(3), pp. 273-292.

Farrell, M. J., (1957) "The Measurement of Productive Efficiency", *Journal of the Royal Statistical Society* Series A, General, 120(3), pp. 253-281.

Fox, B. J., and L. L. Taylor, (1991) "Grading Texas Schools", *The Southwest Economy*, Federal Reserve Bank of Dallas, pp. 1-5.

Greene, William H., (1980) "Maximum Likelihood Estimation of Econometric Frontier Functions", *Journal of Econometrics* 13(1), pp. 27-56.

Greene, William H., (1993) "The Econometric Approach to Efficiency Analysis", in *The Measurement of Productive Efficiency*, pp. 68-119.

Greene, William H., (1998) "Limdep, Version 7.0, User's Manual", *Econometric Software, Inc.*

Grosskopf, S., K. Hayes, L. Taylor, and W. Weber, "Teacher Salaries and Teacher Productivity", *Paper Presented at Western Economic Association Meetings.*

Hanushek, E., (1986) "The Economics of Schooling: Production and Efficiency in Public Schools", *The Journal of Economic Literature*, 24, pp. 1141-1177.

Huang, L. Y-G, and C. P. McLaughlin, (1989) "Relative Efficiency in Rural Primary Health Care: An Application of Data Envelopment Analysis", *Health Services Research*, 24(2), pp. 143-158.

Johnson, S. C., and K. Lahiri, (1992) "A Panel Data Analysis of Productive Efficiency in Freestanding Health Clinics", *Empirical Economics*, 17(1), pp. 141-151.

Jondrow, J., K. Lovell, I. Materov, and P. Schmidt, (1982) "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model", *Journal of Econometrics*, 19, pp. 233-238.

Koopmans, T. C., (1951) "An Analysis of Production as an Efficient Combination of Activities", in T. C. Koopmans, ed., *Activity Analysis of Production and Allocation*, Cowles Commission for Research in Economics, Monograph No. 13, New York: John Wiley and Sons, Inc.

Lovell, C.A. Knox, (1993) "Production Frontiers and Productive Efficiency", *The Measurement of Productive Efficiency*, pp. 1-67.

McCarty, T.A., and S. Yaisawarng, (1990) "A strategy for Effective School Finance Reform", Working Paper, Department of Economics, Union College, Schenctady, N. Y.

McCarty, T.A., and S. Yaisawarng, (1993) "Technical Efficiency in New Jersey School Districts", in *The Measurement of Productive Efficiency*, pp. 271-287

Meeusen, W., and J. van den Broeck, (1977) "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error", *International Economic Review*, 18, pp. 435-444.

Ray, S. C., (1991) "Resource-Use Efficiency in Public Schools: A Study of Connecticut Data", *Management Science*, 37(12), pp. 1620-1628.

Rhodes, E. L., (1986) "An Exploratory Analysis of Variations in Performance among U.S. National Parks", in R. H. Silkman, Ed., *Measuring Efficiency: An Assessment of Data Envelopment Analysis*. San Francisco: Jossey-Bass, pp. 47-71.

Richmond, J., (1974) "Estimating the Efficiency of Production", *International Economic Review*, 15(2), pp. 515-521.

Stevenson, R. E., (1980) "Likelihood Functions for Generalized Stochastic Frontier Estimation", *Journal of Econometrics* 13(1), pp. 58-66.

Winsten, C. B., (1957) "Discussion on Mr. Farrell's Paper", *Journal of the Royal Statistical Society* Series A, General, 120(3), pp. 282-284.

Weinstein, M., (1964) "The Sum of Values from a Normal and a Truncated Normal Distribution", *Technometrics*, 6, pp. 104-105, 469-470.

Wyckoff, J. H., and J. Lavigne, (1991) "The Technical Inefficiency of Public Elementary Schools in New York", Working Paper, Graduate School of Public Affairs, The State University of New York, Albany, N. Y.

CHAPTER 3

MIGRATION AND ECONOMIC GROWTH

I. Introduction

The study of internal migration in the United States has been a long and respectable tradition in the field of regional development, economic growth, and labor mobility. Early studies investigated the relationship between migration and the output level or the rate of economic growth, while recent studies emphasized more the impact of migration on the speed of convergence of economic growth between different areas.

There is substantial evidence that internal migration does speed up the convergence of economic growth between different areas. Barro and Sala-i-Martin (1992) include migration in a modified neoclassical growth model to make endogenous migration as a source of linkage between population growth and the log of per capita income. The estimated parameter of convergence speed is much higher in the model with migration than the model without migration (about 30~50% higher). Persson (1994) also found that migration has a positive though small effect on the speed of convergence in per capita income across the twenty-four Swedish counties from 1906 to 1990.

If internal migration improves the convergence across different economies, it implies in-migration will lower the speed of growth in the rich area, and speed up the growth in the poor area. Out-migration has opposite effects. However, what we want to know is how will migration affect income growth when we control for the level of income.

The simple Solow model merits that the capital stock in steady state is determined by the intersection of break-even investment $(n+g+\delta)\,k$ and the actual investment $s\,f(k)$. Other things equal, the higher the growth rate of population n, the lower the level of capital stock in steady state is. Since output is an increasing function of capital stock, therefore, the level of output in steady state will be lower too. To be one of the positive components of population, net migration might have a negative relationship with the output level in steady state. However, there are many early empirical studies finding a positive relationship between the net migration and the level of per capita income. Okun (1968) found that internal population migration tends to increase the rate of economic growth of a country. Olvey (1972) also found that the in-migration responds to both employment growth and wage levels. Greenwood (1976) provided evidence that white and nonwhite migrants have different performance, while the former is more responsive to the growth of job opportunities, and the latter is more responsive to high income levels and income growth.

To explore the possible reason that explains the positive impact of migration on the economic growth, we consider that the migrants may have different characteristics between different groups, such as between white people and nonwhite people. There may exist self-selection behavior that people who carry more human or physical capital are more likely to move to find a better environment. Our data also support this possible reason. About 80 to 90 percent of migration flows is constituted by white native population in most of states.

The other issue we are concerned with is that the net migration and the level of per capita income may have a circular relationship. That is, the observed positive relationship between the net migration and the level of per capita income may come from the attractions of higher income level for the migrants, but not vice versa. To explore this simultaneous relationship, a simultaneous-equations model should be adopted, such as Greenwood (1976), Greenwood (1978), Olvey (1972), and Okun (1968).

In this paper, we will use a recently developed econometric approach "Dynamic Panel Data Model" to estimate the GMM coefficients for the relationship between migration and growth. In Section II, we review some previous studies in the migration model, and empirical studies of the migration and economic growth issues. Section III introduced the methodology of dynamic panel data we used in our analysis. Section IV describe the specification of our model, the data set used in our model is also summarized as well. Section V reports the regression result, and Section VI concludes.

II. Literature Review

Most of the early studies on the migration and economic growth use the cross-sectional data model. Okun (1968), Olvey (1972), and Greenwood (1976) employed a simultaneous equation approach for their estimation since they believed there are causality relationships between migration and economic growth. The econometric methodology of two-stage least squares or three-stage least squares was applied to estimate the system of simultaneous equation. In addition, they all used the data for the United State.

Okun (1968) focused mainly the effect of interstate migration on the inequality of per capita income for 1940 to 1950 among the states in the United States. He claimed that at that time labor was generally in short supply as a result of the World War II and its after-effects, therefore, an inflow of migration may be relatively more beneficial to the receiving region than in a more normal time period.

Two of the endogenous variables in Okun's model are net migration rate and the change of per capita service income[63]. In addition to the change of per capita income, the explanatory variables for net migration rate include the level of per capita service income, the change of agricultural employment, and the fertility rate. Turning to the growth equation, the level of per capita service income, racial composition of migration streams, and age-sex composition in migration as well as the net migration are used as the explanatory variables, in which the net migration and age-sex composition in migration are endogenous. Age-sex composition in migration relative to that in total population is the third endogenous variables in Okun's model which is determined by the fertility rate and net migration in definition.

