

Gender and Urban Form¹

Stephen Sheppard
Williams College

Alison Kraley
Williams College

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Abstract

In this paper we focus attention on the increasing participation of women in the labor market, and the impact that this participation has on urban form. We emphasize the impact of gender on urban form – in particular the total amount of urban land use or urban footprint – because of its relevance to urban policy formation and contemporary concerns about urban expansion. We consider both simple first difference models of urban land use and cross-section models estimated using instrumental variable techniques. In general we find support for the theoretical predictions. An increase in the FLFPR is associated, *ceteris paribus*, with reduced urban land use.

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I. Introduction

The year 2008 has been identified by the UN Population Fund as the year in which half of the world's population could be said to live in urban areas. This closes a century in which the urban population increased by more than ten fold. More alarming, in the view of some, is the observation that at current growth rates the urban population in developing countries will double over the next 25 years.

Why should this be alarming? One answer is the tremendous resource requirements associated with providing the new infrastructure and providing accommodation for this growing urban population. Data from a sample of cities around the globe (and described more fully below) suggests that total urban land use in cities is increasing at an annual rate of about 2.56%. This implies that total urban land cover on earth will double in 27 years. Thus in less than three decades, if current trends continue, we will have to build as many hectares of urban environment as humans collectively managed to construct in the several thousand years since urban places began.

Policy makers and others are also concerned about the environmental impact of urban populations in general and in particular the impact of the expanding urban "footprint" – or amount of land covered by buildings, concrete, roadways, and other impervious surfaces that characterize the built environment. Finally, we might be concerned about the changing nature of human society organized in these urban communities, in which regular social interaction of rural, village and small-town life are replaced with the social segregation or isolation of cities.

Whether these concerns are reasonable is, of course, debatable (or at least a matter for further empirical investigation) but each of them are related in some way to the compactness of the urban form – the extent to which the built environment constructed to accommodate the new urban population is extensive and large in quantity or more modest, higher density, and more 'compact' (however this might be measured). An urban area that generates less total urban cover for a given population will involve less extensive and sprawling infrastructure requirements. Higher density building places more of the costs of urban expansion on developers and the new residents and less on the overstretched and often under financed public sector. Reduced urban footprints makes for more compact cities, and these may have reduced environmental impacts both in terms of reduced use of open space as well as reduced energy use and commuting (as argued by Newman and Kenworthy (1989) but challenged by Breheny (1995)). Finally, urban expansion might lead to increased urban isolation and exclusion. This is argued with a variety of

anecdotal data by Power (2001), although recent research by Brueckner and Largey (2007) calls this hypothesis into question.

In order to better anticipate the infrastructure investment that will be required as well as other social and economic problems (if any), it is important to understand the forces that drive urban expansion and determine the extent of urban land use. This should include the obvious factors suggested by economic theory such as income, population, transportation costs, and the opportunity cost of urban land. It should also include an exploration of social and economic forces whose role in determining urban form is less widely appreciated.

In this paper we focus attention on one such factor: the increasing participation of women in the labor market, and the impact that this participation has on urban form. We emphasize the impact of gender on urban form – in particular the total amount of urban land use or urban footprint – because of its relevance to urban policy formation and contemporary concerns about urban expansion. There are many issues that are affected by the changing economic role of women and their (generally) increasing access to employment in the economy. These concerns: income distribution, relative influence in household decision making, or labor market discrimination, are not directly addressed. We take the female labor force participation rate as exogenously determined by social and labor market conditions, and ask: what impact do these changes have on total urban land use?

II. Simple Models of Gender and Urban Expansion

Interest in the differences between male and female workers in the context of an urban labor market goes back at least to the seminal paper by White (1977) and perhaps even to some limited observations and conjectures by Kain (1962). Most papers considering the issue deal with an important empirical regularity: on average, women in the labor market experience shorter commutes than men. From this starting point the analyses follow a variety of paths, ranging from a focus on job search and the labor force participation decision (such as Ommeren, Reitveld and Nijkamp (1998)). Others continue a focus on the locations where females are likely to find employment and explore some of the consequences for urban land rents (such as Hotchkiss and White (1993)).

For the purposes of our analysis, the first difficulty we must confront is to separate the impact of female labor force participation from the increase in household income that it might bring. The impact of

increasing household income on urban form is unambiguous and empirically validated in many studies, among them Angel, Sheppard and Civco (2005) and Blomberg and Sheppard (2007). These studies all suggest that increasing income is associated with increased urban land use, holding all other factors constant. The elasticity of total urban land use with respect to income is estimated to be between 0.4 and 0.8.

Let us consider for the moment a world in which all households are identical and consist of two adults. One of them is always employed and works in the city center. The other may or may not work, and if employment is sought it may be located between the urban center and the urban periphery. If we hold household income constant and imagine the household switching from a state in which one adult works to a state in which both work, the impact is obviously identical to an increase in commuting costs for the household. If the second workplace is more suburbanized, then the impact on transport costs may be quite small, but it clearly constitutes an increase in transport costs (with no corresponding change in income or other economic variables). In this world, the impact of increasing female labor force participation is clear. Letting \bar{x} represent the maximum extent of urban development and t represent the per unit distance cost of transportation:

$$\frac{\partial \bar{x}}{\partial FLFPR} = \frac{\partial \bar{x}}{\partial t} < 0$$

The inequality in the expression has been established by several analysts in the context of a monocentric model, notably Brueckner (1987).

Based on this, a simple model of urban land use would predict that an increase in the female labor force participation rate would, *ceteris paribus*, be associated with reduced urban land use and more compact cities. Note that even if this is found to be empirically valid, the claim does NOT imply a policy conclusion that policies that increase FLFPR (such as improved educational opportunities) will necessarily result in more compact cities, since these policies may also have impacts on transportation costs, household incomes, or other variables whose net contribution to urban expansion may be ambiguous.

