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The Impacts of Terrorism on Urban Form

DURING THE PAST DECADE, terrorist attacks in New York, Washington, London, and other major cities have been popularly regarded as having profound impacts on the security and confidence of urban residents. The loss of life and damage to structures that transforms the urban landscape may similarly transform the structure of the urban economy. For example, many of the companies that resided in the World Trade Center were forced to relocate to midtown and the outer boroughs or New Jersey. Still others—no one knows for sure how many—have disappeared altogether. The World Trade Center housed 700 companies employing some 50,000 people. What happened to these firms and workers? More generally, what happens to economic agents in the aftermath of a terrorist attack?

Fortunately, terrorist attacks of the magnitude of those that struck the United States on September 11, 2001, are rare and extraordinary events. In some cities, however, the terrorist attacks can be unrelenting, providing a constant threat of danger for years on end. These events, and the use of these tactics, could have significant impacts on the economic vitality of an urban area and the form of urban development. In this paper we address this issue by cataloging a large sample of terrorist attacks in major cities in the past two decades and linking these data to a new data set providing information on urban land use in a globally representative sample of cities. In doing so,

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we examine whether events like September 11 and much more frequent, smaller attacks influence the decisions to build and rebuild cities.

This issue has been addressed extensively in the news media. Some have raised doubts about the viability of open cities with easily accessible public transportation systems. Some fear that organizations may disrupt economic activity by creating a "climate of terror." Stephen Ambrose of the *Wall Street Journal* has suggested that cities should reorganize by employing existing technology in electronic communication to limit population density virtually. Others such as Admiral William Crowe have advised companies to move away from dense urban centers and toward low-profile locations. Seager, Moore, and Long, writing in the *Guardian,* even go so far as to provide estimates on how much output was reduced in London and the United Kingdom following the July 2005 attacks. They estimate that London's output fell 0.6 percent and national output fell 0.1 percent.[1] Although, in the context of the national economy, these numbers may seem modest, when concentrated in a single urban area or part of the city, the impact of a sustained pattern of attacks over a longer horizon would soon disrupt the economy of any urban center.

Other experts expect little or no impact. Much of the empirical economic research has concurred with this group of commentators. Harrigan and Martin provide one of the first papers analyzing the impact of terrorism on urban structure.[2] They develop a model based on a new economic geography model of the type used by Krugman, in which wage variability across firms may be smoothed through worker relocation to market centers.[3]

Harrigan and Martin employ both a labor pooling and core-periphery model to examine the impact of terrorist attacks on urban centers. In both cases, they find that a one-time attack has no significant long-run impact on relocation. However, an ongoing threat can act as a tax on a particular region. In the core-periphery model, an ongoing risk of terrorism causes workers to leave the large urban centers and reduces firm agglomeration. In summary, they find that one-time terrorist events are unlikely to create significant changes in urbanization, whereas repeated attacks can create a climate of terror, leading to lower rates of urbanization.

1. Seager, Moore, and Long (2005). Estimates are provided by Douglas McWilliam of the Centre for Economics and Business Research.
2. Harrigan and Martin (2002).
3. Krugman (1991).

Glaeser and Shapiro employ historical data to analyze the impact of war on cities.[4] They find that the effect of wars on urban form can be large (for example, Berlin in World War II), but that more commonly neither terrorism nor war has significantly altered urban form. Glaeser and Shapiro's work supports Harrigan and Martin, positing that terrorism can only be viewed as significantly reducing urban centers when the threat of attack is large or ongoing.

Redfearn examines land-rent gradients around potential targets for evidence that consumers' perception of risk from terrorism changed following the September 11 attacks.[5] In doing so, he seeks to measure the extent to which the risk of future attacks in Southern California affected the real estate market. He analyzes the housing markets in the Long Beach and Los Angeles areas, concentrating on airports as potential targets. He finds insignificant changes in prices and sales volume in these neighborhoods following the attacks.

Somewhat larger negative impacts are found in Gordon and others, who estimate the economic impact of a terrorist attack on the twin ports of Long Beach and Los Angeles, and in Bae, Blain, and Bassok, who estimate the economic impact of a terrorist attack on Seattle.[6] However, their models focus primarily on route diversion. For example, Bae, Blain, and Bassok find that total travel time increases 10.7 percent if bridges are destroyed and 15.6 percent if bridges and interstates are knocked out.[7] The increases are obviously greater during peak periods. The upper-end cost estimate is $808 million for bridges destroyed and $1.144 billion for bridges and interstates shut down.[8]

There are many possible reasons why the impact of terrorism on urbanization has been less worrisome than originally discussed in the aftermath of September 11. One possibility is that the impact really is small so that concern over terrorism's negative influence on cities has been misplaced. Another possibility is that much of the recent empirical research has been highly focused on the United States, which has only recently been the subject of large-scale terrorist attacks. There are no published studies that consider the impact of sustained terrorist presence in a broad sample of cities and regions around the globe.

4. Glaeser and Shapiro (2002).
5. Redfearn (2005).
6. Gordon and others (2005); Bae, Blain, and Bassok (2005).
7. Bae, Blain, and Bassok (2005, p. 293).
8. Bae, Blain, and Bassok (2005, p. 295).

Rossi-Hansberg develops a more detailed theoretical model that allows the agents residing in urban areas to respond to an *ongoing* threat of terrorism.[9] In the model, firms benefit when locating near other productive firms, providing an incentive for clustering and urbanization. However, firms must face the risk of capital destruction at each location where the density of investment exceeds a certain level due to the likelihood of a terrorist attack. This risk reduces the incentive to cluster, decreasing urbanization. Rossi-Hansberg shows that, in a model with no adjustment costs, a terrorist attack reduces investment in residential areas and makes the capital density gradient flatter. While the impacts may be small, he shows that in a model with adjustment costs, destruction of an area reduces productivity in nearby areas of the city and leads to a slower recovery of the destroyed area.

The important difference in the impact of terrorism on urban form in Rossi-Hansberg's paper appears to stem from the degree of persistence of terrorist shocks and their associated adjustment costs. Hence, his paper provides theoretical support for the previous studies that found little impact of terrorism on urbanization if the events in question were relatively transitory and adjustment costs were relatively small. Since much of the previous research examined one-time events, often in countries with relatively well-developed and flexible political systems, it is not surprising that the magnitude of the effects is modest. If instead one were to match these events with others across the globe where the risk is more pronounced and persistent and the polity is less able to aid in reconstruction, then one might find something different altogether.

As evidence, Sheppard points to the reconstruction of urban systems after major wars and continued population growth in select cities subject to terrorist attack.[10] By considering a larger cross section of cities, he is able to examine the impacts of a greater degree of variation than had been studied previously. He finds limited evidence that terrorism can actually reduce the urban footprint. That work is limited in scope in that it does not address the temporal component of terror. Only when considering both a larger time and country sample can one uncover the possible negative correlation due to both the persistence and variability of the risk of terrorism.

This paper analyzes the issue using two rich data sources that allow us to measure carefully both the probability of a terrorist attack and the urban footprint. We use a new source of data on urban structure based on a global sam-

9. Rossi-Hansberg (2004).
10. Sheppard (2005).

ple of cities located around the world. The sample is constructed to be representative of the global urban population in cities with more than 100,000 residents, and each city is observed at two points in time, roughly a decade apart. We combine these data with information that calculates the incidence of terrorist attacks in major cities during the same time period. Integrating these two data sets allows us to investigate how terrorism has influenced urbanization globally. This allows us to estimate precisely the impact of terrorism on urban land use temporally and spatially. In doing so, we find that terrorism has a statistically significant negative effect on urbanization. We estimate that a doubling in the number of terrorist attacks to which a city has been subject over a decade results in about a 20 percent decline in urban land use, holding population, income, and other factors constant.

The magnitude of the effect is larger than reported in previous studies. We believe that our estimated effect is larger because we analyze the impact in cities that span the globe rather than in concentrated localized areas, as others have done. There are a variety of possible reasons why the effect may be so large. First, there may be an "option value" effect. That is, in the aftermath of a spate of terrorist attacks, new construction may halt as investors keep open their options to build at a future date, after the nature of the terrorist threat is understood more clearly. Second, there may be an investment substitution effect. In other words, new construction may relocate into sister cities that appear to be safer havens than the terrorist hot spots.

Modeling the Impact of Terrorism

Angel, Sheppard, and Civco develop a model based on Brueckner to derive the comparative static properties of total urban land use with respect to urban population, income levels, agricultural land values, transport costs, and productivity of land in the production of housing and an export good.[11] There are several ways in which this model could be extended to account for the impacts of terrorism.

Following the research of Gordon and others, we might regard terrorism as increasing the effective cost of transportation.[12] Essentially, each journey in an urban area subject to terrorist attacks imposes on the commuter or transported goods a risk of injury or damage, and we might regard this as an increase in

11. Angel, Sheppard, and Civco (2005); Brueckner (1987).
12. Gordon and others (2005).

transport costs. If the risk of terrorist attack is distributed evenly throughout the urban area, the impact would be the same as a general increase in transport costs and we would expect terrorism to reduce total urban land use, ceteris paribus. If the threat of attack is concentrated near the urban center (for example, government offices), then the effect could be more complex, with possibly ambiguous implications for total urban land use if the costs could be avoided by choosing peripheral locations for production. If the threat of attack is concentrated at points near the urban periphery (for example, airports or resorts), then the tendency to increase urban density and decrease total urban land use would be even greater than if the risk of attack were uniform.