Okun found that the states with relatively high service incomes per capita tend to attract migrants. However, the decline of agriculture share in the labor force causes out-migration to increase, which is in conflict with the fact that the net migration and change of agricultural employment have positive correlation with each other in the data set. Okun suggested this maybe because those factors affecting net migration of labor between the state's farm sector and other states are of more considerable importance than those factors affecting net migration of labor between the state's nonfarm sector and other states during the 1940's. This will contribute to a net positive correlation between

[63] Note that Okun defines service income per capita as total income per capita minus property income per capita.

the net migration and the change of the agricultural employment. He also found a significant but negative effect of migration on the growth of service income per capita. Okun tried to explain this striking result by examining the correlation coefficient between the level of per capita service income and its growth rate. Because they are so strongly positively correlated, Okun suggested that migrants necessarily moved in the direction of states with both high level of income and growth rate and it is difficult to separate these two effects. He concluded that it was the high level but not the large increase in service income per capita, which attracted migrants to the receiving states since the coefficient for the level of per capita service income is significantly positive.

Turning to Okun's growth equation, he found that high levels of service income per capita tended to contribute to large increases in service income per capita. Besides, the positive net migration also tended to contribute positively to the absolute growth in service income per capita.

Okun's finding concerning the income level and the growth rate is not consistent with the literature on the convergence of economic growth. However, he did find that net migration and income level or income growth and net migration have positive and significant relationship.

Unlike Okun's use of the state as the unit of observations, Olvey (1972) did related empirical work using data for the 56 largest Standard Metropolitan Statistical Areas (SMSA's) in the United States for the period of 1955 to 1960. He defined economic growth as employment growth, and also claimed that the employment growth and migration involve a circular relationship. In his multi-equation model, he specified two employment growth equations in manufacturing and service sectors, three migration equations for in-migration from contiguous states, long distance in-migration, and out-migration, as well as three identities for prospective unemployment[64], net population growth, and growth of total employment. Besides, he used population growth without migration, industrial composition index (employment demand side), metropolitan wage, income level, and climate (employment supply side) to be exogenous variables.

Most of his regression coefficients had expected and significant signs. He found that manufacturing employment growth is deterred by high wage levels and stimulated by net population growth and a mild climate. Service employment growth is closely related to manufacturing employment growth and to population growth and income levels. In-migration responds to both employment growth and wage levels. Short distance or contiguous in-migration is significantly higher for metropolitan areas located in low-income regions. Long distance in-migration is responsive to a mild climate as well. His findings did support the apparent strength of the connection between regional employment growth and migration pattern. Besides, one of the most striking results in Olvey's model is that the responsiveness of out-migration to prospective unemployment is positive and significant. Thus out-migration seems to be explained largely in terms of push factors on the wage and employment condition at the origin.

Greenwood (1976) utilized race specific data relating to the 100 largest Standard Metropolitan Statistical Areas (SMSA's) in the United States for the 1950s and developed a simultaneous-equations model of migration and urban change for white and

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[64] Ovley defined the prospective unemployment as the total increase in population less the increase in employment, assuming zero out-migration.

nonwhite civilian labor force members. In his model, he believed income, employment and unemployment are important determinants of the direction and magnitude for migration. Hence he constructed a larger system of equations than Okun's and Ovley's and included 12 endogenous variables (out-migrants, in-migrants, employment change, unemployment change, income change, and natural population change, each for whites and nonwhites) in his model. The most interesting finding in his regression results is that no endogenous variables in the out-migration equations are significant, that is, there are no important relationships between the change of income, employment, unemployment and the migration. On the contrary, in the in-migration equation, the regressions results show that the growth of income and employment has positive and significant effect on nonwhite in-migration, while the growth of income is positive and significant related with white in-migration and the growth of unemployment discourages white in-migration.

There is also some evidence for the significant relationship between migration and economic growth from the countries other than the United States. Greenwood (1978) estimated a simultaneous-equations model of internal migration and regional economic growth in Mexico for 32 states for the period of 1960 to 1970. By using ordinary least square, two-stage least squares and three-stage least squares, he estimated a system of 10 equations, which contains migration equations, labor force equations and earnings and earnings concentration equations. Eight endogenous variables, in-migration, out-migration, the rate of employment growth in agricultural, manufacturing, and other sectors, the rate of change of unemployment, the rate of change of earnings, and earnings concentration, are included in his model.

Greenwood used both of the growth of employment and earnings to proxy the concept of economic growth. He found that internal migrants in Mexico are quite responsive to employment opportunities. More job opportunities (employment growth) attract more migrants. However, the regression result showed the effect of unemployment rate and its growth rate on migration is positive and significant, which is counterintuitive. For the employment growth equation, in-migration is helpful for the employment growth, while out-migration discouraged the employment in most of sectors. In the earnings growth equations, in-migration has positive and significant effect on earnings growth, which implies labor demand shift derived from in-migration dominates the labor supply shift (in-migration has downward pressure for wage).

III. Methodology of the Estimation

3.1 Dynamic Panel Data Model

Recently, the panel data model has become influential in growth estimation, compared to cross-sectional estimation in most of earlier literatures. Hsiao (1986) claimed the major advantage of using panel data is that it provides a larger information set than conventional cross-section data or time-series data, increasing the degree of freedom, hence improving the efficiency of econometric estimates. We believe a number of unobservable individual-specific, time-invariant fixed effects, which are responsible for individual income level in steady state exist in our model. Panel data estimation suggests that in the presence of those fixed effects, the cross-sectional error term ν_{it} can be decomposed into two terms u_{it} and $\eta_{i,}$ where η_i is unobserved state-specific fixed factors that we mentioned above, and u_{it} is usual error term. We assume u_{it} to be independently normally distributed across individuals with zero mean.

The general model to be estimated in this essay is of the following form:

$$y_{it} = \sum_{k=1}^{p} \alpha_k y_{i(t-k)} + \beta'(L)\, x_{it} + \lambda_t + \eta_i + u_{it}\,,\ t = q+1, \ldots, T_i\ ;\ i = 1, \ldots, N, \quad (3.1)$$

where y_{it} is dependent variable, that is, log of per capita income in the growth equation and net migration rate in the migration equation. We think that the growth rate in the current period may be partly determined by its value in last period, and net migration rate may be also closely correlated with its previous level because the area with more migrants may attract more people moving in than other areas. Therefore, the dependent variable should be auto-regressive of some order. We include the lags of dependent variable in the right hand side of the structural equation. Since this kind of models capture the dynamic property, it is also referred as "dynamic panel data model".

Here $\boldsymbol{x}_{it}$ is a vector of explanatory variables except the lags of dependent variables, which may or may not correlated with the error term, $\beta(L)$ is a vector of associated polynomials in the lag operator, q is the maximum lag length in the model, and λ_t is time specific effect that could capture the random shocks maybe present in a particular period. The variable T_i is the number of time periods available on the ith individual, which is small and the number of individuals N is large. In our model, the maximum value of T_i is 7 (decennial data from 1930 to 1990), and N equals 48[65].

[65] This includes 48 states in the United States. We exclude Hawaii, Alaska, and Washington D.C. because they are very different from other states.

We can also write the general form of our model in the following form;

$$y_{it} = W_{it}\delta + v_{it}, \tag{3.2}$$

where W_{it} is a data matrix containing the time series of the lagged dependent variables, the x's and the time dummies. The error term is $v_{it} = \eta_i + u_{it}$, which is the sum of individual effect and usual error term.

3.2 Endogeneity Problem

Since η_i is unobservable and constant over time, even W_{it} only contains the exogenous explanatory variables, $E(W_{it}v_{it})$ will not be zero. Therefore, OLS estimates will not be consistent. In order to remove the individual fixed effect, there are several transformation methods available. One of them is the fixed effect transformation:

$$y_{it} - \bar{y}_i = (W_{it} - \overline{W}_{it})\delta + (\eta_i - \eta_i) + (u_{it} - \bar{u}_i) = (W_{it} - \overline{W}_{it})\delta + (u_{it} - \bar{u}_i)$$

where $\bar{y}_i$ is average value of y_{it} across time. It is the same for $\overline{W}_i$ and $\bar{u}_i$.