III. Data

In order to determine the impacts of the female labor force participation rate and other economic variables on urban expansion we need to combine two types of data. First is the information required to measure the expansion of urban land use, and second is information on the economic and policy conditions that influence the pace of expansion so that we can test our models of urban expansion and determine the quantitative and qualitative nature of the relationships. For the first we rely upon remotely sensed satellite data and for the second we rely upon a variety of sources including data collected by field researchers deployed to each city in our sample. We discuss each in turn below.

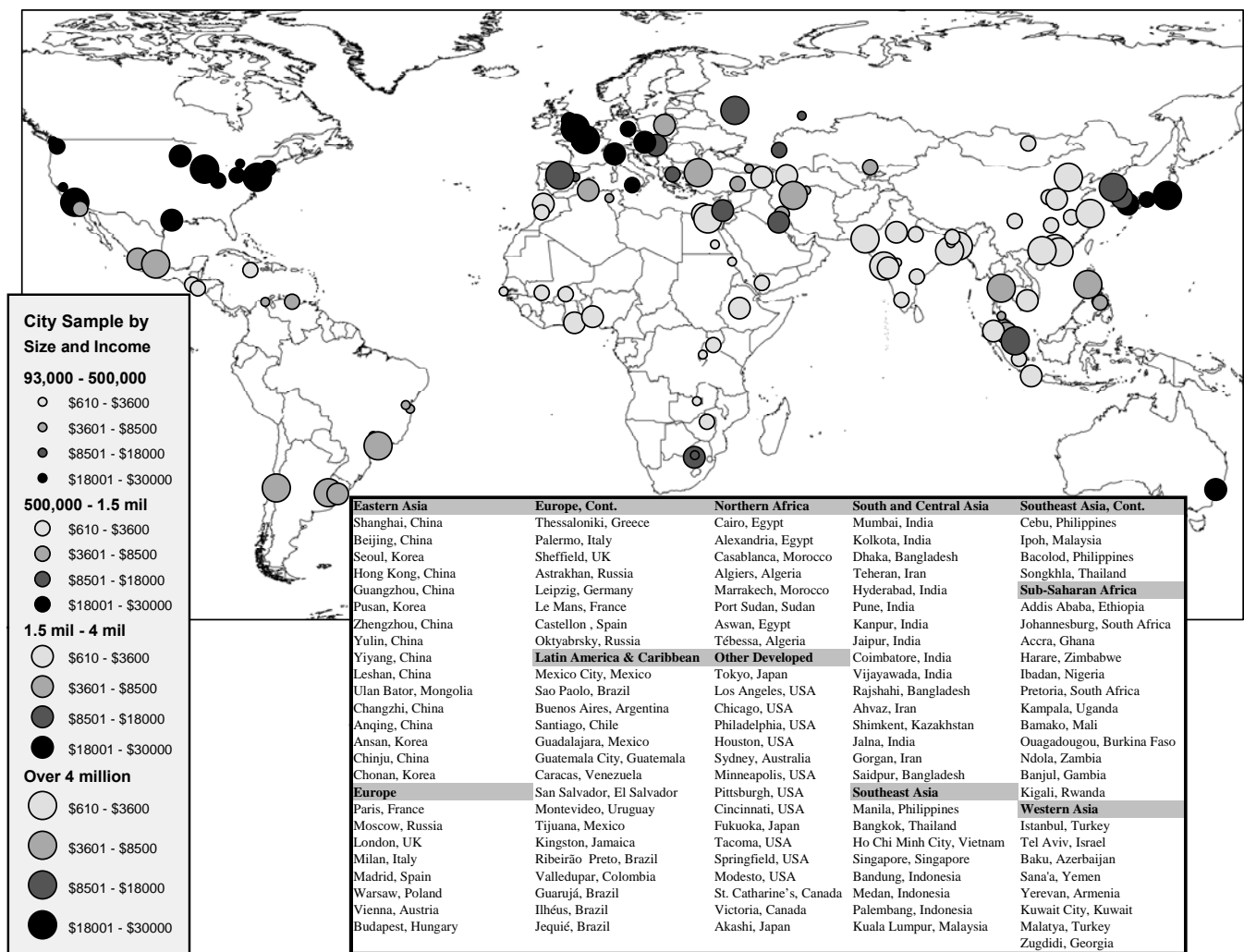


Figure 1: Global Sample of Cities

a. Urban land use

Our data are collected for a global sample of 120 cities. These were randomly selected from a larger random sample constructed by UN Habitat for data collection in connection with their Urban Observatory

program. The larger sample has been constructed to be representative of the global urban population in cities having population over 100,000 persons. The figure below shows the location of each city, with dots sized to indicate population and shaded to indicate per capita income. The table lists the cities by global region.

Remotely sensed data

For each of the cities in our sample, we obtained Landsat thematic mapper satellite images for dates that are relatively near the national census dates and for which cloud-free images are available. Images were obtained for two time periods: approximately 1990 and approximately 2000. The actual image dates vary and the sample mean time period between images is just over 11 years. The images themselves provide data on reflected light intensity in 7 spectral bands (3 visual and 4 infrared). These data are used to classify each point as urban (covered with impervious built structures or surfaces), water, or non-urban (everything else) in each time period. The light intensity data that constitute the images provide values for grids of pixels each of which represents a square region 28.5 meters on a side.

There are several commercial and non-commercial data sources that provide information on global land cover. Some of these can be very useful but we chose to develop our own classification for several reasons. First, many of global land cover classifications that have been undertaken are done at relatively coarse scales (typically 1 km grids) that obscure the microstructure of the urban areas including the open spaces interior to the built-up city. Even for those that are done at finer scale, the usual practice is to “fill in” small interior open spaces and classify them as urban. Our approach has been to regard such spaces as non-urban so that we can distinguish between new capital investment and building at the urban periphery and “infill” development building inside the built up area, and this will be discussed further below.