An alternative approach, suggested by the models developed by Harrigan and Martin, is to regard terrorism as a type of tax on economic activity in the urban area subject to attack.[13] The simplest form for such an approach would be to consider terrorism as equivalent to a lump-sum tax imposed on firms, avoidable only by relocating to an urban area not under threat. In an open city with free mobility between urban areas, producers would relocate so that returns to capital are equalized between cities. In this case, an increase in terrorism would lead to fewer (or smaller) firms, reducing urban land use. Harrigan and Martin obtain a similar result (in a different type of model) and argue that sustained terrorism could be sufficient to overcome agglomeration economies and lead to the loss of firms from the urban area.[14]

One criticism of these two approaches is that they fail to capture the intrinsic character of terrorist attacks:[15] they are violent, designed to cause fear in the potential target, and, while the targets are chosen with the goal of creating fear or anger, the events themselves are random or extremely difficult to predict. While the type or severity of the events might be anticipated in general, their occurrence at a particular location is uncertain. This sug-

13. Harrigan and Martin (2002).

14. Harrigan and Martin (2002).

15. The United Nations "academic consensus" definition portrays terrorism as follows: "Terrorism is an anxiety-inspiring method of repeated violent action, employed by (semi-) clandestine individual, group, or state actors, for idiosyncratic, criminal, or political reasons, whereby—in contrast to assassination—the direct targets of violence are not the main targets. The immediate human victims of violence are generally chosen randomly (targets of opportunity) or selectively (representative or symbolic targets) from a target population and serve as message generators. Threat- and violence-based communication processes between terrorist (organization), (imperiled) victims, and main targets are used to manipulate the main target (audience), turning it into a target of terror, a target of demands, or a target of attention, depending on whether intimidation, coercion, or propaganda is primarily sought."

gests that the analysis should incorporate some dynamic considerations and uncertainty in anticipating the impact and the consequent volatility in the flow of rents or services from land or investment at a particular location.

Blomberg and Sheppard develop a simple version of such a model, in which an increase in terrorism increases the volatility of land values, increasing the option value of vacant land.[16] These results are relatively well known and date back to Titman's seminal paper.[17] A version of the model in which the risk of terrorist attack varies systematically through the urban area could also be derived in the context of the approach of Capozza and Helsley, whose model similarly suggests that an increase in uncertainty increases the value of nonurban land.[18] In either case, the expected impact of terrorism is an increase in uncertainty and hence the volatility of urban land values. This increases the incentive for landowners to hold land vacant and makes conversion of land from nonurban to urban use more difficult, reducing total urban land use.

Does this model imply that the impact of terrorism is felt only at the urban periphery? Not in general. The model implies that urban areas that experience increased levels of terrorism will have reduced urban land use, ceteris paribus. Some of this reduction in urban land use may occur by holding interior space in nonurban form. While simple textbook models have urban land conversion occurring only at the outer periphery of the metropolitan area, actual cities, of course, have extensive open space contained within them (unbuilt land that is completely surrounded by urban land use). Much of the urban land conversion that we observe consists of filling in these interior open spaces. For example, Sheppard finds that, in the same sample of cities analyzed in this paper, total urban expansion could be divided between this type of infill development and "outspill" development at the urban periphery.[19] The share of urban expansion that is infill ranges from more than 22 percent for cities in industrial countries to just over 6 percent for cities in East Asia. Furthermore, even the urban expansion classified as "outspill" can often be relatively close to the inner areas of the city because of irregularity in the patterns of urban development. In summary, the model predicts that an increase in terrorism leads to a reduction in urban land use. When we imagine a developer contemplating a large, irreversible investment on a currently vacant site, it seems quite plausible to

16. Blomberg and Sheppard (2007).
17. Titman (1985).
18. Capozza and Helsley (1990).
19. Sheppard (2007).

Table 1. Model Predictions

Prediction	*Comparative static result*	*Description of prediction and hypothesis*
1	$\frac{\partial \bar{x}}{\partial L} > 0$	An increase in population will increase urban land use and urban expansion.
2	$\frac{\partial \bar{x}}{\partial y} > 0$	An increase in household income will increase urban land use and urban expansion.
3	$\frac{\partial \bar{x}}{\partial A} < 0$	An increase in terrorism will reduce urban land use and limit urban expansion.
4	$\frac{\partial \bar{x}}{\partial t} < 0$	An increase in transportation costs will reduce urban land use and limit urban expansion.
5	$\frac{\partial \bar{x}}{\partial r_f} < 0$	An increase in the opportunity cost of nonurban land will reduce urban land use and limit urban expansion.
6	$\frac{\partial \bar{x}}{\partial f_l} > 0$	An increase in marginal productivity of land in production of the export good will increase urban land use and urban expansion.

suggest that an increase in terrorist attacks could lead the developer to delay that investment, perhaps for decades.

Before proceeding to describe the empirical tests of the hypotheses derived from this model, we might wonder whether the uncertainty from relatively unusual events, even as frightening and significant as a terrorist attack, could significantly alter urban form and the incentive to develop. One might argue that these events, bad as they are, average out over the hundreds of locations within an urban area.

A recently published study by Cunningham undertakes a detailed, parcel-by-parcel analysis of properties in Seattle, Washington.[20] The study tests for impacts of uncertainty about future housing prices and finds strong support for an options model of land development such as we are using. He finds that a one standard deviation increase in price uncertainty increases vacant land prices modestly (1.6 percent) and reduces the likelihood of development of the parcel (11 percent). This important finding suggests the possibility that data from a cross section of cities might provide similar results: an increase in uncertainty associated with an increase in terrorist activity might have a detectable impact on urban structure.

Table 1 summarizes our predictions concerning the impact on total urban land use and urban extent resulting from changes in key parameters.

20. Cunningham (2006).

The Data and Empirical Regularities

In assembling our data, we combine terrorism and urban development data with international economic data.[21] This has certain implications for the organization of our data. Our analysis proceeds using either a city-year or country-year panel, so we convert data on the incidence of terrorism (and other variables) accordingly. Our intent is to examine the effects of terrorism on urban land use, controlling for myriad other factors that could also affect the incidence of terrorism.

Terrorism Data

Several sources of data provide information on terrorist incidents around the world. We employ the Terrorist Knowledge Base (TKB) of the Memorial Institute for the Prevention of Terrorism (MIPT), which includes a computerized database of worldwide international terrorist incidents since 1968. While the database coverage is quite extensive, it generally excludes violence carried out by terrorists within their own country against their own nationals and terrorism perpetrated by governments against their own citizens (even if located abroad). The TKB provides detailed information on terrorist incidents, groups, and trials by integrating data from the Rand Terrorism Chronology and Rand-MIPT Terrorism Incident databases, the Terrorism Indictment database, and DFI International's research on terrorist organizations.

The MIPT was established following the April 1995 bombing of the Murrah federal building in Oklahoma City. The U.S. Congress directed MIPT to conduct "research into the social and political causes and effects of terrorism" and to "serve as a national point of contact for antiterrorism information sharing among federal, state, and local preparedness agencies, as well as private and public organizations dealing with these issues."[22]

Other available data sets include ITERATE (International Terrorism: Attributes of Terrorist Events), the State Department data set, TWEED (Terrorism in Western Europe), and IPIC (the International Policy Institute for Counter-Terrorism). ITERATE, a data set developed by Mickolus and others, covers 179 countries over thirty-five years, providing an unbalanced panel data set of more than 4,000 observations.[23] The State Department issues an

21. From World Development Indicators and sources described more fully in Angel, Sheppard, and Civco (2005).
22. MIPT's Terrorism Knowledge Base (www.tkb.org/AboutTKB.jsp [April 2007]).
23. Mickolus and others (2006).

annual report, *Patterns of Global Terrorism,* which contains information on the number and location of international terrorist events.[24] The TWEED data set catalogs all terrorist events, including domestic and international events, in Western Europe since 1950. IPIC began to systematize the data in 1987. In each of these cases, the data are given at the country level and so are difficult to employ in our city analysis.

Trends in Terrorism

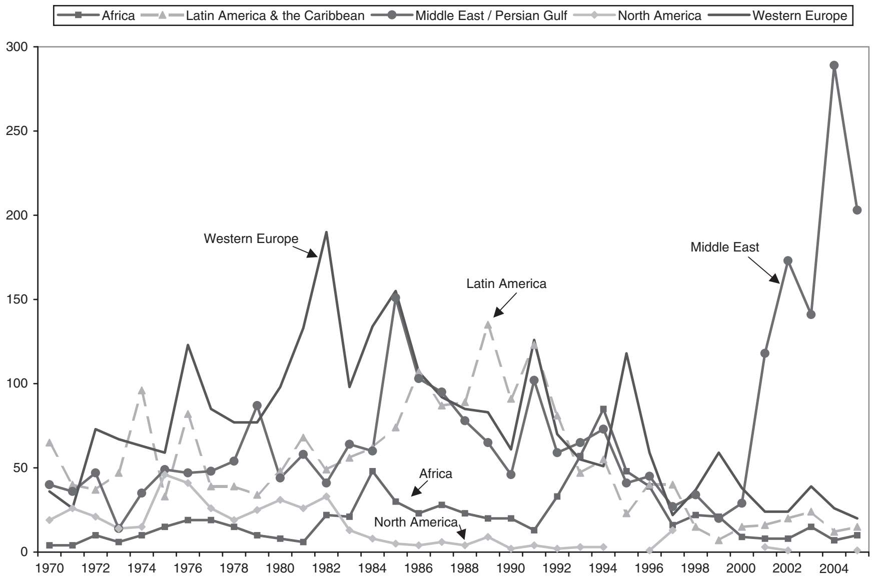
In aggregate, the dynamics across the major data sets are roughly similar. Table A-1 in the appendix to this paper presents the total number of incidents reported in the State Department, ITERATE, and TKB data sets. In each data set, the number of events increased during the period 1969 to 1987. The State Department and ITERATE estimate a similarly steady increase from approximately 100 to 200 incidents a year up to 500 to 600 incidents a year. TKB estimates a similar trend, although the levels are smaller (from a base of approximately 100 incidents a year). Likely the difference in the levels of terrorism in these data sets is that TKB does not include terrorism by a state actor on a nonstate actor within a country and so systematically underestimates the number of attacks.

Figure 1 employs the TKB data to depict the trends in terrorist incidents across select regions of the world. For many of the regions shown, there has been a noticeable drop in terrorist incidents since the 1980s. In particular, Western Europe, which was a hotbed of terrorism in the 1980s, with annual incidents peaking at around 200, has seen the largest decline. The one region that has had a clear upsurge in the most recent period is the Middle East.