However, the fixed-effects transformation is not well suited because the errors after the fixed-effect transformation are $u_{it} - \bar{u}_i$ and $\bar{u}_i$ is correlated with all W_{it}. Instead of the fixed effect transformation, first differencing is preferred. After first differencing, the equation becomes:

$$y_{it} - y_{i,t-1} = (W_{it} - W_{i,t-1})\delta + (u_{it} - u_{i,t-1}) \Rightarrow \Delta y_{it} = \Delta W_{it}\delta + \Delta u_{it}.$$

Then we have

$$E(\Delta W'_{it}\Delta u_{it}) = E(W'_{it}u_{it}) + E(W'_{i,t-1}u_{i,t-1}) - E(W'_{i,t-1}u_{it}) - E(W'_{it}u_{i,t-1}). \qquad (3.3)$$

In order to get consistent OLS estimators, we need the four terms in the right hand side of equation (3.3) to equal zero. Generally, we always assume W_{it} has no correlation with the error term in past periods, which means the last term of equation (3.3) is zero. However, the other three terms in our model are not zero. Since W_{it} includes lags of the dependent variable, the assumption of strictly exogeneity is not satisfied. In this situation, we need to allow the existing of correlation of W_{it} with future error term. To see how this works, suppose W_{it} only includes $y_{i,t-1}$ for simplicity.

$$y_{it} = \beta_1 y_{i,t-1} + \eta_i + u_{it} \qquad (3.4)$$

Let $W_{it} = y_{i,t-1}$, then $W_{i,t+1}$ and u_{it} are necessarily correlated because

$$E(W_{i,t+1}u_{it}) = E(y_{it}u_{it}) = E(u_{it}^2) = Var(u_{it}) > 0,$$

where u_{it} is also correlated with all other future values of W_{it}.

$E(u_{it} \mid W_{it}, W_{i,t-1}, \ldots, W_{i1}, \eta_i) = 0$ is also known as weakly exogeneity condition. Therefore, the third term in equation (3.3) is not zero, either.

Beside the problem of lags of dependent variables, there is another endogeneity[66] problem with our model. Since one or more of the explanatory variables, such as net

[66] Economically endogenous and Econometrically endogenous: The former means variables that are jointly determined within the specification of the economic model, while the latter one describes the variables as they are determined simultaneously with the dependent variables, that is, correlated with the error terms.

migration rate in growth equation, may be determined simultaneously with the dependent variable, $E(x_{it} u_{it}) \neq 0$, then $E(W_{it} u_{it}) \neq 0$. Similarly, $E(W_{i,t-1} u_{i,t-1}) \neq 0$

3.3 Choices of Instrumental Variables

In our estimation, the instrumental variable method is used to deal with the endogeneity problem. There are many choices of instrumental variables. Anderson and Hsiao (1982) proposed two simple choices. One possibility is to use the fact that $\Delta W_{i,t-1}$ is uncorrelated with Δu_{it} under weak exogeneity, and we also assume $\Delta W_{i,t-1}$ is sufficiently correlated with $\Delta W_{i,t}$. Then the model

$$\Delta y_{it} = \Delta W_{it} \delta + \Delta u_{it} \tag{3.5}$$

can be estimated by pooled 2SLS using instruments $\Delta W_{i,t-1}$. Note here $t=3, \ldots T$ since we lose one more observation by using instrumental variables. The second possibility to be the instrumental variable is lagged levels of W_{it}. For instance, $W_{i,t-1}$ can be the instrumental variables for $\Delta W_{i,t}$. The disadvantage with the previous two procedures is that they do not use all available instruments, therefore, cannot be expected to be efficient.

Arellano and Bond (1991) suggested not only $W_{i,t-1}$, $W_{i,t-2}$ are good instrumental variables, but also any further lags of W_{it} are. They also tested several specifications for dynamic panel data by estimating employment equation. Among eight different equations, which includes one-step GMM, two-step GMM, Anderson and Hsiao type estimates, OLS, within-group…etc., they found that the GMM estimators offer significant efficiency gains compared to other simpler IV alternatives, and produces estimates that are well determined in dynamic panel data models.

Let us define the matrix of GMM-type instruments as follows:

$$Z_i = \begin{bmatrix} W_{i1}^0 & 0 & 0 & \cdots & 0 \\ 0 & W_{i2}^0 & 0 & \cdots & 0 \\ 0 & 0 & W_{i3}^0 & 0 & 0 \\ \vdots & \vdots & 0 & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & W_{i,T-1}^0 \end{bmatrix} \quad (3.6)$$

where $W_{it}^0 \equiv (W_{i1}, W_{i2}, \ldots, W_{it})$. The general form of linear GMM estimators of δ is:

$$\hat{\delta} = \left[(\sum_i W_i^{*\prime} Z_i) A_N (\sum_i Z_i' W_i^*) \right]^{-1} \left[\sum_i W_i^{*\prime} Z_i) A_N (\sum_i Z_i' y_i^*) \right]$$

where $A_N = (\frac{1}{N} \sum Z_i' H_i Z_i)^{-1}$, W_i^* and y_i^* denote some transformation of W_i and y_i, that is, first differencing in our estimation.

For one-step estimation, we use

$$H_i = \begin{bmatrix} 2 & -1 & 0 & 0 & \ldots & 0 \\ -1 & 2 & -1 & 0 & & \vdots \\ 0 & -1 & 2 & \ddots & 0 & \\ \vdots & 0 & \ddots & \ddots & \ddots & 0 \\ & & & \ddots & \ddots & -1 \\ 0 & \ldots & \ldots & 0 & -1 & 2 \end{bmatrix}$$

and if u_{it} are heteroskedastic, a two-step estimator use $H_i = \hat{u}_i^* \hat{u}_i^{*\prime}$, where $\hat{u}_i^*$ is transformation of one-step residual.

For instance, the GMM-type instrumental variable for equation (3.1) is

$$
Z_i = \begin{bmatrix} y_{i1} & x_{i1} & x_{i2} & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & y_{i1} & y_{i2} & x_{i1} & x_{i2} & x_{i3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & y_{i1} & y_{i2} & \cdots & y_{i,T-2} & x_{i1} & x_{i2} & \cdots & x_{i,T-1} \end{bmatrix}
$$

Note that the most distant observation used as instrument is y_{i1} for y and x_{i1}, x_{i2} for x here since we first-difference our original model. Therefore, one more observation is lost.

3.4 Statistical Tests

There are several statistical tests to measure the efficiency of the model. The first one is Wald test statistics, which measure the joint significance of explanatory variables. The second statistics is Sargan test statistics that tests the validity of instrumental variables. Finally, the m2 test statistics is a test for the lack of second-order serial correlation of the errors.

IV. Specification of the Model

In this section we apply the strategies for estimation and testing outlined earlier to a model of migration and economic growth, using decennial data for forty-eight states in the United States from 1930 to 1990. Alaska, Hawaii and Washington D.C. are not included in our estimation because their characteristics on economic and social aspects are very different compared to the other states. We consider the dynamic migration and economic growth equations in the following:

The migration equation we estimated in our model is as follows:

$$m_{it} = \gamma\, m_{i,t-1} + \theta \ln y_{i,t} + \phi X^{m}_{i,t} + \lambda^{m}_{t} + \eta^{m}_{i} + u^{m}_{it} \tag{4.1}$$

The growth equation we estimated in our model is as follows:

$$\ln y_{it} - \ln y_{i,t-1} = c \ln y_{i,t-1} + \beta m_{i,t-1} + \psi X^{y}_{i,t-1} + \lambda^{y}_{t} + \eta^{y}_{i} + u^{y}_{it} \tag{4.2}$$

$$\Rightarrow \ln y_{it} = \alpha \ln y_{i,t-1} + \beta m_{i,t-1} + \psi X^{y}_{i,t-1} + \lambda^{y}_{t} + \eta^{y}_{i} + u^{y}_{it} \tag{4.3}$$

Here the subscript i indexes 48 states in the United States, the subscript t = 1930, 1940, 1950, 1960, 1970, 1980 and 1990, and X^{m}_{it}, X^{y}_{it} represent the exogenous explanatory variable matrix for the migration and economic growth, respectively.

Considering the data used in our regressions, we should distinguish the flow variables from the stock variables. Note the time subscript t in our specification has different meanings for flow variables and stock variables. For flow variables, such as the net migration, the growth rate of population...etc., t represents the current decade instead of a specific year. Hence, the variable with subscript t represents the flow amount or the value change during the decade. On the other hand, for stock variables, such as the average years of schooling completed, the number of farms per person...etc., t represents the specific year at when the stock variables were measured. In the following we introduce variables used in our model, and descriptive statistics is reported in Table 1.