The actual classification of land cover was done using Erdas Imagine utilizing an iterated supervised cluster analysis approach. Three passes were used for each of the two images for each city. The goal was to provide a very simple classification suited to purposes of our research: to classify each pixel as ‘urban’ or ‘non-urban’ and then in post-processing to remove water pixels (which are easily identified using unsupervised classification).

Figures 2 and 3 present stylized views of ‘before’ and ‘after’ classification using actual data for the Chicago, USA metro area. Figure 2 shows the actual Landsat image covering most of the city. After completing the analysis the result was the data shown in Figure 3, where pixels are colored red if they

were ultimately categorized as predominantly under urban cover and tan if not. The small insets showing a region in the southwestern suburban fringe show the image for the region available online from Google Earth (on the left of each figure) and the ultimate classification showing the urban dynamic discussed in section 3 below.

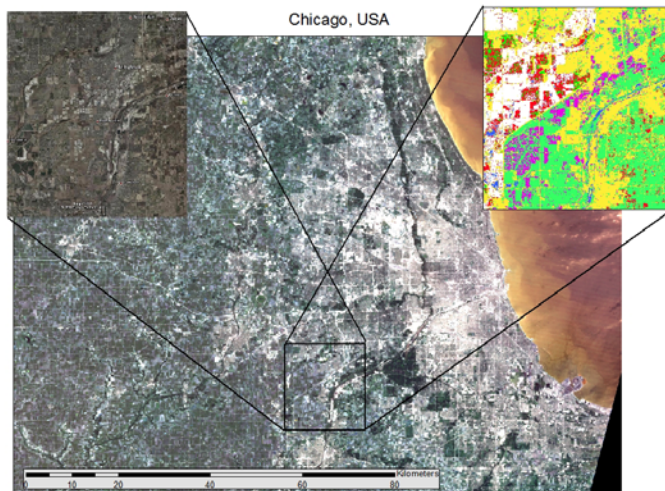


Figure 2: Chicago Landsat Image

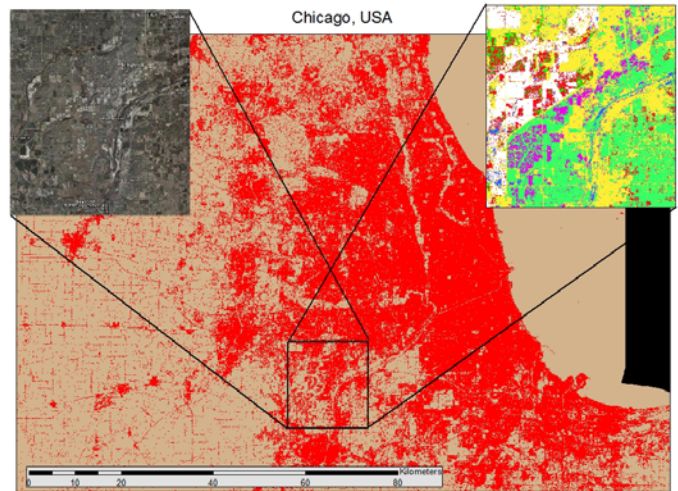


Figure 3: Chicago Urban Land Cover

All of the land cover classifications produced for our study are available for download from <http://www.williams.edu/Economics/UrbanGrowth/DataDownload.htm> in a format that will display in Google Earth. These images include links to photographs taken at ‘ground truth’ points (used for evaluating the accuracy of our classifications). The areas representing urban land cover have been filtered to eliminate all areas that do not represent at least 10 hectares of contiguous urban land cover. This greatly reduces the amount of data to be downloaded. The image for Chicago is shown in Figure 4 below.

An important advantage of the approach we have followed is that **identical** procedures and **identical types of source data** were applied for all 120 cities in both time periods. This is essential if we want to reliably combine and compare data from different time periods for the same city, and also if we want to use the data to assemble a panel data set that compares a cross-section of cities around the globe over time. Such data are central to our approach of measuring and modeling urban expansion. Further details concerning the remote sensing data and classification procedure are provided in Angel, Sheppard and Civco (2005).