The leading explanation for this changing dynamic points to changes in ideology. Since the November 1979 takeover of the U.S. embassy in Tehran, religious fundamentalism has been the driving force in terrorism. Until that point, terrorism was motivated primarily by revolutionary and separatist ideologies.[25] For example, the percentage of terrorist organizations that are religiously based grew from 3 percent to nearly 45 percent by 1995.[26] Crenshaw asserts, "Terrorism should be seen as a strategic reaction to American power in the context of a globalized civil war. Extremist religious beliefs play a role in motivating terrorism, but they also display an instrumental logic."[27]

24. State Department (various years).
25. Wilkenson (2001).
26. See Hoffman (1997).
27. Crenshaw (2001, p. 425).

Figure 1. Terrorist Incidents in Selected Regions, 1968–2006



Source: MIPTs Terrorism Knowled ge Base.

Such a shift in the underlying cause of terrorism suggests that investigating the impact of terror on urban form might best be addressed by analyzing incidents around the globe rather than in one specified region. This is a central contribution of our paper. To see this best, however, it makes sense to begin with an examination of the geography of terrorism.

The Geography of Terrorism

Previous research has shown that certain countries of the world are more susceptible than others to terrorism. The United States, Western Europe, and certain parts of the Middle East have the most terrorism, while Africa has far less. Could it be that terrorism is an unfortunate consequence of economic development and political freedom? As Blomberg and Hess point out, "After Lebanon at 24.4 terrorist events per year, the United States experiences the second highest terrorist incidence, with an average of about 19.6 terrorist events a year, followed closely by Germany and France at 18.4 and 17.9, respectively. However, neighboring countries with similar income and political systems often do not suffer from terrorism. Countries such as Canada, at

1.4 incidents per year, and the Nordic countries such as Sweden (1.5), Norway (0.5), and Finland (0.0) do not have such problems."[28]

Such a conclusion would be unwarranted without considering the importance of the terrorist incident within the boundaries of a particular country. As a starting point, we provide a summary of the incidence of terrorism on maps of selected countries (figures 2–4). Each country has graduated circles to indicate cities with terrorist incidents, with the largest dots representing the areas with the most terrorist events and the smallest representing those with the least.

Figure 2 compares two countries with highly publicized attacks in the last five years: the United States and the United Kingdom. In both cases, attacks are concentrated in specific urban centers. For the United States, several cities have experienced a high incidence of terrorism: New York, Los Angeles, Washington, and Miami. For the United Kingdom, only one city appears to be a terrorist hot spot: London. Figure 2 suggests that for two countries with frequent terrorist attacks, most of the burden appears to be borne by a few select cities.

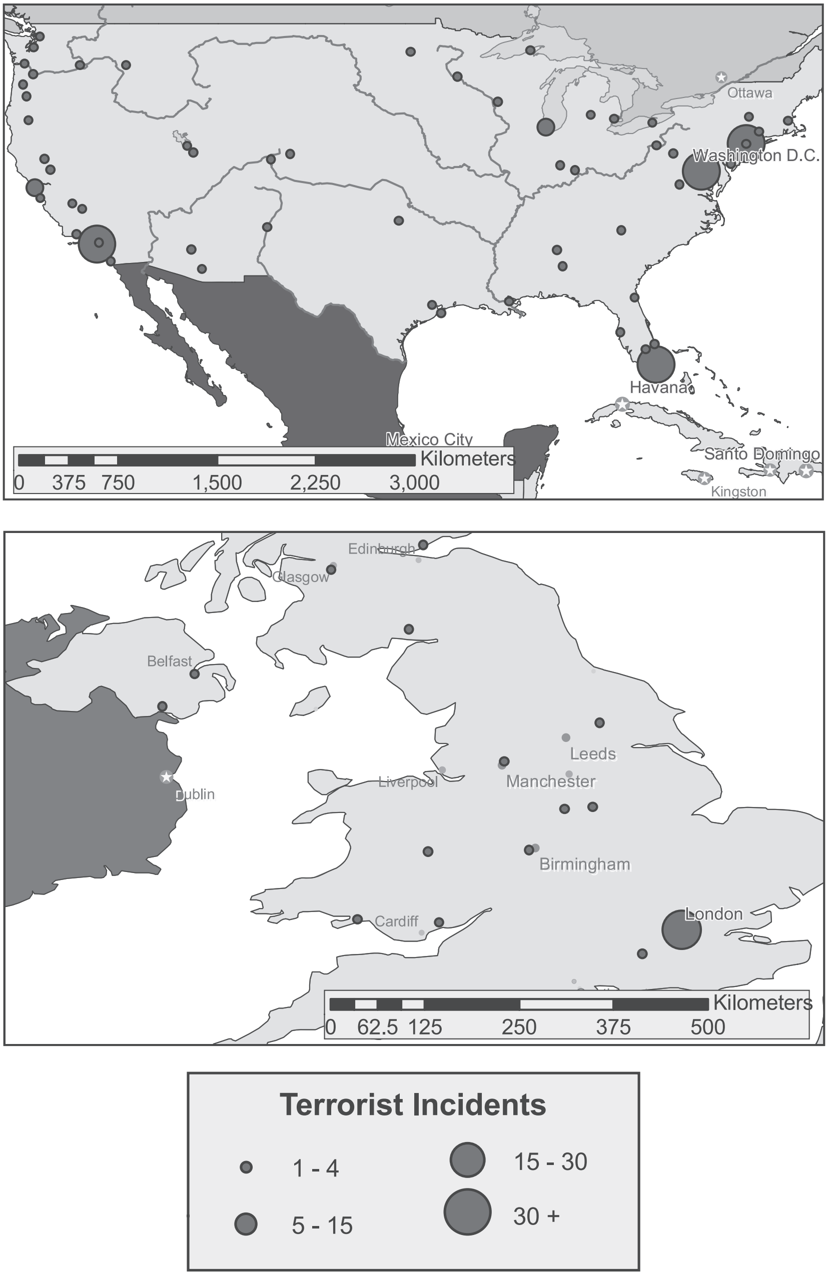
If we compare this outcome with other countries, we begin to see a great deal of variation across the globe. Figure 3 depicts France and Turkey. At first glance, France appears to be very similar to the United States and the United Kingdom. Continental France has a few hot spots, which include Paris. However, closer examination shows that Corsica is rife with terror. Both small and large centers of terror are scattered throughout the island. Turkey provides yet another degree of variation in terror. Terrorism appears to be distributed pretty evenly around the entire land mass, with high concentrations in Istanbul and Ankara.

Figure 4 demonstrates yet another variation in terrorist incidence by depicting Colombia and the West Bank and Gaza. In this case, terrorism appears to have affected almost all of the land mass in each region. For Colombia, there are many small cells of terrorism, whereas the West Bank and Gaza have high concentrations in most of the land mass.

What conclusions can be drawn from this? First, major cities and port cities appear to have a higher incidence than smaller cities and inland cities. Second, there is a great deal of variation across the globe. This may mean that attempts to analyze certain cities or certain events will miss a significant portion of the impact of terrorism on urban form. This empirical issue is at the heart of our paper. However, before we can address it in a systemic fashion,

28. Blomberg and Hess (2007).

Figure 2. Terrorist Incidents in U.S. and U.K. Cities, 1968–2006



Source: MIPT's Terrorism Knowledge Base.

Figure 3. Terrorist Incidents in French and Turkish Cities, 1968–2006

Source: MIPT's Terrorism Knowledge Base.

Figure 4. Terrorist Incidents in Colombian and West Bank and Gaza Cities, 1968–2006

Source: MIPT's Terrorism Knowledge Base.

we need to explain the data we employ to measure urban form. We pursue this issue in the following section.

Urbanization Data

The data used to measure urban land cover is from a global sample of cities, which we combine with population for jurisdictional areas within each city, measures of income, relevant economic variables for the city or for the country in which each city is located, and measures of the number of terrorist incidents in each city (for the city panels) or for the country in which the city is located (for the country panel).

Our data are collected for a sample of 120 cities randomly selected from a larger random sample constructed by UN Habitat for data collection in connection with its 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.

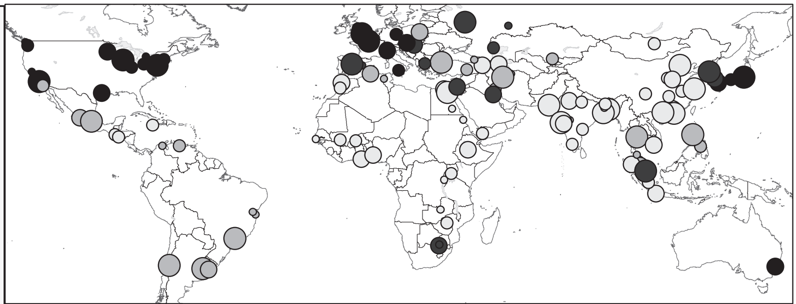
For each of the cities in our sample, we obtained Landsat thematic mapper satellite images for dates that are near the national census dates and for which cloud-free images are available. Images were obtained for two time periods: approximately 1990 and approximately 2000. The images themselves provide data on reflected light intensity in seven spectral bands (three visual and four infrared). These data are used to classify each point as urban (covered with impervious built structures or surfaces), water, or nonurban (everything else) in each time period.