The main focus in this paper is on migration. We use the migration rate, which is the percentage of net inflow of the migrants in total population for each state, to be the dependent variable in the migration equation. As we mentioned earlier, the migration rate is also one of the explanatory variables in the growth equation because we suspect the migration rate and growth rate have causality relationship with each other. When the migration rate is positive, the state attracts people to move in. On the other hand, when the migration rate is negative, the state is losing residents. We can see the migration rate is pretty high in 1940s and 1950s, for both moving in and moving out. North Dakota and South Dakota always experience large out-migration with the migration rate around 15~16% before 1950s, while Florida and Nevada experience large in-migration with a migration rate of up to 30% in some decades. We can also find that after 1950s, both of the lowest and highest migration rate increase a lot decade by decade.

Table 1: Data Statistics Summary by Decades

Variable[67]	1930	1940	1950	1960	1970	1980	1990
Area	61655.98 (46819.13)						
Total Population	2547.71 (2529.20)	2729.29 (2690.55)	3122.90 (3101.28)	3702.06 (3785.45)	4195.54 (4361.41)	4678.00 (4745.77)	5134.42 (5505.94)
Total Population Growth	7.94 (7.38)	15.04 (13.96)	18.90 (18.94)	13.11 (12.62)	15.81 (14.43)	8.71 (10.97)	--
Population Density	0.09 (0.15)	0.10 (0.15)	0.11 (0.17)	0.13 (0.20)	0.15 (0.22)	0.16 (0.23)	0.17 (0.24)
Minority Race Share	10.55 (13.22)	10.20 (12.63)	9.92 (11.20)	10.08 (10.17)	10.42 (8.86)	13.57 (10.02)	14.92 (9.38)
Absolute Value of the Migration Rate	4.37 (4.53)	8.35 (6.98)	8.66 (8.15)	6.33 (5.96)	7.64 (7.28)	5.40 (5.19)	--
Number of Farms Per Hundred Persons	62.83 (34.80)	57.12 (30.76)	45.33 (28.40)	28.47 (21.02)	19.51 (17.07)	14.43 (12.98)	13.28 (12.31)
Percentage of Manufacturing Employees	6.94 (4.66)	5.96 (4.22)	7.62 (5.05)	7.46 (3.87)	8.33 (3.50)	7.77 (2.98)	7.32 (2.73)
Investment in Manufacturing	--	--	42.41 (23.49)	58.29 (30.48)	110.73 (42.75)	299.75 (129.63)	382.81 (171.08)
Percentage of Foreign Born Population	9.83 (7.54)	7.20 (5.88)	5.46 (4.44)	4.07 (3.26)	3.31 (2.74)	4.10 (3.36)	4.62 (4.38)
Per Capita Income	617.63 (224.24)	536.83 (191.59)	1401.27 (324.71)	2058.33 (407.24)	3675.81 (544.63)	5077.06 (667.40)	19351.19 (3202.25)
Growth Rate of Per Capita Income	-12.47 (7.57)	173.75 (42.88)	48.36 (9.46)	80.71 (13.74)	38.59 (7.25)	280.93 (32.84)	--
Percentage of Urban Population	46.02 (19.92)	47.75 (18.24)	55.57 (16.00)	61.95 (14.85)	65.77 (14.37)	66.59 (14.42)	67.06 (21.91)
Average Years of Adults Schooling	--	8.42 (0.85)	9.45 (0.77)	10.05 (0.68)	10.92 (0.62)	11.88 (0.55)	12.53 (0.42)
Percentage of Adults with High School Education	--	24.99 (5.76)	34.31 (7.90)	41.35 (7.21)	52.64 (7.89)	66.90 (7.33)	75.98 (5.51)
Crime Rate	--	1.71 (0.69)	1.59 (0.62)	0.92 (0.38)	2.31 (0.89)	5.43 (1.40)	5.05 (1.41)
Percentage of Age of Under 5 Population	9.69 (1.49)	8.56 (1.49)	11.20 (1.11)	11.63 (0.92)	8.54 (0.57)	7.54 (1.18)	7.60 (0.64)

Note: Numbers in parenthesis present standard deviation.

[67] Detailed data definition and source please see Appendix A.

The growth variable is the other one of main variables in our model. In the growth equation, we use the logarithm of per capita income in thousand dollars in state i at the beginning year during a specific decade t, to be the dependent variable. It is also one of the explanatory variables in migration equation. In some regressions, we replaced the logarithm of per capita income by the growth rate of per capita income for comparison. Although theoretically $\ln y_t - \ln y_{t-1}$ is approximately equal the growth rate, empirically their values are somewhat different, especially when the per capita income grows rapidly. For example, for state of Maine, $\ln y_{1970} = 8.09$, $\ln y_{1980} = 8.40$, $\ln y_{1990} = 9.82$, however, $yg_{1980} = 35\%$, $yg_{1990} = 317\%$. This makes the coefficients in our estimations using different measures of economic growth change a lot.

Note that the coefficient α in equation (4.3) equal $(1 + c)$ in equation (4.2). From the previous studies on the convergence of economic growth, c is expected to be negative. The region with low-income level grows faster than the region with high-income level. Therefore, we expect α much smaller than 1, and if α approaches to 1, we will have the unit root problem. It also means that the income level has no impact on the economic growth rate, which is contradicted by the theories.

Besides the growth variables, several geographic variables are included in the right hand side of the migration equation.

Persky and Kain (1970) argued that social factors such as the racial composition are as important as the economic opportunities to explain the flow of migrants between different areas. The migrants always face the problems of assimilation in the destination area. People might like to live with others of the same ethnic group. This is why there are always Chinatown, Italiantown...etc. in the metropolitan area. Persky and Kain (1970) also prove that the racial distribution of employment is a prime determinant of the racial composition of migration. In our estimation, we do not have the data of racial distribution of employment, however, we believe the racial distribution of population also has similar impacts on the migration flow. Therefore, we include the percentage of nonwhite people in total population to be one of the explanatory variables in the migration equation. Since the internal migration flow is composed mostly of white people, we expect a negative relationship between net migration and the percentage of nonwhite population.

Some people argued that the characteristics of states possibly affect interstate migrants and international immigrants differently. For example, international immigrants tend to choose the cities with major entries points such as an international airport or harbor as their migration destination, regardless the level of per capita income, public security, and the geographic environment...etc. While the internal migrants may be more concerned with a better living environment and more job opportunities when they make the decision to move. What we focus on in this paper is the internal migration within the United States, however, the migration data we have were measured as the net amount of people who move into the specific state, regardless of point of origin. In order to separate out the impact from international migrants, we include the number of foreign-born people in both of the migration and growth equations.

The percentage of urban resident in total population is expected to positively relate to the migration rate. A more urbanized area might have more job opportunities. Therefore, it maybe attracts more people moving in. When people consider moving, the amenity of an area matters. For example, the mild weather is a positive factor, while crime is a negative one. Since the weather in an area doesn't change much over time, the two weather variables, highest temperature in summer and lowest temperature in winter, are constant over time.

Now let us consider the factors affecting the growth rate. Population growth is an important one of them. In the simple Solow model, the population growth is expected to have a negative impact on the level of income in steady state. The accumulation of human capital and physical capital is also a positive factor to the economic growth. The former can be measured by the education level for a region, while we use the new capital establishment to measure the accumulation of physical capital. We have two measures of education level in our estimation. The fist one is average years of schooling completed for persons 25 years old and over. The other education variable is percentage of persons 25 years old and over who have at least high school education. In the modern growth literature, accumulation of human capital is expected to have positive effect on economic growth.

Industry decomposition may also have impacts on economic growth. The number of farms per thousand people and the percentage of people who work for manufacturing industry in the total population are our industry variables.

V. Regression Results

We compare the regression results estimated by different econometric methods for migration and growth equation in Table 2A and Table 2B respectively.

The first column in Table 2A and Table 2B reports coefficients and standard errors estimated by Anderson and Hsiao type of instrumental variable method, while the other three columns are estimated by GMM method. All four estimations use the transformation of first differencing to remove the unobserved individual effects. In addition, they are all estimated by using variables in levels as instruments. Moreover, robust variance-covariance matrix is also applied except in the second column. Note that the m2 statistics for all of four estimations are small enough that we can accept the null hypothesis of no serially correlation between error terms. Besides, the Sargan Tests in all GMM estimations are significant, except the last column in Table 2B, which shows we use the right instrumental variables.