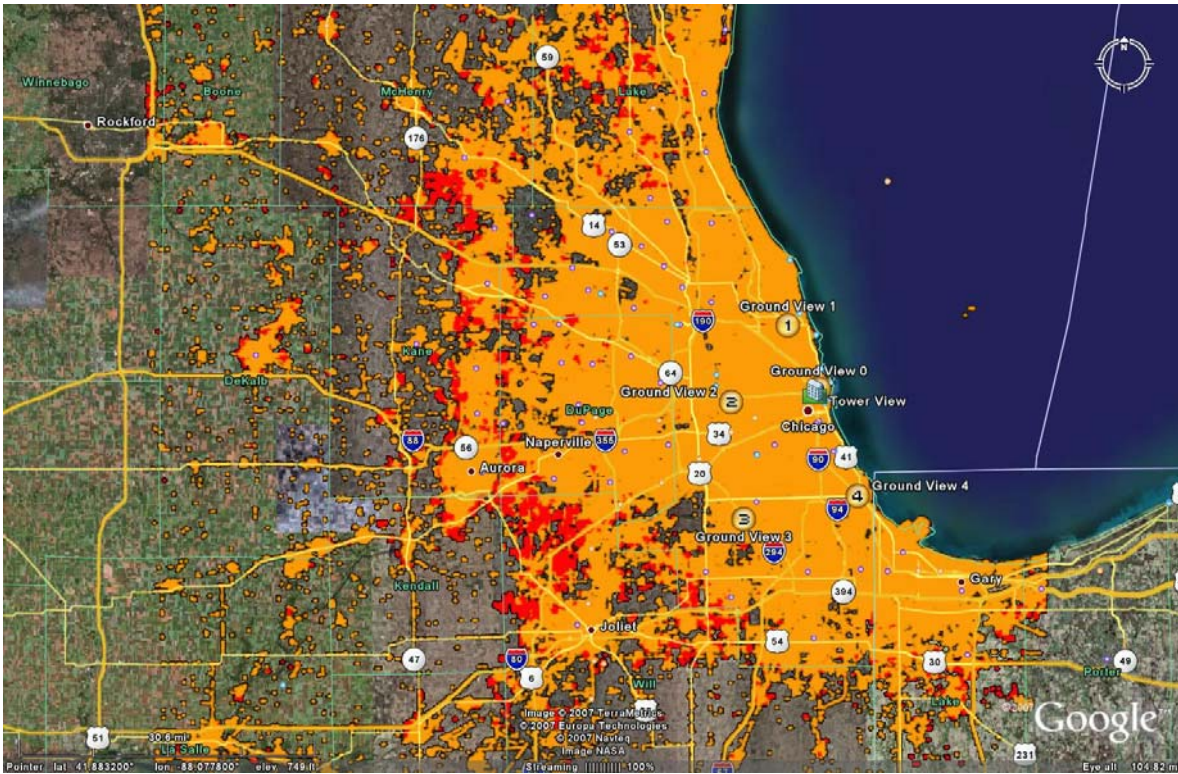


Figure 4: Chicago Urban Land Cover Available via Google Earth

b. Measuring Urban Expansion

Before proceeding to discuss models of observed urban expansion, it is necessary to make a few observations concerning our measures of urban land, the calculations of ‘urban dynamics’ and the microstructure of urban land markets.

Urban use and urban cover

As implied in the discussion above, since our approach to measurement of global urban expansion relies upon the use of satellite images in order to have comparable data for all cities, we actually measure urban cover (buildings and roofing material, asphalt, concrete and other impervious surfaces) rather than urban land use. What this means in principle is that we do not necessarily measure total land consumption by urban residents or producers. From the perspective of a satellite image, an urban worker who purchases a 1 hectare plot adjacent to her home and plants a large and elaborate flower garden is essentially indistinguishable from a rural peasant who grows vegetables on the 1 hectare field next to his farm house. From the perspective of urban land use theory, however, these two are very different. Irwin, et al. (2006), for example, are skeptical of reliance on urban cover as the measure of urban land use, and criticize the work of Burchfield, *et al.* (2006) and others for such reliance. They advocate instead use of cadastral data with associated recorded types of activities and uses actually taking place on the land.

While the use of cadastral data is no doubt interesting, there are two responses to be made. First is that many of the most interesting urban areas in the world have very limited cadastral systems and the data recording actual land uses may either be non-existent or so prone to error that they represent little improvement over remote sensing data. Second, in practice at the scale of land use in modest to large urban areas, it seems to make very little difference. Irwin, et al. (2006) compare remotely sensed with cadastral data in particular areas of the US and while they find the total amounts of land in each category different, the qualitative nature of changes and even the rates of change of different types of land use are similar using either measure.

Finally, we note that if one is interested in the ecological, economic or social value of open space then use of urban land cover data may be preferable. From the perspective of maintaining habitat for a variety of species or providing positive externalities for which residents are willing to pay, our hypothetical urban gardener may be as productive, even more so, than the peri-urban farmer. In any event, it should be acknowledged that the measure of urban expansion and urban land consumption used below is based on urban cover. We maintain the hypothesis that this measurement is very highly correlated with actual urban land use in consumption and production. In a sense, the empirical estimates derived below and compared with theoretical predictions of the comparative static properties of models of urban land use provide a test of this hypothesis.

Open space and infill development

The simplest theories of urban land markets identify urban land use as clustered around a central business district of the city, with density of urban land use gradually diminishing as distance from the city increases. Eventually the value of land in urban use falls to the level where land is more valuable in agricultural use than in urban use. That distance identifies the maximum extent of urban land use. Up to this distance, land should all be in urban use and after that distance all land is in agricultural use.

Real cities, of course, are never like this. There are areas of open, unbuilt land within – sometimes deep within – the urban area. We might regard these as mild departures from the “ideal type” of human settlement represented by our theory. Alternatively, we might note that these spaces arise for several reasons: land may be preserved for use as a public good (like a park), land may be owned by a person with idiosyncratic preferences who prefers the land this way (like our urban gardener discussed above),

the land itself may be heterogeneous so that some areas are more difficult to build on due to slope or drainage, and finally the dynamic structure of the urban economy may generate greater volatility of structure prices in some areas than in others. Areas with higher volatility present land owners with increased incentive to hold land vacant since, as observed by Titman (1985) and others, vacant land is equivalent to an option to buy a building in the future with an exercise price equal to construction costs.

Sheppard (2006) considers this issue explicitly in modeling the microstructure of urban land use, in which different parts of the city have different levels of coverage by urban surfaces versus open space. The issue is certainly relevant for understanding why some cities achieve much higher gross population densities than others and exhibit more compact spatial structure. Measurement of this microstructure at different points in time allows us to describe more completely the emerging dynamics of urban expansion. In a simply “von Thunen” style city, urban growth takes a very simple form: an increase in population or income simply adds another growth ring onto the periphery of the urban area. Again, actual cities exhibit more complex growth behavior because of the presence of interior unbuilt spaces. Using our classification of land use at two different points in time (T_1 and T_2) we can reveal considerable complexity. By combining the two classifications and undertaking considerably GIS computation, we divide and measure the land in the urban area into 9 categories:

	Category	Description
1.	Urban T_1	Land that was urbanized in T_1 (and remains so at time T_2)
2.	Interior Open T_1	Land that was unbuilt in T_1 but surrounded by land in urban use in T_1
3.	Exterior Open T_1	Land that was unbuilt in T_1 and was not surrounded by urban use
4.	Infill	Land that was Interior Open T_1 but under urban cover in T_2
5.	Outspill	Land that was Exterior Open T_1 but under urban cover in T_2
6.	Urban T_2	Urban T_1 + Infill + Outspill
7.	Interior Open T_2	Land that was unbuilt in T_2 but surrounded by land in urban use in T_2
8.	Captured Open T_2	Exterior Open T_1 but interior open in T_2
9.	Exterior Open T_2	Land that was unbuilt in T_2 and was not surrounded by urban use

Figure 5 below shows the final classification of Chicago into these land types.