Commercial products are available that provide this information, but the usual practice is to "fill in" small interior open spaces and classify them as urban. Motivated by considerations of our theoretical model, our approach has been to regard such spaces as nonurban so that we can distinguish between new capital investment and building at the urban periphery and "infill" development building inside the built-up area. Further details concerning the remote-sensing data and classification procedure are provided in Angel, Sheppard, and Civco.[29]

The remote-sensing data provide us with measures of total urban land use at two points in time. These measures are then 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

29. Angel, Sheppard, and Civco (2005).

Figure 5. The Global Sample of 120 Cities



Eastern Asia	**Europe, Cont.**	**Northern Africa**	**South and Central Asia**	**Southeast Asia, Cont.**
Shanghai, China	Thessaloniki, Greece	Cairo, Egypt	Mumbai, India	Cebu, Philippines
Beijing, China	Palermo, Italy	Alexandria, Egypt	Kolkota, India	Ipoh, Malaysia
Seoul, Korea	Sheffield, UK	Casablanca, Morocco	Dhaka, Bangladesh	Bacolod, Philippines
Hong Kong, China	Astrakhan, Russia	Algiers, Algeria	Teheran, Iran	Songkhla, Thailand
Guangzhou, China	Leipzig, Germany	Marrakech, Morocco	Hyderabad, India	**Sub-Saharan Africa**
Pusan, Korea	Le Mans, France	Port Sudan, Sudan	Pune, India	Addis Ababa, Ethiopia
Zhengzhou, China	Castellon, Spain	Aswan, Egypt	Kanpur, India	Johannesburg, South Africa
Yulin, China	Oktyabrsky, Russia	Tébessa, Algeria	Jaipur, India	Accra, Ghana
Yiyang, China	**Latin America & Caribbean**	**Other Developed**	Coimbatore, India	Harare, Zimbabwe
Leshan, China	Mexico City, Mexico	Tokyo, Japan	Vijayawada, India	Ibadan, Nigeria
Ulan Bator, Mongolia	São Paulo, Brazil	Los Angeles, USA	Rajshahi, Bangladesh	Pretoria, South Africa
Changzhi, China	Buenos Aires, Argentina	Chicago, USA	Ahvaz, Iran	Kampala, Uganda
Anqing, China	Santiago, Chile	Philadelphia, USA	Shimkent, Kazakhstan	Bamako, Mali
Ansan, Korea	Guadalajara, Mexico	Houston, USA	Jalna, India	Ouagadougou, Burkina Faso
Chinju, China	Guatemala City, Guatemala	Sydney, Australia	Gorgan, Iran	Ndola, Zambia
Chonan, Korea	Caracas, Venezuela	Minneapolis, USA	Saidpur, Bangladesh	Banjul, Gambia
Europe	San Salvador, El Salvador	Pittsburgh, USA	**Southeast Asia**	Kigali, Rwanda
Paris, France	Montevideo, Uruguay	Cincinnati, USA	Manila, Philippines	**Western Asia**
Moscow, Russia	Tijuana, Mexico	Fukuoka, Japan	Bangkok, Thailand	Istanbul, Turkey
London, UK	Kingston, Jamaica	Tacoma, USA	Ho Chi Minh City, Vietnam	Tel Aviv, Israel
Milan, Italy	Ribeirão Preto, Brazil	Springfield, USA	Singapore, Singapore	Baku, Azerbaijan
Madrid, Spain	Valledupar, Colombia	Modesto, USA	Bandung, Indonesia	Sana'a, Yemen
Warsaw, Poland	Guarujá, Brazil	St. Catharine's, Canada	Medan, Indonesia	Yerevan, Armenia
Vienna, Austria	Ilhéus, Brazil	Victoria, Canada	Palembang, Indonesia	Kuwait City, Kuwait
Budapest, Hungary	Jequié, Brazil	Akashi, Japan	Kuala Lumpur, Malaysia	Malatya, Turkey
				Zugdidi, Georgia

Source: Authors' calculations based on sample design in Angel, Sheppard, and Civco (2005).

through 2000, we interpolate to obtain population estimates for the dates of each image. Similarly, we interpolate national per capita GDP to provide an estimate of income levels in each city matched to the date of the image. 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 the World Bank's World Development Indicators or from sources described more fully in Angel, Sheppard, and Civco.[30]

Figure 5 shows the global distribution and some characteristics of the sample and provides a list of sample cities. The entire sample and details on sample design are provided in Angel, Sheppard, and Civco.[31] Table 2 provides

30. Angel, Sheppard, and Civco (2005).
31. Angel, Sheppard, and Civco (2005).

Table 2. Descriptive Statistics for the Main Variables

Variable	*Mean*	*Standard deviation*	*Coefficient of variation*	*Minimum*	*Maximum*	*City with minimum value*	*City with maximum value*
Total urban land use (square kilometers)	402.81	635.11	1.58	8.92	4268.00	Saidpur, Bangladesh	Chicago
Change in urban land	115.21	126.09	1.09	3.19	549.66	Aswan, Egypt	Shanghai
Total metropolitan population	3,363,025.00	4,459,765.00	1.33	93,040.91	27,200,000.00	Zugdidi, Georgia	Tokyo
Change in population	584,872.90	964,112.00	1.65	–898,818.00	4,916,813.00	Yulin, China	Guangzhou, China
GDP per capita	9,914.08	9,916.70	1.00	609.88	35,354.00	Addis Ababa, Ethiopia	Springfield, Mass.
Change in GDP per capita	2,059.08	2,599.40	1.26	–4,866.77	12,000.34	Oktyabrsky, Russia	Singapore
Terrorist incidents	5.32	17.63	3.31	0.00	170.00	Many with 0 incidents	Istanbul
Terrorist injuries	43.83	338.91	7.73	0.00	5,000.00	Many with 0 injuries	Tokyo
Terrorist fatalities	6.74	30.58	4.54	0.00	319.00	Many with 0 fatalities	Mumbai
Air transport linkages	108.21	133.39	1.23	0.00	659.00	Several with no airport	London
Cost per gallon of gasoline	0.62	0.36	0.58	0.02	1.56	Ibadan, Nigeria	London
Agricultural rent	3,347.65	12,569.78	3.75	68.84	150,542.90	Shimkent, Kazakhstan	Singapore
Number of observations = 240							

Sources: MIPT's Terrorism Knowledge Base; ITERATE; State Department (various years).

descriptive statistics for the main variables used in modeling the determinants of total urban land use, including the sample mean, variance, coefficient of variation, sample minimum and maximum, and sample city in which the minimum or maximum is measured. For our measures of terrorist activity, cities in which the minimum is achieved are not listed. For our sample, with 240 possible observations (120 cities at two time periods), 144 have no terrorist incidents.

Model Estimates

To test our hypotheses, we begin by using the entire cross section of data and consider several model formulations. All of our estimates share some common features. Each estimates a functional form in which the dependent variable is the natural log of total urban land use, and independent variables are the natural log of population and income (GDP per capita), natural log of air linkages (1 plus the number of international flights per day from the cities' major airports), the log of measures of terrorist activity, agricultural rent, and fuel costs. We also consider fixed effects for global regions.

The measure for agricultural land rent used is the total value added in agriculture in the economy per hectare under cultivation. This provides a measure for agricultural output per unit of land and should provide a reasonable measure of the opportunity cost of land in urban use.

Two possible measures of terrorist activity are considered: the number of terrorist incidents and the number of persons fatally wounded in terrorist incidents. Both of these are summed over a ten-year period prior to the date of each satellite image. While significant efforts are made to attribute terrorist incidents to the appropriate city, there is always the possibility of errors in which the event is attributed to a suburban location that is not recognized as part of the urban area. In addition, certain conventions in recording terrorist incident data may not always be correct. For example, airplane hijackings are attributed to the origin of the plane journey. This makes some sense, but it may not always correctly reflect the target of the terrorist group. There are always some events that are considered terrorism by some agencies and conventional criminal activity by others. Further small discrepancies can arise in attributing deaths to a particular event or cause. Some indication of the magnitude of these discrepancies can be inferred from table A-1 in the appendix, which lists total terrorist incidents and deaths over the period 1968 through 2003 as reported by three sources: the State Department, the ITERATE data, and TKB data. Fortunately, the disagreements among these sources appear to be modest.

The six predictions contained in table 1 imply expected signs for our estimated parameters. Predictions 1 and 2 imply the expected positive signs associated with population and income, respectively. Predictions 4 and 5 imply the expected negative signs associated with fuel costs and agricultural land values, respectively. As suggested by the data assembled for Chinese cities in Wu and Yusuf, we take the number of international air linkages to the city as a proxy for the level of demand for the city's export goods and expect this variable to have a positive sign in accord with prediction 6.[32] In accord with prediction 3, we expect an increase in the number of terrorist incidents during the decade prior to the measured urban land use to be associated with a negative impact on the magnitude of this use.

Our estimation strategy must be concerned with the extent to which these variables, central to our tests of the theoretical perspective offered above, are themselves endogenous to the realized form of the urban area. We begin by considering the traditional ordinary least squares (OLS) estimates. Columns 2, 3, and 5 of table 3 present these estimates for three types of models, along with standard errors and the usual statistics for evaluating model performance. Here and in all subsequent results, *t* statistics and other statistical tests are based on robustly estimated standard errors using clustered observations (since each city is observed twice), except in first-difference models, where we consider the change in urban land use as a function of the changes in relevant variables, where there are no repeated observations.

The results in table 3 indicate that population, income, and the value of agricultural land and fuel costs have the expected signs and are generally estimated with precision. The impacts of linkages to the wider global economy are positive as expected, but in some of the models (those estimated using OLS in particular), the estimates are imprecise. The estimated impacts of terrorism are always the sign we expect, but in the OLS estimates the precision of the estimates is low. The estimated impact of terrorist incidents is significant at the 10 percent level in the model with regional fixed effects. It may be argued that the impact of fatalities is bound to be estimated with less precision because the number of fatalities associated with terrorist incidents is volatile and so the impact of these noisy data is difficult to estimate with precision.