The first two GMM regressions are estimated by one-step procedure and the last one is estimated by two-step procedure. However, the evidence from the simulation of Arellano and Bond (1991) showed that the standard errors are not reliable in two-step estimation when we have finite sample size. In their simulation, the standard errors of two-step GMM estimates are much smaller than of one-step GMM estimates. Therefore, they suspect that most of this apparent gain in precision may reflect a downward finite-sample bias. We can also see the same situation occurred in our estimation. The standard errors of the estimates from GMM two-step estimation in the fourth column are always much smaller than that in the second and third column, which uses GMM one-step estimation.

Table 2A: Migration Equation in Different Estimation Methods

Estimation Method	AHi	GMM1	GMM1r	GMM2
Variable Transformation	First Difference	First Difference	First Difference	First Difference
Time Period	4	4	4	4
Dependent Variable	Migration Rate	Migration Rate	Migration Rate	Migration Rate
Instrumental Variable	ly: 1 lag m: 1 lag	ly: 2 lag m: 2 lag	ly: 2 lag m: 2 lag	ly: 2 lag m: 2 lag
Migration Rate in Previous Decade	0.6030 (0.2683) **	-0.0571 (0.0979)	-0.0571 (0.0665)	-0.0593 (0.0441)
Logarithm of Per Capita Income in the Beginning Year of Current Decade	8.5653 (6.8970)	16.6719 (5.8760) **	16.6719 (6.5940) **	14.6598 (4.4380) **
Logarithm of Per Capita Income in the Beginning Year of Previous Decade	-2.8937 (7.2080)	12.3922 (5.6610) **	12.3922 (4.1660) **	11.5140 (2.6780) **
Percentage of Urban Population	-0.2894 (0.1627) *	-0.2553 (0.1259) **	-0.2553 (0.1854)	-0.1900 (0.1338)
Crime Rate	-1.9685 (1.1890) *	-2.5643 (0.9496) **	-2.5643 (0.9198) **	-2.2532 (0.5788) **
Minority Race Share	-0.0701 (0.1933)	-0.0566 (0.1771)	-0.0566 (0.1101)	-0.1317 (0.0631) **
Percentage of Foreign-Born Population	1.4470 (0.5389) **	0.3261 (0.3674)	0.3261 (0.3331)	0.2534 (0.2407)
Constant	-4.5875 (7.5690)	-12.7191 (6.6290) *	-12.7191 (6.9890) *	-11.7520 (4.4090) **
Year Dummy: 1960	7.5526 (10.7100)	-4.9299 (8.4510)	-4.9299 (7.4490)	-4.8424 (4.4160)
Year Dummy: 1970	11.0603 (4.5650) **	8.8254 (5.0420) *	8.8254 (4.2220) **	8.6508 (2.3530) **
Year Dummy: 1980	1.6988 (7.6340)	4.7840 (7.7170)	4.7840 (6.6100)	4.3251 (3.9440)
Wald Test**	77.30 **	103.7 **	120.3 **	246.2 **
Sargan Test**	--	53.62 **	53.62 **	27.25**
m2 Test	-0.5158	-1.852	-1.901	-1.905

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Table 2B: Growth Equation in Different Estimation Methods

Estimation Method	AHi	GMM1	GMM1r	GMM2
Variable Transformation	First Difference	First Difference	First Difference	First Difference
Time Period	4	4	4	4
Dependent Variable	Logarithm of Per Capita Income	Logarithm of Per Capita Income	Logarithm of Per Capita Income	Logarithm of Per Capita Income
Instrumental Variable	ly: 1 lag m: 1 lag	ly: 2 lags m: 2 lags	ly: 2 lags m: 2 lags	ly: 2 lags m: 2 lags
Logarithm of Per Capita Income 10 Years Ago	0.1235 (0.0749) *	0.1298 (0.0505) **	0.1298 (0.0742) *	0.0980 (0.0600) *
Migration Rate in Last 10 Years	0.0025 (0.0018)	0.0019 (0.0009) **	0.0019 (0.0010) *	0.0021 (0.0006) **
Natural Population Growth in Last 10 Years	-0.0423 (0.0125) **	-0.0471 (0.0074) **	-0.0471 (0.0107) **	-0.0443 (0.0080) **
Average Years of Adults Schooling	0.0407 (0.0268)	0.0554 (0.0269) **	0.0554 (0.0262) **	0.0673 (0.0211) **
Percentage of Manufacturing Employee	-0.0003 (0.0035)	-0.0022 (0.0033)	-0.0022 (0.0032)	-0.0009 (0.0026)
Percentage of Foreign-Born Population in Last 10 Years	0.0039 (0.0038)	0.0027 (0.0026)	0.0027 (0.0035)	0.0025 (0.0024)
Investment in Manufacturing	0.0001 (0.0001) *	0.0001 (0.0001) **	0.0001 (0.0001) **	0.0001 (0.0000) **
Constant	0.3601 (0.0832) **	0.3549 (0.0522) **	0.3549 (0.0827) **	0.3731 (0.0684) **
Decade Dummy: 1970	0.1588 (0.0603) **	0.1500 (0.0424) **	0.1500 (0.0598) **	0.1319 (0.0488) **
Decade Dummy: 1980	-0.3156 (0.0764) **	-0.3472 (0.0492) **	-0.3472 (0.0743) **	-0.3414 (0.0580) **
Decade Dummy: 1990	0.8630 (0.0774) **	0.8460 (0.0466) **	0.8460 (0.0743) **	0.8314 (0.0588) **
Wald Test**	173.8 **	362.7 **	262.6 **	753.2 **
Sargan Test**	--	32.66 **	32.66 **	20.10
m2 Test	-0.1335	-0.3592	-0.3898	-0.3713

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

In the rest of this paper, we will focus on the estimation using GMM one step without robust variance-covariance matrix and refer it as our base regression. The second column in Table 2A represents the estimated relationship between the migration rate and its explanatory variables. The result suggests that the previous migration rate does not have an important impact on current migration rate. That is, the migration rate does not have a dynamic property. However, the previous income level and the growth rate of income do have significant effect on migration rate. If we transform lny and lny(-1) into lny-lny(-1) (growth rate), and lny (income level), we will get the coefficient for growth rate with value of −12.3922, and the coefficient for previous income level with the value of 29.0641. Therefore, the migration rate is positively related with the previous level of logarithm of per capita income. When per capita income increases one percent, the migration rate will increase 0.29 percentage points. However, the growth rate of income is negatively and significantly related with the migration rate. It shows that people do not move to the area with high growth rate, but to the area with high level of per capita income. It may be clear that people will choose to move into the area with higher income level conditional on the same growth rate. However, it seems surprisingly that people prefer the area with the lower growth rate when conditional on the same level of income.

Another significant impact of explanatory variable comes from the crime rate. This is a negative factor to the migration flow as we expected. The GMM estimates suggest that one more percentage point of the crime rate will reduce about 2.56 percentage points of the migration rate. Besides, the percentage of urban population also has negative impact on the migration rate in our estimation. It is a surprising result because we expect people will move to the state with large city, which can provide more job opportunities. On the other hand, large cites may be congested, which can generate incentives for out-migration.

Now let us consider the growth equation. The second column in Table 2B represents the estimated relationship between current income level and its explanatory variables. Note that the coefficient of lagged per capita income is significantly positive and much smaller than one. Remember that in equation (4.2) and (4.3), α (the coefficient of lagged of ln$y$) = 1 + c. In the third column, $\alpha = 0.1298$, therefore, $c = -0.8702$. Therefore, the approximate growth rate of per capita income is negatively related with the previous level of per capita income. When the previous level of per capita income increases one percentage point, the growth rate decreases about 0.87 percentage point. The growth rates of different states indeed converge, as expected by the previous studies on the convergence of the economic growth.

The migration rate is also a significantly positive factor to the growth of income, though the effect is not large. One percentage increase of the migration rate will increase 1.9 percent of per capita income. We also include the natural population growth in our explanatory variable set. As the Solow model predicts, we also find that higher natural population growth will decrease the level of per capita income. Additions to the population which come from immigration have a positive effect on growth, increasing population through a rise in fertility has positive impact on the level of income. This finding can be explained as follows: Immigrants might bring with them a diverse set of skills which can provide a stimulus for growth. The negative relationship between fertility and growth can be explained easily by a Solow type growth model.