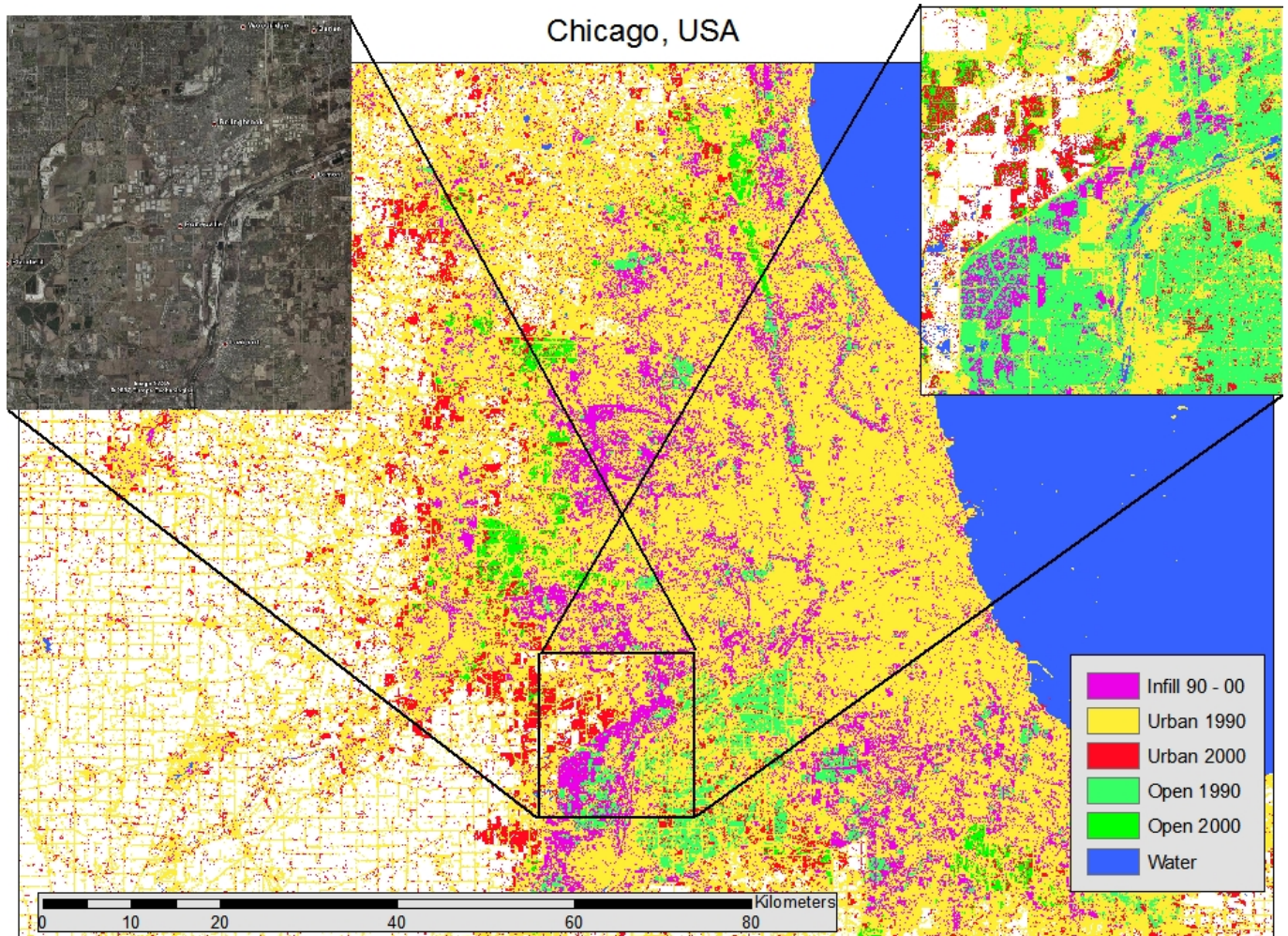


Figure 5: Chicago showing the microstructure and dynamics of urban expansion

Interestingly, there is considerable variation across the globe in the dynamics of urban expansion. In all countries, most urban expansion consists of outspill – new development on what was exterior open space. In some regions (such as North America and other non-European developed countries) urban expansion consists of a relatively high share of infill. In others (such as East Asia or South Asia) urban expansion involves very little infill. Table 1 below summarizes the regional patterns observed in our sample.

While Sheppard (2006) provides some discussion of how we might derive a theory to help explain these differences, and Cunningham (2006) provides suggestive empirical evidence on development probabilities for individual parcels in a single US city (Seattle), at this point it must be observed that standard economic theories have little to offer by way of an explanation for these differences.

Table 1: Division of urban expansion between infill and outspill

Regional variation in infill and outspill					
Region	Infill	% Infill	Outspill	% Outspill	Freq.
East Asia	12.608	6.159	234.849	93.841	16
	14.714	4.962	282.265	4.962	
Europe	22.174	14.231	116.851	85.769	16
	31.165	9.166	111.874	9.166	
LAC	19.489	17.339	68.138	82.661	16
	26.967	10.955	68.371	10.955	
North Africa	7.248	9.263	77.807	90.737	8
	8.553	7.578	69.979	7.578	
Other Developed	73.309	22.830	184.889	77.170	16
	85.016	20.012	157.840	20.012	
South Central Asia	7.815	7.554	74.883	92.446	16
	9.628	5.155	55.208	5.155	
Southeast Asia	16.461	12.646	113.593	87.354	12
	22.892	7.007	124.924	7.007	
Sub-saharan Africa	9.590	9.216	75.170	90.784	11
	13.376	7.131	54.653	7.131	
West Asia	9.562	9.179	96.786	90.821	8
	12.056	4.686	100.448	4.686	
Total	21.881	12.525	121.517	87.475	119
	41.119	11.235	147.691	11.235	

Our main concern here, however, is with measuring and modeling overall urban expansion. Traditional monocentric urban models do make clear predictions about the variables that are likely to impact urban land use, and the qualitative impacts of changes in these variables.

c. Labor force participation and transport costs

In addition to the data on urban land cover and its components discussed above, and the economic and population data discussed in the following section, our analysis makes use of two variables that we have constructed and that are not typically used by researchers. We single these out for more extensive discussion.