A further concern in evaluating the estimates obtained using OLS arises because of the endogeneity that is almost certainly present in the data. We

32. Wu and Yusuf (2004).

Table 3. Ordinary Least Squares (OLS) and Two-Stage Least Squares (2SLS) Model Estimates[a]

Indicator	*OLS incidents*	*OLS incidents*	*2SLS incidents*	*OLS fatalities*	*2SLS fatalities*
Population	0.7357***	0.775***	0.3378*	0.7619***	0.3861*
	(0.0588)	(0.0644)	(0.1957)	(0.0644)	(0.2165)
Income	0.5398***	0.5518***	0.582***	0.5541***	0.5593***
	(0.0452)	(0.0609)	(0.1435)	(0.0616)	(0.1592)
Air linkages	0.0719*	0.0532	0.3144**	0.0472	0.2341
	(0.038)	(0.0431)	(0.1397)	(0.0431)	(0.1447)
Terrorism	–0.0412	–0.0595*	–0.3049**	–0.0172	–0.3851*
	(0.0356)	(0.0338)	(0.1389)	(0.0304)	(0.2157)
Agricultural rent	–0.2324***	–0.2229***	–0.1791***	–0.2318***	–0.2022***
	(0.033)	(0.0368)	(0.0586)	(0.0378)	(0.0605)
Fuel cost	–0.1169**	–0.1799***	–0.1837**	–0.1773***	–0.1141
	(0.0588)	(0.0596)	(0.0728)	(0.061)	(0.0882)
East Asia		0.1247	0.572	0.1688	0.4994
		(0.2178)	(0.3753)	(0.2187)	(0.4243)
West Asia		0.3376*	0.6393**	0.3081	0.6993*
		(0.1926)	(0.3128)	(0.1965)	(0.3558)
Latin America		–0.1416	–0.0011	–0.1531	–0.1078
		(0.1611)	(0.2246)	(0.1606)	(0.2472)
North Africa		–0.2425	–0.2143	–0.2275	–0.0636
		(0.2796)	(0.3327)	(0.2851)	(0.3592)
South-Central Asia		–0.3747*	0.1005	–0.3552*	0.0634
		(0.2076)	(0.3546)	(0.2055)	(0.3879)
Southeast Asia		–0.2521	–0.0796	–0.215	–0.0577
		(0.2234)	(0.3196)	(0.2247)	(0.3476)
Sub-Saharan Africa		0.3283*	0.2718	0.3339*	0.2875
		(0.1802)	(0.3759)	(0.1811)	(0.4081)
Constant	–8.6658***	–9.3271***	–4.4849*	–9.123***	–4.5345
	(0.8544)	(0.9971)	(2.6904)	(0.9959)	(2.9258)
F	117.94	77.11	15.5	76.12	13.07
R^2	0.8094	0.8387	0.703	0.8371	0.6496
Adjusted R^2	0.5602	0.5233	0.6859	0.5259	0.6294
Root MSE			0.71008		0.77125
		H0: Regressors exogenous			
Wu-Hausman F test			4.9808**		4.8893**
Durbin-Wu-Hausman χ^2			19.7647**		19.4312**

Sources: MIPT's Terrorism Knowledge Base; ITERATE; State Department (various years).
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.10$.
a. Numbers in parentheses are standard errors.

can plausibly expect some of the variables to be independent of the extent of urban land use in the city (although this should be tested). For example, it might make sense to argue that agricultural productivity is determined largely by climate and soil conditions coupled with international or regional food prices. Similarly, fuel prices are determined largely by international markets and might be taken as independent of the extent of urban land use.

The situation is different for most of the other variables. The potential for large cities to attract internal or international migration—either for job opportunities or for cultural reasons—is well known. Population might therefore be determined by (and clearly is expected to partially determine) the extent of urban land use. A similar observation is true for income, where the nature of urban land use can affect factor productivity and influence per capita income. Terrorism itself is generally regarded as being influenced by the nature of the city, as indicated in the discussion above. Certain cities present inviting targets that can bring visibility to the terrorist's cause. If terrorist attacks increase with urban size, then the OLS estimate of the impacts of terrorist attacks may be biased upward (depending on the structure of covariance that exists with other variables) since the "inviting target" effect will associate more terrorist attacks with larger cities. If the true impact of terrorism is to reduce urban land use (as suggested by the models discussed above), but this "inviting target" endogeneity is not taken into account, we might conclude that terrorism has no impact on urban land use or at least might underestimate its impact.

Therefore, we need to consider an instrumental variables strategy for estimation. The theoretical motivation for our strategy is inspired by a newly developing literature on the political economy of institutions. For example, Blomberg and others develop a model in which a terrorist attack can be the equilibrium outcome when dissident groups receive an unequal distribution of the economic pie.[33] The basic prediction of the model is that the choice between a "rebellion attack" and a "terrorist attack" is influenced by the country's ability to not give in to the dissident groups. In particular, economies with well-established institutions and defense capabilities are more likely to be affected by terrorism, whereas economies with weak institutions and defense capabilities are more likely to see civil wars, coups, and other types of conflict designed to overthrow the government.

How can one identify the important factors that lead to well-established institutions that would influence these dissidents? One possible strategy is to

33. Blomberg, Hess, and Weerapana (2004).

focus on variables that are invariant in the long run yet likely to encourage positive institutions. We develop a combination of instruments including the "biome" that characterizes the location of each city (this characterizes the general climatic conditions and types of plant growth in the region of the city and is determined largely by a combination of soil moisture, rainfall, and temperature) along with latitude and longitude and the maximum slope of the area where the urban area is located. These variables might be interpreted as characterizing the environment in which the urban area was nurtured and grew. They determine the relationship between the city and the hinterland, yet remain stable and are largely independent of the final urban form that develops (and errors in its measurement or realization).

Columns 4 and 6 in table 3 present two-stage least squares estimates of our models, in which biome, location, and the maximum slope of the area where the city is located are used as instruments. Complete reports of first-stage model estimates, which are available in Blomberg and Sheppard, support our estimation strategy.[34] The two-stage least squares models provide a more appropriate approach for our data, and the Wu-Hausman and Durbin-Wu-Hausman tests presented in the final two lines consistently reject the null hypothesis of endogeneity of the independent variables at the 5 percent level or better.[35] At least for our sample, therefore, it appears that using an instrumental variables approach is necessary in order to obtain consistent estimates. Of course, in this context a larger sample size would be welcome, but the cost of collecting the data and the novel and important nature of this information may be offered as justification for presentation, and at least provisional acceptance, of these results.

The two-stage least squares estimates in table 3 provide more satisfactory results for the predictions presented in table 1. For fully specified (including regional fixed effects) models, the estimates are consistent with all of our predictions, and the estimated coefficients are statistically significant at the 10 percent level or better for the models using the number of incidents or the number of fatalities as the measure of terrorism intensity. The models also perform reasonably well overall, with adjusted R^2 between 0.63 and 0.69.

The estimates presented in table 3 do not treat all of the independent variables as endogenous and hence require instrumental modeling. Agricultural land-rent and fuel costs are taken as exogenous. Naturally this maintained hypothesis of exogeneity should be tested, along with the exogeneity,

34. Blomberg and Sheppard (2007).
35. Wu (1973); Hausman (1978); Durbin (1954).

relevance, and strength of our instruments and the general specification of the model. We undertake each of these tests within the context of generalized method of moments (GMM) estimates, which are presented in table 4 along with other control variables.[36]

As an additional check on our analysis and the stability of our parameter estimates, we inquire whether it is possible that terrorism is not having a direct impact on total urban land use, but rather that some other factor is affecting both the propensity for an area to be subject to terrorism and total urban land use. As with all analysis of this type, an almost infinite variety of potential factors could be considered. For the most part, we focus on two types of potential factors: the type of governance structure that characterizes the country (which, as discussed above and in the analysis of Blomberg, Hess, and Weerapana, could be expected to change the likelihood of terrorism) and the extent of ethnic, linguistic, and religious fractionalization, as discussed in Alesina and others.[37] In addition to these, we consider whether the impact is significantly affected by the type or tactic of terrorist attack. The most common tactic recorded is bombing, but there are kidnappings, assassinations, and others as well. We record the modal tactic for each city and each time period and consider the separate impact of bombings on urban land use. Table 4 presents GMM estimates for this bombing variable, along with the

36. Several observations about the estimates presented in table 4 are primarily of statistical interest and not germane to the economic discussion and so are included in a working paper version of our model (Blomberg and Sheppard 2007). In a battery of tests, we note that the *C* statistic calculated to test exogeneity of agricultural rent and fuel costs always fails to reject the null hypothesis that these two variables are independent of the model error. This justifies our approach in estimation. The values of Hansen's *J* statistic also fail to reject the null hypothesis, suggesting that, even without these variables, we have an orthogonal set of instruments. In this situation, however, our separate theoretical interest in the impact of these variables justifies their inclusion in the model. Continuing to examine the tests of the full model, the Ramsey RESET test examines impacts up to the fourth power of the residuals and fails to reject the null hypothesis of a correctly specified model. Hansen's *J* test for the complete set of instruments fails to reject the null hypothesis that the instruments are not exogenous of the model error term. This supports our approach and suggests that the instruments we have chosen satisfy the required orthogonality requirements. These would be of little benefit if the instruments were so weak as to be essentially uncorrelated with the model variables that are the object of our interest. To examine this, we present the results of Anderson's test examining the canonical correlation between the set of instruments and the set of endogenous variables (Anderson 1984). Here we are able to reject the null of instrument irrelevance in both versions of the model using the number of terrorist incidents. Weaker levels of rejection are possible for the injury and fatality models, where the more limited variation in the cross-sectional data make establishing the correlation between instruments and endogenous variables more difficult.