Besides, the average year of schooling completed is also a positive factor to per capita income in our estimation. One more year of average schooling will result in a 5.54 percent increase of income. Finally, investment plays a very important role in economic growth. In our estimation, the coefficient for investment is positive and significant.

Table 3A: GMM Estimations with Different IVs for Migration Equation

Regression	1	2	3	4	5	6	7
Time Period	4	4	4	4	4	4	4
Dependent Variable	Migration Rate						
Instrumental Variables	ly: 2 lag m: 2 lag	m: 2 lag ly: 3 lag	m: 3 lags ly: 2 lags	m: 3 lags ly: 3 lags	m: 3 lags ly: All lags	m: All lags ly: 3 lags	m: All lags ly: All lags
Migration Rate in Previous Decade	-0.0571 (0.0979)	-0.0569 (0.0976)	-0.0629 (0.0968)	-0.0657 (0.0965)	-0.0612 (0.0962)	-0.0814 (0.0952)	-0.0768 (0.0949)
Logarithm of Per Capita Income in the Beginning Year of Current Decade	16.6719 (5.8760)**	16.0063 (5.7910)**	16.4933 (5.8540)**	15.6699 (5.7610)**	15.4804 (5.7550)**	15.5294 (5.7380)**	15.3221 (5.7310)**
Logarithm of Per Capita Income in the Beginning Year of Previous Decade	12.3922 (5.6610)**	12.4306 (5.6390)**	12.4402 (5.6430)**	12.4845 (5.6190) **	12.4139 (5.6220)**	12.9049 (5.5860)**	12.8360 (5.5890)**
Percentage of Urban Population	-0.2553 (0.1259)**	-0.2613 (0.1225)**	-0.2543 (0.1252)**	-0.2655 (0.1220)**	-0.2610 (0.1218)**	-0.2667 (0.1216)**	-0.2619 (0.1214)**
Crime Rate	-2.5643 (0.9496)**	-2.5829 (0.9464)**	-2.6073 (0.9433)**	-2.6512 (0.9392)**	-2.6558 (0.9399)**	-2.7169 (0.9339)**	-2.7230 (0.9345)**
Minority Race Share	-0.0566 (0.1771)	-0.0747 (0.1746)	-0.0552 (0.1766)	-0.0795 (0.1741)	-0.0840 (0.1740)	-0.0828 (0.1734)	-0.0876 (0.1733)
Percentage of Foreign-Born Population	0.3261 (0.3674)	0.3426 (0.3637)	0.3390 (0.3623)	0.3593 (0.3594)	0.3633 (0.3596)	0.3174 (0.3562)	0.3210 (0.3564)
Constant	-12.7191 (6.6290)*	-11.9837 (6.5390)*	-12.5244 (6.6000)*	-11.5872 (6.5030)*	-11.4394 (6.5020)*	-11.4591 (6.4770)*	-11.2969 (6.4760)*
Year Dummy: 1960	-4.9299 (8.4510)	-5.3911 (8.3990)	-5.1205 (8.4290)	-5.7045 (8.3660)	-5.7330 (8.3730)	-6.2909 (8.3180)	-6.3322 (8.3240)
Year Dummy: 1970	8.8254 (5.0420)*	8.5341 (5.0190)	8.7873 (5.0290)*	8.4483 (5.0020)*	8.4295 (5.0060)*	8.3167 (4.9810)*	8.2940 (4.9850)*
Year Dummy: 1980	4.7840 (7.7170)	4.3478 (7.6830)	4.7722 (7.6890)	4.3002 (7.6530)	4.2502 (7.6590)	4.3125 (7.6240)	4.2586 (7.6290)
Wald Test**	103.7 **	104.0 **	105.0 **	105.1**	105.1**	106.1 **	106.2**
Sargan Test**	53.62 **	54.26 **	54.40 **	55.48 **	55.67 **	57.29 **	57.54 **
m2 Test	-1.852	-1.822	-1.860	-1.840	-1.818	-1.888	-1.865

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Table 3B: GMM Estimations with Different IVs for Growth Equation

Regression	1	2	3	4	5	6	7
Time Period	4	4	4	4	4	4	4
Dependent Variable	Logarithm of Per Capita Income						
Instrumental Variable	ly: 2 lags m: 2 lags	ly: 3 lags m: 2 lags	ly: 2 lags m: 3 lags	ly: 3 lags m: 3 lags	ly: All lags m: 3 lags	ly: 3 lags m: All lags	ly: All lags m: All lags
Logarithm of Per Capita Income 10 Years Ago	0.1298 (0.0505)**	0.1405 (0.0495)**	0.1256 (0.0497)**	0.1339 (0.0486)**	0.1332 (0.0479)**	0.1281 (0.0483)**	0.1283 (0.0476)**
Migration Rate in Last 10 Years	0.0019 (0.0009)**	0.0020 (0.0009)**	0.0018 (0.0009)*	0.0021 (0.0009)**	0.0022 (0.0009)**	0.0022 (0.0009)**	0.0023 (0.0009)**
Natural Population Growth in Last 10 Years	-0.0471 (0.0074)**	-0.0434 (0.0074)**	-0.0458 (0.0074)**	-0.0422 (0.0073)**	-0.0421 (0.0072)**	-0.0415 (0.0072)**	-0.0417 (0.0071)**
Average Years of Adults Schooling	0.0554 (0.0269)**	0.0506 (0.0259) *	0.0622 (0.0264)**	0.0527 (0.0254)**	0.0516 (0.0246)**	0.0511 (0.0252)**	0.0521 (0.0244)**
Percentage of Manufacturing Employee	-0.0022 (0.0033)	-0.0007 (0.0032)	-0.0018 (0.0033)	-0.0005 (0.0032)	-0.0019 (0.0031)	-0.0004 (0.0031)	-0.0016 (0.0031)
Percentage of Foreign-Born Population in Last 10 Years	0.0027 (0.0026)	0.0027 (0.0026)	0.0023 (0.0025)	0.0029 (0.0025)	0.0034 (0.0025)	0.0034 (0.0025)	0.0034 (0.0025)
Investment in Manufacturing	0.0001 (0.0001)**	0.0001 (0.0001)**	0.0002 (0.0001)**	0.0002 (0.0001)**	0.0002 (0.0001)**	0.0002 (0.0001)**	0.0002 (0.0001)**
Constant	0.3549 (0.0522)**	0.3377 (0.0516)**	0.3512 (0.0513)**	0.3402 (0.0507)**	0.3415 (0.0501)**	0.3457 (0.0503)**	0.3453 (0.0498)**
Decade Dummy: 1970	0.1500 (0.0424)**	0.1643 (0.0411)**	0.1481 (0.0417)**	0.1615 (0.0404)**	0.1618 (0.0394)**	0.1591 (0.0402)**	0.1593 (0.0392)**
Decade Dummy: 1980	-0.3472 (0.0492)**	-0.3193 (0.0481)**	-0.3433 (0.0484)**	-0.3189 (0.0472)**	-0.3241 (0.0459)**	-0.3201 (0.0470)**	-0.3241 (0.0457)**
Decade Dummy: 1990	0.8460 (0.0466)**	0.8679 (0.0455)**	0.8479 (0.0458)**	0.8668 (0.0446)**	0.8646 (0.0435)**	0.8648 (0.0444)**	0.8633 (0.0433)**
Wald Test**	362.7 **	360.9 **	363.2 **	363.7 **	365.8 **	369.5 **	370.4 **
Sargan Test**	32.66 **	49.05 **	39.49 **	53.84 **	59.84 **	56.13 **	62.65 **
m2 Test	-0.3592	-0.3696	-0.4344	-0.4049	-0.4444	-0.3760	-0.4191

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Different sets of instrumental variables are applied in the estimations both for migration and growth equations in Table 3A and Table 3B. The first column is our base regression, and more lags of the potential endogenous explanatory variables are added into the GMM instrumental variable set for the regressions in other columns. We can see the coefficients and significance level do not change much except some insignificant variables, and the regression results are robust across estimations. We can also see the Sargan test improves when more lagged dependent variables and more lagged endogenous variables are added as the instrument variables in our regressions.