Female Labor Force Participation Rate

While there are several sources of data for the female labor force participation rate, we combined data on the total number of working age females in each country, total employment by gender for each country, and (where possible) total unemployed persons by gender for each country. All of our data are at the national level, and are drawn from combined UN and World Bank data sources. The resulting derivations

compare reasonably well with published results for the female labor force participation rate in countries (like the US) where the participation rate is routinely calculated and reported.

We calculated participation rates for each time period for the year in which the satellite image used to measure urban land cover was collected. Most cities experienced an increase in the FLFPR during the time period between the images. As shown in Table 2 below, the average increase is about .09. There is considerable variation, however, across the sample. There are 15 cities that experienced decreases in the FLFPR, with the largest decrease being a decline of -0.28. Eight of these cities were in countries that also experienced declines in real incomes. There were 7 cities in 4 countries (Egypt, Turkey, Hungary and Poland) that appear to have experienced declines in the FLFPR while also experiencing increases (although modest) in real incomes.

Female labor force participation rates, while often considered an indicator of development, are not monotonically related to per capita income. As shown in Figure 6 below, there is a “U-shaped” relation that is apparent between income levels and FLFPR.

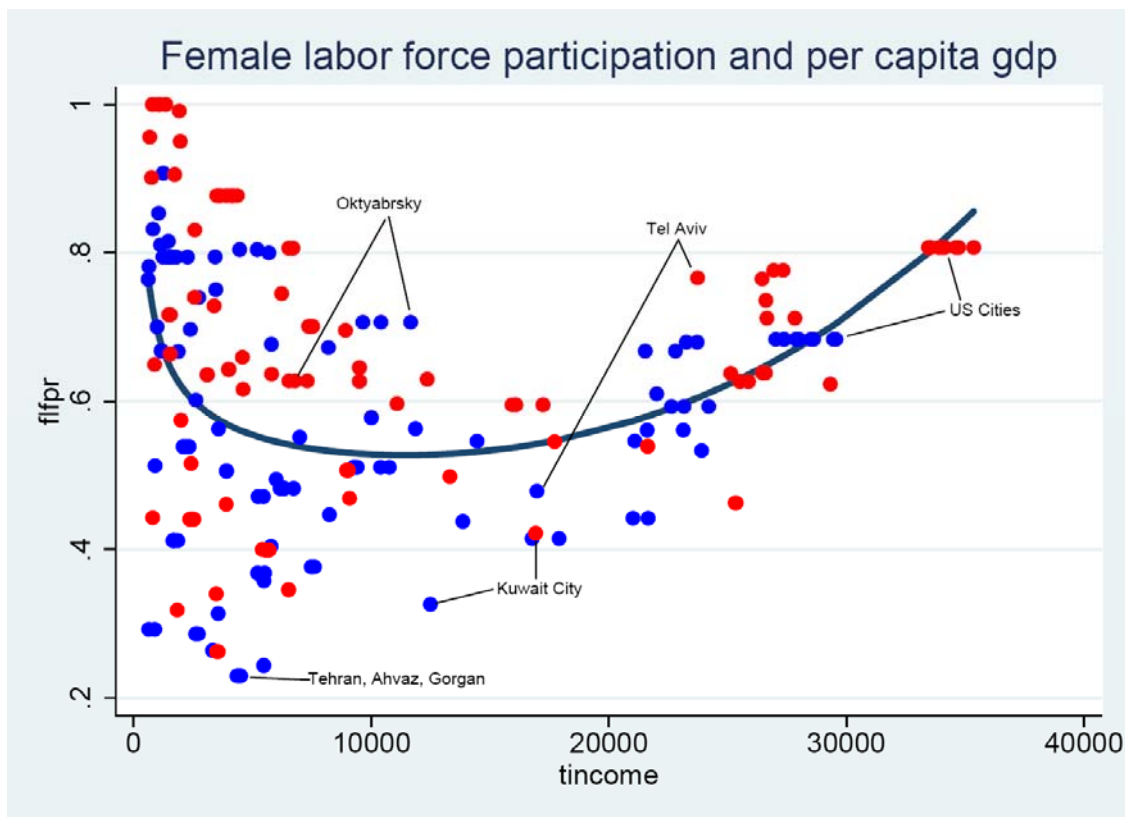


Figure 6: relation between FLFPR and per capita income

In the figure, the blue dots indicate the position of a city at the time of the first image (approximately 1990) and the red dots correspond to the time of the second image (approximately 2000).

Time cost of travel

We make use of two variables to capture the time cost of travel. The first is the real cost of motor fuel at the pump, taken from World Bank data sources. Naturally, the fuel costs are only a small part of the total costs of travel, with time costs generally being more significant in household decision making. In empirical models that focus on a single city, it is generally safe to rely on a single measure because the price of motor fuel is roughly equal throughout the urban area, and the fuel costs are highly correlated with the time costs of travel.

When modeling urban form across a global cross-section of cities, however, this comfortable relationship breaks down. Road capacity varies greatly between cities, affecting the average speed of travel. In addition, local wage rates vary so that the economic sacrifice associated with commuting varies. To address this problem, we have relied on data collected by our field researchers in each of the 120 cities in our sample.

Each field researcher was asked to travel by car to each of 4 or 5 different points within the urban area. They recorded the time elapsed between each point, and the total number of kilometers traveled. They also collected (using a handheld GPS device) the exact coordinates of the location for each stop. An example, Figure 7 below shows the urban land cover for Budapest, Hungary. The five locations labeled “Ground View” are the five stops on the journey around the city taken by our field researcher.