37. Blomberg, Hess, and Weerapana (2004); Alesina and others (2003).

Table 4. GMM Instrumental Variables (IV) Estimates with Additional Variables[a]

Variable	*Regions*	*IV*	*Bomb*	*Democracy*	*Checks*	*Executive*
Population	0.2971	0.6556***	0.2642	0.3733	0.3323	0.4702*
	(0.2491)	(0.1626)	(0.2429)	(0.2525)	(0.2501)	(0.239)
Income	0.7083***	0.6572***	0.6816***	0.7691***	0.711***	0.7673***
	(0.1417)	(0.0763)	(0.1929)	(0.1493)	(0.1235)	(0.1271)
Air linkages	0.2889*	0.1014	0.3957**	0.2287	0.2713*	0.1799
	(0.1498)	(0.0885)	(0.1886)	(0.1542)	(0.1445)	(0.1518)
Terrorism	–0.2135*	–0.2228**	–0.7576*	–0.2509*	–0.2229**	–0.2131*
	(0.1255)	(0.1072)	(0.4211)	(0.1287)	(0.1125)	(0.113)
Agricultural rent	–0.2275***	–0.235***	–0.275***	–0.2309***	–0.2264***	–0.2381***
	(0.0613)	(0.0457)	(0.0856)	(0.062)	(0.0576)	(0.0612)
Fuel cost	–0.1804**	–0.0973	–0.2217*	–0.0884	–0.1637*	–0.1163
	(0.0801)	(0.0627)	(0.1247)	(0.0878)	(0.0922)	(0.0772)
East Asia	0.8873**		1.2509**	0.5874	0.8079*	0.5957
	(0.4274)		(0.6018)	(0.4096)	(0.4491)	(0.42)
Latin America	0.0962		0.1054	0.1528	0.0889	0.1614
	(0.228)		(0.3319)	(0.2392)	(0.2145)	(0.2216)
North Africa	–0.057		0.0525	–0.1932	–0.0982	–0.1001
	(0.3539)		(0.4897)	(0.3252)	(0.3207)	(0.3003)
South-Central Asia	0.2352		0.3925	0.1832	0.214	0.1114
	(0.3473)		(0.5131)	(0.3445)	(0.332)	(0.3019)
Southeast Asia	0.1632		0.3072	0.0482	0.1223	0.0377
	(0.3422)		(0.4849)	(0.3376)	(0.3463)	(0.3096)
Sub-Saharan Africa	0.5179		0.0242	0.3389	0.4935	0.529*
	(0.371)		(0.5426)	(0.353)	(0.31)	(0.3186)
West Asia	0.7072**		0.7813	0.7383**	0.6803**	0.6949**
	0.338		(0.5405)	(0.3421)	(0.3255)	(0.314)
Bombing as tactic			2.1063			
			(1.3062)			
Democracy index				–0.1634*		
				(0.1028)		

(*continued*)

Table 4. GMM Instrumental Variables (IV) Estimates with Additional Variables[a] (*Continued*)

Variable	*Regions*	*IV*	*Bomb*	*Democracy*	*Checks*	*Executive*
Checks and balances index					–0.0502	
					(0.121)	
Unelected executive						–0.0872
						(0.3512)
Elected one candidate executive						–0.2223
						(0.3511)
Parties legal, one party dominates						–0.5486
						(0.5138)
Elected executive by more than 75 percent						–0.2311
						(0.3653)
Elected executive by 75 percent						–0.6009
						(0.5055)
Elected executive by less than 75 percent						–0.4372
						(0.4108)
Constant	–4.755	–8.4314***	–4.397	–5.7451*	–5.1191	–6.8484**
	(3.4258)	(2.2347)	(3.2387)	(3.4528)	(3.2116)	(3.1863)
Number of observations	240	240	240	238	240	240
F	14.98	25.81	11.47	14.66	14.98	14.93
R^2	0.7083	0.7673	0.395	0.7284	0.7188	0.7633
Root MSE	0.7036	0.619	1.016	0.6829	0.6924	0.6424
Anderson IV relevance	13.598	13.477	4.242	13.038	14.434	12.127
Pval	0.0929	0.0964	0.7515	0.1105	0.0711	0.1456
Hansen J (OverID)	6.742	6.936	3.849	5.914	7.031	6.625
Pval	0.4562	0.4355	0.697	0.5499	0.4256	0.4689

Sources: MIPT's Terrorism Knowledge Base; ITERATE; State Department (various years).
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.10$.
a. Numbers in parentheses are standard errors.

impact of level of democracy, the number of checks and balances, and the nature of the executive authority in the government.

As can be seen from the table, inclusion of these alternative explanations leaves the endogeneity and relevance of the instruments intact and, if anything, strengthens the results on the impacts of terrorism. The executive power indexes are generally not statistically significant, and neither is the indicator of the number of checks and balances. The index of democracy is significant at the 10 percent level, but inclusion of this variable generates no statistically significant change in the estimated impact of terrorism.

Several observations about the parameter estimates themselves are possible. For the most part we focus on models using the number of terrorist incidents as the measure of terrorism intensity, but many of our remarks apply to all the models. In every case, the parameter for both population and income is well below 1. This indicates, for example, that doubling population increases urban land use but does not double it. As a result, increasing population, ceteris paribus, increases population density. Note also that the impact of income on urban land use is generally somewhat greater than the impact of population: doubling population increases urban land use 29 to 65 percent, while doubling income increases urban land use 65 to 70 percent, holding other factors constant. Urban population has a slightly higher coefficient of variation, so that, in practice, the impact of the two forces might be more comparable than is suggested by the parameter estimates. It is nevertheless quite striking how little attention is paid to income as a driving force in urban expansion, relative to the attention given to population and transportation.

As noted, we use air linkages as a proxy for the productivity of land in production of the export good (both because establishing such linkages is a signal of interest in connecting with and trading with the global economy and because the extent of such commercial infrastructure is crucial for factor productivity). For all models, the sign is as expected: an increase in air linkages increases urban land use. The impact of agricultural rent strongly confirms hypothesis 5: an increase in the value of farm land diminishes urban land use. The impact is consistent in magnitude and statistically significant. The impact of fuel cost is estimated with less precision but is statistically significant at the 10 percent level or better in the majority of the models with regional fixed effects.

What about the impacts of terrorism? For all models that include regional fixed effects our results are relatively strong and statistically significant at the 10 percent level. An increase in the terrorism experienced by the city is associated with a decrease in total urban land use in the city, just as predicted by hypothesis 3. Using measures of terrorist activity for the entire country (rather than the urban area) also provided estimates consistent with our hypothesis and generally statistically significant. Doubling the amount of terrorism in an urban area is associated with approximately a 25 percent decline in the total urban land area, holding all other variables constant qualitatively, as is predicted by the theoretical analysis presented above. Not only is the impact of terrorism negative and statistically significant, but the magnitude of the estimated parameter is larger in absolute value when compared to the estimates obtained using OLS. Correcting for the endogeneity that both common sense and statistical tests suggest is present in the data appears to remove what might be an upward bias in the OLS estimates of this impact.

In addition to the results reported here, we also have explored a variety of fixed-effect corrections to capture unmeasured features constant within countries. No national fixed effect is statistically significantly different from the default case (the United States), except for Bangladesh. We find this result somewhat surprising since it implies that the principal differences in levels of urban land use between the cities of these different countries can be explained by the economic variables included in our model. When regions are used as the basis for fixed effects, East Asia is significant in some cases, but only West Asia manages to be statistically significant in the majority of models. It is noteworthy that this includes most of the Middle East where, as seen in figure 1, the level of terrorism has increased significantly.

A more mixed set of results emerges when we incorporate indexes of ethnic, religious, and linguistic fractionalization. An interesting finding is that inclusion of the variable that some might expect to be associated with terrorism—religious fractionalization—leaves the estimated impact of terrorism almost completely unchanged. The parameter estimate does not change much when the ethnic and linguistic fractionalization is included, but the precision of parameter estimation is reduced so that the estimate is not statistically significant. Whether these results are simply due to our modest sample size, coupled with colinearity in the data, remains a subject for future analysis.

The final part of our analysis exploits the repeated observations of cities to estimate a model of first differences rather than logarithms of levels. The analysis may serve to isolate the importance of nationalism and the dynamics of terrorism. By converting our two-period panel data set of countries and cities into a cross section of countries and cities in first differences of our variables, we investigate this line of reasoning more carefully. This estimation strategy has many advantages. First, when examining the country cross section, we are able to better measure the impact of terrorism on the nation-state.

Table 5. Impact of Fractionalization on Urban Form[a]

Variable	*Religion*	*Ethnic*	*Language*
Population	0.2648	0.559**	0.2426
	(0.2647)	(0.2312)	(0.2588)
Income	0.7102***	0.6653***	0.6728***
	(0.1441)	(0.1233)	(0.1475)
Air linkages	0.3083*	0.1136	0.2945*
	(0.1646)	(0.1487)	(0.1679)
Terror incidents	–0.2127*	–0.1262	–0.1777
	0.1254	0.1185	0.136
Agricultural rent	–0.2316***	–0.1269**	–0.1656**
	(0.0614)	(0.0612)	(0.0708)
Fuel cost	–0.1815**	–0.0967	–0.1505*
	(0.0822)	(0.0719)	(0.0839)
East Asia	0.9641**	0.646*	0.9124**
	(0.4529)	(0.3644)	(0.4487)
Latin America	0.1524	–0.1064	0.0874
	(0.2304)	(0.208)	(0.2383)
North Africa	0.0792	–0.139	–0.1243
	(0.3713)	(0.3143)	(0.3735)
South-Central Asia	0.3315	–0.1567	0.081
	(0.3799)	(0.3201)	(0.3883)
Southeast Asia	0.2184	–0.23	–0.0713
	(0.3527)	(0.3158)	(0.3699)
Sub-Sahara Africa	0.529	0.4102	0.3127
	(0.3744)	(0.3199)	(0.3809)
West Asia	0.7726**	0.3538	0.5339
	(0.3564)	(0.3099)	(0.3563)
Religion fractionalization	0.039		
	(0.054)		
Ethnic fractionalization		0.1837***	
		(0.062)	
Language fractionalization			0.1043
			(0.0631)
Constant	–4.3567	–7.8244**	–3.8744
	(3.6376)	(3.2218)	(3.5462)
Number of observations	240	240	240
F	13.39	20.24	13.52
R^2	0.696	0.8109	0.699
MSE	0.7199	0.5678	0.7164
Anderson	13.127	10.985	12.539
Pval	0.1076	0.2026	0.1287
Hansen J	6.7	11.267	9.153
Pval	0.4608	0.1274	0.2419

Sources: MIPT's Terrorism Knowledge Base; ITERATE; State Department (various years).
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.10$.
a. Numbers in parentheses are standard errors.

Second, by converting levels into differences, we may be better able to control for country-, city-, or time-specific fixed-effects. Obviously, there is some information cost to this robustness check as we greatly reduce our sample size. For our country-level analysis, we have fifty-nine observations; for the city-level analysis, we have 120 observations. Losing such information may prevent very precise estimation. In addition to first differences in population, income, air linkages, terrorist incidents, and agricultural rent, we also include the level of fuel costs and agricultural rents at the beginning of the time period (T1 fuel cost and T1 agricultural rent), as well as indicator variables for regions to capture region-specific differences in the changes in urban land use that might arise due to different stages of urban development.