Table 4A reports the results from alternative specifications for the migration equation. The first column is the base regression. Since we found that the migration rate does not have a significant dynamic property, we remove the lag of migration rate in the second column. The result shows that most of the coefficients do not change much. The fourth column replaces the percentage of urban population by the population density. The results shows that people like to move to the state with lower population density and which is parallel to our previous finding, which shows the state with smaller percentage of urban population attracts more migrants.

The last column includes 8 regional dummies in the regression. The level of income still has positive impact on the migration rate, and the growth of income and the crime rate are negative factors to the migration rate. However, urban population loses its significance now. Besides, we find that joint significance decreases a lot.

Table 4A: Alternative Specifications for Migration Equation

Regression	1	2	3	4	5
Time Period	4	4	4	4	4
Dependent Variable	Migration Rate in This Decade				
Instrumental Variables	ly: 2 lags m: 2 lags	ly: 2 lags	ly: 2 lags m: 2 lags	ly and lyg: 2 lags m: 2 lags	ly: 2 lags m: 2 lags
Migration Rate in Previous Decade	-0.0571 (0.0979)	--	-0.0429 (0.0972)	-0.0648 (0.0971)	-0.0559 (0.1036)
Growth of Logarithm of Per Capita Income in Previous Decade	--	--	--	-12.5214 (5.6320) **	--
Logarithm of Per Capita Income in the Beginning Year of Current Decade	16.6719 (5.8760) **	17.6223 (6.0830) **	14.7487 (5.8220) **	28.8798 (6.6630) **	10.9585 (6.7630) *
Logarithm of Per Capita Income in the Beginning Year of Previous Decade	12.3922 (5.6610) **	11.8908 (5.6120) **	7.1925 (5.4110)	--	10.0878 (5.7150) *
Percentage of Urban Population	-0.2553 (0.1259) **	-0.2795 (0.1332) **	--	-0.2572 (0.1247) **	-0.2000 (0.1800)
Population Density	--	--	-35.3526 (13.0300) **	--	--
Crime Rate	-2.5643 (0.9496) **	-2.2147 (0.9794) **	-1.9026 (0.9834) *	-2.5809 (0.9441) **	-2.6681 (0.9644) **
Minority Race Share	-0.0566 (0.1771)	-0.0572 (0.1849)	-0.1006 (0.1761)	-0.0644 (0.1764)	-0.0146 (0.2026)
Percentage of Foreign-Born Population	0.3261 (0.3674)	0.3905 (0.3741)	-0.1123 (0.3056)	0.3303 (0.3642)	0.5491 (0.4799)
Constant	-12.7191 (6.6290) *	-13.4007 (6.8190) *	-13.7472 (6.2790) **	-12.3759 (6.5910) *	-5.8932 (7.5520)
Year Dummy: 1960	-4.9299 (8.4510)	-3.6397 (8.4050)	0.9207 (8.0380)	-5.2691 (8.4290)	-5.8369 (8.5400)
Year Dummy: 1970	8.8254 (5.0420) *	8.7494 (5.1530) *	11.4339 (4.7190) **	8.6602 (5.0270) *	7.8599 (5.2440)
Year Dummy: 1980	4.7840 (7.7170)	3.9923 (7.9200)	7.9560 (7.2100)	4.5859 (7.6890)	2.6379 (8.1160)
Wald Test**	103.7 **	98.42 **	111.8 **	104.1 **	34.67 **
Sargan Test**	53.62 **	41.57 **	57.79 **	55.66 **	51.62 **
m2 Test	-1.852	-1.576	-1.714	-1.872	-1.828

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

Table 4B: Alternative Specifications for Growth Equation

Regression	1	2	3	4	5	6
Time Period	4	4	4	4	4	4
Dependent Variable	Logarithm of Per Capita Income					
Instrumental Variables	ly: 2 lags m: 2 lags	ly: 2 lags m: 2 lags	ly: 2 lags m: 2 lags	ly: 2 lags m: 2 lags	ly: 2 lags m: 2 lags	ly: 2 lags m: 2 lags
Logarithm of Per Capita Income 10 Years Ago	0.1298 (0.0505) **	0.1432 (0.0555) **	0.1668 (0.0495) **	0.0047 (0.0588)	0.0007 (0.0579)	0.0959 (0.0494) *
Migration Rate in Last 10 Years	0.0019 (0.0009) **	0.0016 (0.0008) **	0.0023 (0.0009) **	0.0011 (0.0009)	0.0013 (0.0009)	0.0015 (0.0009) *
Natural Population Growth in Last 10 Years	-0.0471 (0.0074) **	-0.0486 (0.0069) **	-0.0478 (0.0076) **	-0.0459 (0.0069) **	-0.0450 (0.0068) **	-0.0450 (0.0072) **
Average Years of Adults Schooling	0.0554 (0.0269) **	0.0593 (0.0264) **	--	0.0683 (0.0254) **	0.0668 (0.0251) **	0.0350 (0.0288)
Percentage of Adults with High School Education	--	--	-0.0006 (0.0025)	--	--	--
Percentage of Manufacturing Employee	-0.0022 (0.0033)	-0.0012 (0.0031)	-0.0029 (0.0034)	-0.0047 (0.0033)	--	0.0086 (0.0039) **
Number of Farms Per Hundred Persons	--	--	--	-0.0024 (0.0008) **	-0.0019 (0.0007) **	--
Percentage of Foreign-Born Population in Last 10 Years	0.0027 (0.0026)	--	0.0035 (0.0027)	0.0034 (0.0025)	0.0021 (0.0022)	0.0050 (0.0028) *
Growth Rate of Percentage of Foreign-Born Population	--	0.0043 (0.0056)	--	--	--	--
Investment in Manufacturing	0.0001 (0.0001) **	0.0001 (0.0001) **	0.0002 (0.0001) **	0.0001 (0.0001) **	0.0001 (0.0001) **	0.0000 (0.0001)
Constant	0.3549 (0.0522) **	0.3386 (0.0578) **	0.3580 (0.0532) **	0.4284 (0.0533) **	0.4384 (0.0521) **	0.4498 (0.0528) **
Decade Dummy: 1970	0.1500 (0.0424) **	0.1548 (0.0441) **	0.1858 (0.0439) **	0.0957 (0.0424) **	0.0884 (0.0411) **	0.1318 (0.0415) **
Decade Dummy: 1980	-0.3472 (0.0492) **	-0.3476 (0.0487) **	-0.3244 (0.0541) **	-0.3649 (0.0467) **	-0.3597 (0.0465) **	-0.3189 (0.0503) **
Decade Dummy: 1990	0.8460 (0.0466) **	0.8564 (0.0494) **	0.8690 (0.0486) **	0.7991 (0.0462) **	0.7980 (0.0456) **	0.8375 (0.0475) **
Wald Test**	362.7 **	353.1 **	337.4 **	421.1 **	424.5 **	203.6 **
Sargan Test**	32.66 **	32.99	31.82 **	33.77 **	33.01 **	26.67 *
m2 Test	-0.3592	-0.5245	0.0132	0.4292	0.4457	-1.648

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

We also try different specifications for the growth equation in Table 4B and the first column is our base regression again. The second column uses the measure of foreign-born population growth instead of the percentage of foreign-born population, and we get very similar result as the base regression. The foreign-born population still has no important impact on per capita income. We replace the average years of adult schooling by the percentage of adult with at least high school education, and now the educational variable becomes insignificant. The result that the average year of schooling completed is positive and significant, but the percentage of high school education is insignificant suggests the overall level of education, instead of distribution of higher education, has important effects on the growth of income.

In the fourth column, we add the number of farms per hundred person to proxy composition of industry in our estimation, while in the fifth column, we remove the share of employee in manufacture and leave the number of farm per hundred person to be the only one industry variable. Both of the columns show that the number of farm per hundred person have negative impact on per capita income. The reason may be that our estimation is focused on the period after 1960. During this period, agriculture is no longer the push power for economic growth. The area with less share of agriculture, more share of manufacture and service will have higher level of per capita income.

The 8 regional dummies are included in the last column. Now the share of manufacture employees and percentage of foreign-born population become the positive important factors to the income level. This may imply within the same region, different share of manufacturing employee and foreign-born population determine different level of per capita income.