This information was used to calculate an average speed of travel during the journey. The speed data were then combined with information collected on local incomes to produce an estimate of the time cost per kilometer of travel. As shown in Table 2 below, this averages 0.25 \$ppp per kilometer of travel, but varies from a minimum of .01 to a maximum of \$1.73. These data provide a novel opportunity to examine the impact of changing the time costs of travel on urban form, and permit a more careful filtering of this cost to assist in isolating the separate impact of female labor force participation.



Figure 7: Budapest, Hungary – showing ‘Ground View’ locations

d. Other economic variables

The urban land cover data described above are matched with population data for jurisdictional boundaries in each area, obtained from the Center for International Earth Science Information Network’s Global Rural-Urban Mapping Project. Using growth rates observed for each jurisdiction during 1980 through 2000 we interpolate to obtain population estimates for the dates of each image. There are many cases where the Landsat images did not provide complete coverage of the jurisdictional boundaries for which population data were available. In these cases we sometimes purchased additional Landsat images, but in other cases made use of an interpolation procedure using our land cover classification and distance from the urban center to apportion the jurisdiction population between portions covered by our remote sensing images and the portions not covered. In general the data include not only the jurisdictions covering the central city and largest contiguous regions of classified urban land cover, but extend to peripheral jurisdictions until the mean size of contiguous urban cluster falls below 25 hectares. This provides coverage that approximates a “metro area” definition for all cities even though for most of the cities we

lack the data on labor markets and commuting patterns generally required for formal definition of such areas.

We also interpolate national per capita GDP to the date of the satellite image to provide an estimate of income levels in each city matched to the remote sensing data. Data on biome type, availability of shallow groundwater aquifer, air transport links, and the value of agricultural land (approximated by agricultural output per hectare) were obtained from World Development Indicators or from sources described more fully in Angel, Sheppard and Civco (2005)

Table 2: Descriptive Statistics for Sample

Variable	Mean	Std. Dev.	Min	Max	Obs
Total urban land (km ²)	402.81	635.11	8.92	4,268.00	240
Total Population	3,363,025.00	4,459,765.00	93,040.91	27,200,000.00	240
Per capita income (ppp \$)	\$9,914.08	\$9,916.70	\$609.88	\$35,354.00	240
Agricultural rent (ppp\$ / ha)	\$3,347.65	\$12,569.78	\$68.84	\$150,542.90	240
Fuel cost (ppp\$ / US gallon)	\$0.62	\$0.36	\$0.02	\$1.56	240
Air linkages	108.21	133.39	0	659	240
Shallow ground water	0.24	0.43	0	1	240
East Asia	0.13	0.34	0	1	240
Europe	0.13	0.34	0	1	240
Latin America	0.13	0.34	0	1	240
North Africa	0.07	0.25	0	1	240
South Central Asia	0.13	0.34	0	1	240
Southeast Asia	0.10	0.30	0	1	240
Sub-saharan Africa	0.10	0.30	0	1	240
West Asia	0.07	0.25	0	1	240
Other Developed Countries	0.13	0.34	0	1	240
Years between images	11.24	2.21	5.19	16.97	240
Change in total urban land	115.21	126.09	3.19	549.66	240
Growth rate in urban land	0.05	0.05	0	0.36	240
Urban rank	19.09	38.05	1	196	240
Cars per 1000 in country	139.47	180.55	0.39	573.28	238
Non rush hour travel speed (KPH)	27.11	13.64	2.61	75	198*
Maximum urban slope (%)	25.96	14.96	4.16	78	240
Pct Agriculture Female	9.07	9.41	0.10	48.28	240
Female labor force participation rate	0.60	0.18	0.23	1.00	240
Change in FLFPR	0.09	0.09	-0.28	0.29	240
Wage (ppp\$) per KM	0.25	0.30	0.01	1.73	198

Table 2 presents descriptive statistics for the central variables used in our modeling for two times periods and 120 cities. Use of a globally representative sample provides extensive variation in the data, with cities ranging from under 9 square kilometers to over 4200, and population in the ‘metro area’ ranging from 93,000 to over 27 million persons.

In addition to the variables used in the models of urban expansion presented below, Table 2 provides information on additional variables that are likely to be of interest. While the sample includes many primate cities (of rank 1 in the national urban system) it includes cities down to rank 196 as well. The rate of automobile ownership varies across the sample even more than per capita income, although in general it is income rather than automobile ownership that turns out to be the most important factor influencing total urban land cover. In part this may be because increased automobile ownership does not necessarily imply reduced transportation costs, since congestion can slow travel considerably below the maximum speed of the vehicle. The average non-rush hour travels speeds are seen to vary widely. These have been collected by our field researchers.

IV. Analysis

Our data permit two types of test of the prediction that increasing FLFPR will be associated with reduced urban expansion. One is to estimate the impact based on the change, in each city, of total urban land use as a function of the change in population, change in income, change in the female labor force participation rate, and changes in agricultural land values, global linkages, fuel costs in each city. There are two difficulties with this approach. First is that it reduces our sample size from to 118 cities (the number for which we have all of these variables at both time periods. The second problem is that while we might be comfortable using average travel speeds measured by our field researchers as applying to both the time period of the first and of the second images, if we take the first difference of these we will have no variation in the sample to determine an impact of the time cost of travel.

Table 3 presents our estimates of the first difference models. The dependent variable in each case is the change (in square kilometers) in total urban land cover. Each column presents parameter estimates and, beneath each estimate, the standard error of the estimate. An estimated parameter is marked with *** if the estimate is statistically significant at the 1% level, with ** if it is statistically significant at the 5% level, and with * if it is statistically significant at the 10% level.