Table 6 reports the results from this estimation. As expected, our ability to estimate precisely the impacts of many of the covariates has been greatly reduced. While many of the right-hand-side variables continue to have the same sign as predicted in table 1, we cannot reject the null that the impact is zero. For example, population is indeed positive in each case but is not statistically significant in the city-level specification. Most important for our analysis, however, terrorism continues to be negative and is statistically significant at the nation-level specification in the models reported in columns 3, 4, and 5. It appears to lose its significance at the city level. This suggests that the dynamics of terrorism are better captured at the nation-state rather than the city level. This might arise, for example, if terrorist incidents at the national level affect development decisions in all cities, even those that have not been subject to significant attacks.

Many more of the regional indicator variables are significant in these models, revealing significant differences across regions in the changes in urban land use. This is not surprising given regional differences in the levels of urbanization. Finally, in evaluating whether variable endogeneity requires an instrumental variables approach to estimation, we have a less clear-cut result. Analysis of first differences using OLS may be less problematic than analysis of levels of urban land use.

Conclusions

Overall, our estimates seem remarkably successful in providing support for the hypotheses and building our confidence in using the model discussed above. They generally confirm our hypothesis that sustained terrorism can have a profound impact on urban form. Although the notion that increasing

Table 6. Difference Models[a]

	National data				City data
Variable	*OLS*	*OLS + region*	*IV*	*IV + region*	*IV + region*
Population	0.00018***	0.00019***	0.00017***	0.00022***	0.000007
	(0.00002)	(0.00003)	(0.00003)	(0.00005)	(0.00005)
Income	0.0283	0.0058	0.033	–0.0167	0.0126
	(0.0187)	(0.0186)	(0.0274)	(0.0406)	(0.0101)
Air linkages	–0.2856	–0.5158	–0.0852	0.2424	–0.7572
	(0.2948)	(0.6293)	(1.057)	(2.2595)	(0.8778)
Terror incidents	–0.5614	–0.5592*	–0.6333***	–0.9051**	–0.1921
	(0.3511)	(0.3212)	(0.2262)	(0.3786)	(0.3474)
Agricultural rent	–0.0073**	–0.0003	–0.0297	0.0143	0.0134
	(0.0036)	(0.0035)	(0.0324)	(0.055)	(0.0228)
Fuel costs	–0.0132	0.0035	182.5637	320.4813	–167.2584
	(0.0089)	(0.0095)	(282.5889)	(449.6966)	(249.7344)
T1 fuel cost	–14.5446	–201.7612	–51.9784	–658.0995	–79.19
	(88.4926)	(168.3691)	(256.9893)	(407.9918)	(110.447)
T1 agricultural rent	185.2761*	83.0715	–0.0128	0.008	0.0011
	(111.65)	(144.0187)	(0.0097)	(0.0181)	(0.0079)
East Asia		–313.1553		–684.1734**	–2.329
		(255.8939)		(317.9014)	(93.6797)
Latin America		–331.314**		–443.6084**	–89.6094
		(160.4678)		(183.3605)	(55.3272)
North Africa		–381.8031**		–604.932***	–103.1583*
		(180.1433)		(207.6831)	(60.1652)

(*continued*)

Table 6. Difference Models[a] (*Continued*)

	National data				*City data*
Variable	*OLS*	*OLS + region*	*IV*	*IV + region*	*IV + region*
South-Central Asia		−433.9342**		−688.2239***	−69.7099
		(192.448)		(228.9848)	(49.5597)
Southeast Asia		−334.3902*		−615.7723**	−37.5343*
		(193.8897)		(270.5764)	(75.3374)
Sub-Saharan Africa		−290.2754**		−493.5526***	−28.9663**
		(143.2202)		(176.4136)	(57.1868)
Western Asia		−214.2356		−347.895**	25.3971
		(131.4468)		(170.4873)	(73.6665)
Constant	−20.7157	350.0393*	13.1841	653.519**	207.7135**
	(59.1147)	(202.9553)	(141.0413)	(273.6327)	(86.3533)
Number of observations	59	59	59	59	120
F	73.44	24.65	14.59	5.86	1.28
R^2	0.794	0.8514	0.7859	0.7451	0.0741
Root MSE	217.99	199.34	222.24	261.07	130.06
		H0: Regressors exogenous			
Wu-Hausman *F* test			0.21	1.40861	1.43347
Durbin-Wu-Hausman χ^2			1.9074	12.4147*	12.80509

Sources: MIPT's Terrorism Knowledge Base; ITERATE; State Department (various years).
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.10$.
a. Numbers in parentheses are standard errors.

terrorism reduces urban land use for a given population conjures images of urban residents "huddling together" for safety, our model provides an alternative interpretation. Increasing terrorism significantly adds to the uncertainty associated with housing supply and land development. The natural response is for landowners to put development plans on hold, until the nature of the terrorist threat is better understood.

Our results stand in contrast to a variety of other studies, noted above, that have found (or hypothesized) minimal impacts from terrorism. We offer three explanations for this. First, our analysis suggests that measurement of the impact of terrorism requires careful accounting for the endogeneity that is intrinsic to the process of emerging urban form. Results obtained using OLS may be biased because they do not correct for this problem.

A second explanation is our ability to test for impacts in a global sample of cities. This results in much greater variety in terrorism levels and permits greater precision in the estimation process. A third explanation hinges on where we look for an impact. Our model guides us to look for an impact in the footprint of the urban area—total urban land use. Some other studies have considered employment, population, and even the price of structures. To the extent that the impact of terrorism is reflected less in structures and more in the price of land, it may be difficult or impossible to obtain precise estimates of impacts. Furthermore, if structure and land prices adjust to compensate for living in a risky environment, long-run impacts on population or employment may only be observed in the most severe circumstances. That does not mean that there are no impacts, however. It remains for further studies to confirm our estimates of an impact on total urban land use and to discern the broader impacts of these changes for the environment, for the welfare of the inhabitants, and for economic performance.

APPENDIX

Table A-1. Transnational Terrorist Incidents and Deaths, 1968–2003

	ITERATE data		*State Department data*			*TKB data*
Year	*Incidents*	*Violent incidents*	*Incidents*	*Deaths*	*Deaths per incident*	*Incidents*
1968	123	123	125	34	0.27	106
1969	181	181	193	56	0.29	103
1970	344	344	309	127	0.41	181
1971	301	301	264	36	0.14	157
1972	480	480	558	151	0.27	210
1973	341	341	345	121	0.35	176
1974	426	426	394	311	0.79	237
1975	342	342	382	266	0.70	215
1976	455	455	457	409	0.89	330
1977	341	341	419	230	0.55	240
1978	290	284	530	435	0.82	227
1979	336	319	434	697	1.61	248
1980	525	522	499	507	1.02	241
1981	469	469	489	168	0.34	306
1982	423	421	487	128	0.26	368
1983	428	295	497	637	1.28	299
1984	473	355	565	312	0.55	330
1985	525	364	635	825	1.30	450
1986	538	360	612	604	0.99	383
1987	504	504	665	612	0.92	369
1988	417	318	605	407	0.67	387
1989	359	281	375	193	0.51	364
1990	371	371	437	200	0.46	293
1991	578	578	565	102	0.18	427
1992	359	359	363	93	0.26	276
1993	554	554	431	109	0.25	274
1994	377	377	322	314	0.98	316
1995	315	315	440	163	0.37	272
1996	223	223	296	314	1.06	246
1997	189	189	304	221	0.73	183
1998	96	96	274	741	2.70	162
1999	295	295	395	233	0.59	125
2000	167	167	426	405	0.95	103
2001	52	52	355	3,296	9.28	205
2002	130	130	202	725	3.59	293
2003	275	275	208	625	3.00	273
Total	12,602	11,807	14,857	14,807	0.997	9,375

Sources: Authors' calculations based on MIPT's Terrorism Knowledge Base (TKB), ITERATE, and State Department (various years).

Comment

Edward Glaeser: The connection between violence and cities is as old as the walls of Jericho. Historically, the threat of war caused people to cluster together behind city walls, because of the strength that came from numbers. The actual impact of war was often to disperse population, as people fled cities and returned to subsistence farming, when chaos challenged the secure property rights needed for urban commerce. In the wake of the September 11, 2001, attacks on the World Trade Center and the Pentagon, many observers suggested that a new threat of terror would act as a dispersing form, as people sought to avoid tall skyscrapers that were obvious terrorist targets.

Blomberg and Sheppard's fine paper represents an attempt to ask whether terrorism is indeed a force for urban dispersal or whether terrorism instead drives people together. Certainly, the theoretical case is ambiguous. High levels of density do seem to offer tempting targets to terrorists, and this effect should mean that an increase in terrorism disperses people. Two effects counter the tall targets effect: the costly travel effect and the city walls effect. The costly travel effect notes that terrorism also strikes at transportation modes, including buses and airplanes, and as the costs of transportation rise, people generally come closer together. The city walls effect emphasizes that there are scale economies in defense.[1] London's system of antiterrorist cameras would have been much harder to implement in a lower-density environment.

Blomberg and Sheppard's paper addresses the theoretical ambiguity about cities and terrorism with two extremely rich data sets. They then connect this evidence with city-level evidence on urban expansion. They look across a large sample of cities and ask whether cities with more terrorism are more compact or more spread out. Since their specification has the logarithm of urban land use on the left-hand side and the logarithm of population on the

1. I call this the city walls effect because city walls themselves display scale economies. The ratio of circumference to the area of a round city is, of course, declining in the area of that city.

right, the regressions can be interpreted as asking whether terrorism increases or decreases the amount of land use per resident.

Before proceeding to their main empirical question about terrorism and land use, the authors provide an overview of the Memorial Institute for the Prevention of Terrorism (MIPT) data on terrorist attacks. Perhaps the most empirical fact that comes out of this overview is that terrorism is actually declining in most regions of the world, at least as measured by number of incidents. The decline of terrorism in Europe since the early 1980s is particularly striking. Latin American terror peaked somewhat later, but it has also declined. Terrorism incidents in North America have always been low, but they too have been generally falling since the 1970s.