Up to this point, we haven't deal with the possible endogeneity problem caused by causality between the migration rate and the level of per capita income. Due to the restriction of software we used, we can not do actual two stage or three stage least square. However, we can deal with this problem to some extent by adding migration's explanatory variables into the instrumental variable set of the growth equation, and do the same thing for the migration equation, therefore, get the similar effect of simultaneous equations.

Table 5 reports the "quasi-simultaneous" equation results. The additional instrumental variables for per capita income in the migration equation are natural population growth, average years of schooling, and investment. The additional instrumental variables for the migration rate in the growth equation are the percentage of urban population and the crime rate.

Some coefficients in the migration equation change the value a lot, but are still significant. The reason may be that we lose one more observation by using investment as instrumental variable for per capita income. However, we can see that the m2 test improves a lot in the migration equation.

Table 5: "Quasi-Simultaneous" Migration and Growth Equation

	Migration Equation	Growth Equation
Instrumental Variables	natural population growth, average years of schooling, investment	the percentage of urban population, crime rate
GMM-Type Instrumental Variables	ly: 2 lag m: 2 lag	ly: 2 lag m: 2 lag
Migration Rate in Last 10 Years	-0.6196 (0.1249) **	0.0020 (0.0009) **
Logarithm of Per Capita Income in the Beginning Year of Current Decade	63.5687 (12.7300) **	--
Logarithm of Per Capita Income in the Beginning Year of Previous Decade	12.4301 (6.1400) **	0.1272 (0.0503) **
Percentage of Urban Population	-0.1600 (0.1669)	--
Crime Rate	-4.4001 (0.9688) **	--
Natural Population Growth in Last 10 Years	--	-0.0465 (0.0074) **
Average Years of Adults Schooling	--	0.0553 (0.0268) **
Percentage of Manufacturing Employee	--	-0.0023 (0.0033)
Minority Race Share	0.0947 (0.1951)	--
Percentage of Foreign-Born Population	-0.1691 (0.5109)	--
Percentage of Foreign-Born Population in Last 10 Years	--	0.0029 (0.0026)
Investment in Manufacturing	--	0.0002 (0.0001) **
Constant	-38.6848 (7.1060) **	0.3563 (0.0520) **
Decade Dummy: 1960		
Decade Dummy: 1970	9.4034 (5.0420) *	0.1494 (0.0423) **
Decade Dummy: 1980	24.3865 (4.4550) **	-0.3466 (0.0491) **
Decade Dummy: 1990	--	0.8461 (0.0465) **
Wald Test **	104.6 **	364.7 **
Sargan Test **	45.75 **	33.38 **
M2 Test	0.4159	-0.3559

Note: Number in parenthesis represents standard error.

One asterisk (*) indicates significance at the 90 percent confidence level.

Two asterisks (**) indicates significance at the 95 percent confidence level.

VI. Conclusion

In our dynamic panel data model, the migration rate and the income growth do have significant relationship with each other. The high level of income instead of income growth rate attracts people to move into that state, and the inflow of migrants also increases economic growth. Results also show that per capita income does have dynamic properties themselves, however, the migration rate does not. To deal with the dynamic problem, we use GMM estimation and we find that the serial correlation problem can be improve when we employ more lags of potentially endogenous variables as the instrumental variables.

In addition, the percentage of urban population and the crime rate are important negative factors to the migration rate. The area with lower rate of crime committed will lead to larger net inflow of internal migrants. The more surprising result is that people do not move to the area with higher percentage of urban population or higher population density.

APPENDIX

Appendix: Data Definition and Source

Area: Land area of state in 1990, measured by square mile. *Source: U.S. Bureau of the Census, collected by Statistical Abstract of the United States (Annual).*

Total Population: In thousand persons, 1930-1990. *Source: U.S. Bureau of the Census, collected by Historical Statistics of the States of the United States.*

Natural Population Growth: Percentage of population of age under 5 in total population, in percent. *Source: Historical Statistics of the US, Colonial Times to 1970 and Statistical Abstract of the United States (for 1980 and 1990 data).*

Population Density: Total population divided by land area, in thousand people per square mile.

Minority Race Share: Percentage of nonwhite population in total population, in percent. *Source: Historical Statistics of the States of the United States.*

Percentage of Urban Population: Percentage of population in urban area in total population, in percent. *Source: Historical Statistics of the States of the United States and State and Metropolitan Area Data Book (for 1990 data).*

Migration Rate: Percentage of estimated net intercensal total migration in total population, in percent. *Source: Historical Statistics of the US, Colonial Times to 1970 and Statistical Abstract of the United States (for 1980 and 1990 data).*

Percentage of Foreign-Born Population: In percent. *Source: U.S. Bureau of the Census.*

Growth Rate of Foreign-Born Population: Current foreign-born population minus previous foreign-born population then divided by previous foreign-born population, in percent.

Number of Farms Per Hundred Persons: Total number of farms divided by total population, in number. *Source: Historical Statistics of the States of the United States.*

Percentage of Manufacturing Employees: Total employees in manufacturing industry divided by total population. *Source: Historical Statistics of the States of the United States.*

Investment in Manufacturing: New capital expenditure in manufacturing industry per capita, in thousand dollars. *Source: Historical Statistics of the States of the United States.*

Per Capita Income: In thousand dollars. *Source: Statistical Abstract of the United States (Annual).*

Growth Rate of Per Capita Income: Current per capita income minus previous per capita income then divided by previous per capita income, in percent.

Average Years of Adults Schooling: In years. *Source: Statistical Abstract of the United States.*

Percentage of Adults with High School Education: In percent. *Source: Statistical Abstract of the United States.*

Crime Rate: Offenses known to the police in urban communities, measured by rate per 100 inhabitants, sum of murder, non-negligent manslaughter, forcible rape, robbery, aggravated assault, burglary-breaking or entering, larceny theft, and auto theft. *Source: Statistical Abstract of the United States.*

REFERENCES

REFERENCES

Anderson, T. W., and Cheng Hsiao, (1982) "Formulation and Estimation of Dynamic Models Using Panel Data," *Journal of Econometrics*, 18, pp. 247-82.

Arellano, Manuel, and Stephen Bond, (1991) "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *The Review of Economic Studies*, Vol 58, Issue 2, pp. 277-297.

Baltagi, Badi H., (1995) "Econometric Analysis of Panel Data," *John Wiley & Sons Ltd.*

Barro, Robert J., and Xavier Sala-i-Martin, (1992) "Convergence Across States And Regions," *Economic Growth Center of Yale University*, Center Discussion Paper, No. 629.

Doornik, Jurgen A., Manuel Arellano, and Stephen Bond, (1999) "Panel Data Estimation using DPD for Ox," *Nuffield College*, Oxford and IFS, London, June 11.

Greenwood, Michael J., (1976) "A Simultaneous-Equations Model of White and Nonwhite Migration and Urban Change," *Economic Inquiry*, Vol. XIV, pp.1-15.

Greenwood, Michael J., (1978) "An Econometric Model of Internal Migration and Regional Economic Growth in Mexico," *Journal of Regional Science*, Vol. 18, No. 1, pp. 17-31.

Hsiao, Cheng, (1986) "Analysis of Panel Data," *Cambridge University Press.*

Okun, Bernard, (1968) "Interstate Population Migration and State Income Inequality: A Simultaneous Equation Approach," *Economic Development and Cultural Change*, Vol. 16, No. 2, Part I, pp. 297-313.

Olvey, Lee D., (1972) "Regional Growth and Inter-Regional Migration—Their Pattern of Interaction," *The Review of Regional Studies*, Vol. II, No. 2, pp. 139-163.

Persky, Joseph J., and John F. Kain, (1970) "Migration, Employment, and Race in the Deep South" *The Southern Economic Journal*, pp. 268-276.

Persson, Joakim, (1994) "Convergence in Per Capita Income and Migration Across the Swedish Counties 1906-1990" *Institute for International Economic Studies.*

Tondl, Gabriele, (1999) "What determined the Uneven Growth of Europe's Southern Regions? An Empirical Study with Panel Data," *Working Paper.*

Wooldridge, Jeffrey M., (2000) "Introductory Econometrics," *South-Western College Publishing.*