While the small sample size might be blamed for several variables being insignificant, the impacts of population and income are significant and affect urban land use as we would expect: increasing either of these is associated with increasing urban land use. The impact of fuel costs and agricultural rents are similarly of the sign that would be predicted by theory. An increase in fuel costs or in the value of agricultural land is associated with less urban expansion.

Most interestingly from the perspective of the central question of this paper, an increase in the female labor force participation rate is associated with a reduced level of urban expansion after adjusting for the other factors in the model. The estimate imprecise and not statistically significant in models 1 and 2, but does (barely) reach significance at the 10 percent level in model 3. Overall, it would seem that our first-difference models offer confirmation, if somewhat weak, of the expected impact.

Table 3: First-difference models of urban expansion

Variable	Model 1	Model 2	Model 3
Δ Population	0.0001*** <i>0.0000</i>	0.0001*** <i>0.0000</i>	0.0001*** <i>0.0000</i>
Δ Income	0.0074*** <i>0.0020</i>	0.0074*** <i>0.0020</i>	0.0074*** <i>0.0020</i>
Δ Air linkages	-0.0026 <i>0.2260</i>		
Δ Agric Rent	-0.0118 <i>0.0090</i>	-0.0118 <i>0.0080</i>	-0.0118 <i>0.0080</i>
Δ FLFPR	-171.9459 <i>107.8490</i>	-171.9566 <i>107.3530</i>	-172.3025* <i>106.5550</i>
Δ Fuel Cost	-2.6923 <i>52.4800</i>	-2.698 <i>52.2390</i>	-2.0949 <i>50.0010</i>
T₁ Agric Rent	-0.0057** <i>0.0030</i>	-0.0057** <i>0.0030</i>	-0.0057** <i>0.0020</i>
T₁ Fuel Cost	1.5449 <i>36.9910</i>	1.5471 <i>36.8220</i>	
F	11.19	12.91	15.2
Adj R²	0.4107	0.4161	0.4213
Root MSE	97.779	97.333	96.894

Our next set of models incorporates a much richer set of variables, taking each city in each time period as an “observation” and correcting for clusters and variables fixed within cities by including fixed effects variables for all cities.

In these models endogeneity is of particular concern, since income producing activities and population might be differentially attracted to large (or expansive) cities. Each model is therefore estimated using an instrumental variables approach. The instruments used for the estimation are the same as were used in Blomberg and Sheppard (2007), and make use of local environmental conditions and climate. The estimates are presented in Table 4.

These models provide stronger confirmation of the expected relationship. With one exception, the models indicate that higher levels of the female labor force participation rate are associated with reduced levels of

total urban land use. In three of the models the estimated impact is statistically significant at the 1% level. For these models the estimates are very close to 1. To understand the implications of this consider that the information in Table 2 above indicates that on average, cities in our sample experienced a 15% increase in the FLFPR during the 1990s. If population, income, and other variables had remained constant, this would be associated with about an equal reduction in total urban land use.

Table 4: IV Estimates of Total Urban Land Use

Variable	Model 4	Model 5	Model 6	Model 7	Model 8
Population	0.5206*** <i>0.1070</i>	0.9539*** <i>0.0840</i>	0.8622*** <i>0.1080</i>	0.6783*** <i>0.0810</i>	0.6806*** <i>0.1110</i>
Income	1.686*** <i>0.2290</i>	0.0569 <i>0.1550</i>	0.5303*** <i>0.2130</i>	0.5275*** <i>0.1610</i>	0.7861*** <i>0.1440</i>
Wage/KM	-0.6162*** <i>0.1430</i>	0.0955 <i>0.0900</i>	-0.1993 <i>0.1320</i>	-0.1556 <i>0.1030</i>	-0.0987 <i>0.0970</i>
Fuel Cost	0.0933 <i>0.1350</i>	-0.3541** <i>0.1480</i>			0.0347 <i>0.1220</i>
Air Linkages	0.2138*** <i>0.0550</i>		-0.0465 <i>0.0470</i>		0.1157** <i>0.0570</i>
Agric. Rent	-0.1364 <i>0.1030</i>	-0.3676*** <i>0.0850</i>	-0.3867*** <i>0.0740</i>	-0.4355*** <i>0.0650</i>	-0.3078*** <i>0.0520</i>
FLFPR	-1.5173*** <i>0.3310</i>	0.1374 <i>0.3430</i>	-1.0925*** <i>0.3540</i>	-0.2967 <i>0.2260</i>	-0.9764*** <i>0.2540</i>
Pct Ag Fem	0.2845 <i>0.2200</i>	-0.3095** <i>0.1270</i>	-0.2472 <i>0.1740</i>	-0.3003*** <i>0.1070</i>	
F	22.55	26.09	22.24	36.2	30.31
Adj R2	0.914	0.926	0.913	0.947	0.936
Root MSE	0.373	0.347	0.375	0.294	0.322

Of course, population, income, and other variables don't remain constant and change by amounts that are generally large enough to overwhelm any tendency towards reducing urban land use.

One other variable is worth noting in the context of the impact of changing economic roles for women. As we noted above, if the employment locations chosen by women were relatively suburbanized, the impact on urban form would be moderated. To make some effort to capture this effect, we include a variable that measures the percentage of the agricultural labor force that is comprised of women. This variable is of course somewhat collinear with the female labor force participation rate, so its impact is difficult to separate from the impact of the FLFPR itself. In most of the models, increasing involvement of women in the agricultural labor force is associated with reduced urban land use, but the numerical magnitude is smaller and less frequently statistically significant. We interpret this as being broadly consistent with our theoretical expectations discussed above.

V. Conclusions

We have collected and made use of a unique global data set on urban land use and its driving forces. Using these data, we ask a simple question: what is the impact, holding other factors constant, of increasing the female labor force participation rate? Theoretically, we expect increasing FLFPR to be associated with more compact cities.

We consider both simple first difference models of urban land use and cross-section models estimated using instrumental variable techniques. In general we find support for the theoretical predictions. An increase in the FLFPR appears to be associated, *ceteris paribus*, with reduced urban land use.

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