The one region that has seen an explosion of terror over the past eight years is the Middle East. America's experiences with terrorism since 2000 have essentially reflected the ability of increasingly sophisticated Middle Eastern terrorists to export violence across the Atlantic. The authors have made good use of these data in other papers, and the data set clearly represents a major resource. The declines of terrorism in Europe and Latin America may provide clues about how to combat the new surge of terror in the Middle East. The time trend data also suggest that if we expect terror to have a major impact on urban form, we are more likely to see that impact in the Middle East than in Europe or the United States.

After showing the time series of terror, the authors give us some geographic pictures of terror within a few countries. In the United States and England, terrorist incidents are remarkably concentrated in the largest cities. English (or Irish) terror is strongly concentrated in London. American terror tends to be in New York, Washington, Miami, and Los Angeles. The connection between urban size and terror in these two particularly salient nations might lead us to think that the tall targets effect will dominate and terrorism will push people to decentralize.

However, Blomberg and Sheppard show us that the concentration of terror in America and England is not the only pattern across the world. Terrorism is high in Paris, but it is also abundant in the island of Corsica and on the edges of the Pyrenees. Less urban areas that are proximate to Corsican and Basque terrorists are perfectly capable of attracting terrorist attacks. Terrorism in Turkey, Colombia, and the West Bank is spread throughout the country in small towns as well as big cities. Their maps make it clear that extrapolating from the American or British experience with terror is surely a mistake.

After giving us these maps, the authors then connect the terrorism data with United Nations data on land use for 120 cities. I would have preferred it if the authors had first run some regressions to see whether post-1970 terror is regressed on features of cities in 1970, but the authors charge immediately into their main question of whether terrorism affects urban form. They run a regression where the logarithm of land in the city is regressed on income, population, air linkages, terror, agricultural rent, and fuel costs. The coefficients estimated for these controls seem quite reasonable and are those predicted by a basic urban model.

The more novel results concern the correlation of terrorism and urban land use. The baseline regression shows a modest negative impact of terrorism on land use that becomes significant once they control for regional dummies. This modest statistical significance does not mean that the coefficient is economically small. The standard deviation of their terrorism variable is 17, and the estimated coefficient is around –0.05. This means that a one-standard-deviation increase in terrorism reduces land per capita by 0.85 log point, which is more than 50 percent. This effect seems extraordinarily large.

These results are potentially compromised by the possibility that city characteristics, like land use, are causing terrorism, rather than the reverse. Indeed, I would be more likely to interpret these regressions as suggesting that terrorism is more common in cities with less land per capita than that terrorism causes cities to use less land per capita. If you take this interpretation, then the meaning of the regressions is reversed. Instead of suggesting that people have responded to terrorism by clustering, the regressions suggest that terrorists target cities where people cluster, which surely suggests that the tall targets effect might push cities to cluster less.

Blomberg and Sheppard are well aware of this problem and respond with a two-stage least squares approach where climatic variables are used as instruments. I do not understand how this approach allows them to instrument for terrorism. The key for a valid instrument is orthogonality to the error term, and a valid instrument for terrorism would need to be correlated with terrorism but orthogonal to any other unmeasured forces that would also affect form. I do not see how these instruments could possibly satisfy this condition, although I certainly think that the relationship between climate and urban land use is interesting. My contention that these estimates are not really usable is the fact that the coefficient blows up by a value of five. If this is to be believed, and if I have interpreted the coefficients correctly, then three extra terrorist incidents cause a reduction in land per capita of more than 50 percent in a city. This does not seem plausible.

The paper performs three other empirical exercises. The authors repeat the instrumental variables strategy with more variables. Since I do not find the basic instrumental variables strategy convincing, I do not find this convincing either. They estimate a first-differences model where changes in urban land use are regressed on changes in terrorism. I like this approach somewhat better and think that regressing changes in urban form on earlier terrorism levels is more likely to yield convincing results.

Finally, they include some fascinating regressions linking urban land use with religious and ethnic fractionalization. The big finding is that places with more ethnic fractionalization have more land use per capita. This is a fascinating result that is worthy of more attention. While there is a robust body of research on ethnic heterogeneity and cities within countries, there is much less cross-country work.

While I have some empirical issues with the approach taken, overall this is a fascinating paper that forms part of a splendid research agenda. The authors are taking on important topics and producing new facts and insights.

References

Alesina, Alberto, Arnaud Deveeschauwer, William Easterly, Sergio Kurlat, and Romain Wacziarg. 2003. "Fractionalization." *Journal of Economic Growth* 8, no. 2: 155–94.

Anderson, J. A. 1984. "Regression and Ordered Categorical Variables." *Journal of the Royal Statistical Society, Series B* 46, no. 1: 1–30.

Angel, Shlomo, Stephen C. Sheppard, and Daniel L. Civco. 2005. *The Dynamics of Global Urban Expansion.* Washington: World Bank, Transport and Urban Development Department, September (www.williams.edu/Economics/UrbanGrowth/WorkingPapers.htm [April 2007]).

Bae, Chang-Hee Christine, Larry Blain, and Alon Bassok. 2005. "The Transportation Implications of a Terrorist Attack on Seattle's Highway Network." In *The Economic Impacts of Terrorist Attacks,* edited by Harry W. Richardson, Peter Gordon, and James E. Moore II. Cheltenham, U.K.: Edward Elgar.

Blomberg, S. Brock, and Gregory D. Hess. 2007 (forthcoming). "From (No) Butter to Guns? Understanding the Economic Role in Terrorism." In *Economic Consequences of Terrorism in Developed and Developing Countries,* edited by Philip Keefer and Norman Loayza. Cambridge University Press.

Blomberg, S. Brock, Greg D. Hess, and Akila Weerapana. 2004. "Economic Conditions and Terrorism." *European Journal of Political Economy* 20, no. 2: 463–78.

Blomberg, S. Brock, and Stephen Sheppard. 2007. "Terrorism and Urban Form." Unpublished ms. Claremont McKenna College and Williams College.

Brueckner, Jan K. 1987. "The Structure of Urban Equilibria." In *Handbook of Regional and Urban Economics,* edited by Edwin Mills, pp. 821–45. New York: Elsevier.

Capozza, Dennis R., and Robert W. Helsley. 1990. "The Stochastic City." *Journal of Urban Economics* 28, no. 2: 187–203.

Crenshaw, Martha. 2001. "Why America? The Globalization of Civil War." *Current History* 100, no. 650 (December): 425–32.

Cunningham, Christopher. 2006. "House Price Uncertainty, Timing of Development, and Vacant Land Prices: Evidence for Real Options in Seattle." *Journal of Urban Economics* 59, no. 1: 1–31.

Durbin, James. 1954. "Errors in Variables." *Review of the International Statistical Institute* 22, no. 1: 23–32.

Glaeser, Edward L., and Jesse M. Shapiro. 2002. "Cities and Warfare: The Impact of Terrorism on Urban Form." *Journal of Urban Economics* 51, no. 1: 205–24.

Gordon, Peter, James E. Moore II, Qisheng Pan, and Harry W. Richardson. 2005. "The Economic Impact of a Terrorist Attack on the Twin Ports of Los Angeles–Long Beach." In *The Economic Impacts of Terrorist Attacks,* edited by Harry W. Richardson, Peter Gordon, and James E. Moore II. Cheltenham, U.K.: Edward Elgar.

Harrigan, James, and Philippe Martin. 2002. "Terrorism and the Resilience of Cities." *Economic Policy Review,* Federal Reserve Board of New York 8, no. 2 (November): 97–116.

Hausman, Jerry. 1978. "Specification Tests in Econometrics." *Econometrica* 46, no. 6: 1251–71.

Hoffman, Bruce. 1997. "The Confluence of International and Domestic Trends in Terrorism." *Terrorism and Political Violence* 9, no. 2: 1–15.

Krugman, Paul. 1991. *Geography and Trade.* MIT Press.

Mickolus, Edward F., Todd Sandler, Jean M. Murdock, and Peter A. Flemming. 2006. *International Terrorism: Attributes of Terrorist Events 1968–2004.* ITERATE 3-4 (computer file). Dunn Loring, Va.: Vinyard Software Distributors (ssdc.ucsd/ssdc/ite00001.html [April 2007]).

Redfearn, Christian L. 2005. "Land Markets and Terrorism: Uncovering Perceptions of Risk by Examining Land Price Changes Following 9/11." In *The Economic Impacts of Terrorist Attacks,* edited by Harry W. Richardson, Peter Gordon, and Jams E. Moore II, ch. 9. Cheltenham, U.K.: Edward Elgar.

Rossi-Hansberg, Esteban. 2004. "Cities under Stress." *Journal of Monetary Economics* 51, no. 5: 903–27.

Seager, Ashley, Charlotte Moore, and Heather Long. 2005. "Special Report: Attack on London." *Guardian* (London)*,* July 19.

Sheppard, Stephen. 2005. "Urban Structure in a Climate of Terror." Paper presented at CESifo Conference on Guns and Butter, Munich, Germany, December 9–10.

———. 2007. "Infill versus Outspill: The Microstructure of Urban Expansion." Working Paper in Economics. Williams College.

State Department. Various years. *Patterns of Global Terrorism.* Annual report. Washington (state.gov/s/ct/res/pgtrpt/ [April 2007]).

Titman, Sheridan. 1985. "Urban Land Prices under Uncertainty." *American Economic Review* 75, no. 3 (June): 505–14.

Wilkenson, Paul. 2001. *Terrorism versus Democracy: The Liberal State Response.* London: Frank Cass.

Wu, De-Min. 1973. "Alternative Tests of Independence between Stochastic Regressors and Disturbances." *Econometrica* 41, no. 4: 733–50.

Wu, Weiping, and Shahid Yusuf. 2004. "Shanghai: Remaking China's Future Global City." In *World Cities beyond the West,* edited by Josef Gugler, pp. 27–58. Cambridge University Press.