SHOCKS AND THE SPATIAL DISTRIBUTION OF ECONOMIC ACTIVITY: THE ROLE OF INSTITUTIONS

Patrick A. Testa*

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Abstract

Why do some historical shocks permanently impact local development, while others do not? This paper examines how formal institutions influence local recovery to population shocks, using a model with multiple regions and increasing returns to economic activity within regions. Extractive institutions crowd out productive activity, making its spatial coordination more difficult in the aftermath of large, negative shocks. Hence, when one region experiences such a shock, extractive institutions can hinder recovery, ensuring a redistribution of productive activity away from that region over the long-run. Using a dataset of major earthquakes and 1860 world cities from 1973 to 2018, I find sustained negative effects of earthquakes on city population growth, with effects being driven by cities located outside of stable democracies, consistent with the theory.

JEL codes: B52, C72, J24, P48, R12
Key words: History dependence; multiple equilibria; institutions; increasing returns; earthquakes

*Department of Economics, 6823 St. Charles Avenue, Tulane University, New Orleans, LA 70118, United States of America. Email: ptesta@tulane.edu. Phone: +1 (507) 261-7728. This paper greatly benefited from feedback and suggestions by Dan Bogart, Jean-Paul Carvalho, Areendam Chanda, Matt Freedman, Dan Keniston, Igor Kopylov, Adam Meirowitz, Michael Shin, Stergios Skaperdas, and Cole Williams, as well as seminar participants at UC Irvine, Tulane, LSU, George Mason, and Alberta. All errors are my own. Declarations of interest: none.

1 Introduction

What factors determine the distribution of economic activity across space? And why do some shocks to local development permanently alter this distribution, while others do not? These questions are of central importance in urban and development economics for understanding differences in economic performance within countries, as well as the potential role of policy. Despite this, their answers remain subject to active debate.

One theory is that there exists the potential for multiple equilibria in spatial development but conditions set by both nature and history select among them. In this view, the location of economic activity is driven in part by incentives for humans to locate near each other, such as in production (i.e. agglomeration spillovers). Such increasing returns can generate path dependence, while also implying a potential for policy to induce or transplant economic activity in self-reinforcing ways (Kline and Moretti, 2014; Jedwab and Moradi, 2016). However, some empirical research has cast doubt upon the empirical relevance of multiple equilibria. Davis and Weinstein (2002, 2008) and Miguel and Roland (2011), among others, have shown how even massive shocks may only temporarily redistribute economic activity across space. This literature supports a more deterministic view, in which individuals co-gravitate toward strong fundamentals over the long-run, while returns to scale matter more for determining spatial dispersion (e.g. of cities). Efforts to reconcile these findings have varied considerably, with selection in shock exposure, focal points, and heterogeneity in physical geography all being proposed as potential sources of differential effects (Redding, 2010; Acemoglu et al, 2011; Bleakley and Lin, 2012; Nunn, 2009, 2014; Jedwab et al, 2019).

This paper provides an alternative approach to understanding this empirical puzzle, by considering the interaction of increasing returns with another important force for long-run development: formal institutions (Acemoglu et al, 2001; Dell, 2010; Acemoglu and Dell, 2010). Using a two-region model with migration between regions, I explore the role of institutions in explaining the differential impact of temporary shocks on the long-run spatial distribution of economic activity. In the model, more extractive institutions decrease the return on production relative to "unproductive" activities that do not contribute to the productive process, thus utilizing resources at the expense of it (Nunn, 2007). In the presence of increasing returns to productive activity within regions, a large negative shock to a region's population can temporarily reduce productive spillovers. When institutions are sufficiently extractive, this can induce substitution among workers from productive into unproductive activities. Now absent productive spillovers, relatively fewer workers will prefer to live in the affected region, while those who do migrate there will also prefer to engage in unproductive activities, locking in asymmetries in both population and production between regions.

Hence, the model exhibits multiple equilibria: one with two similarly productive and populated regions, and one with a single highly populated, productive region neighboring a less populated and relatively unproductive region. Moreover, these asymmetries can arise even when there are no differences in natural advantages, local institutions, or endowments *ex ante* between regions. Then, as institutions become stronger and less extractive, spatial equilibria become more robust to large shocks. This illustrates how relatively low levels of economic activity may persist in a region following a negative population shock, causing population and productive inputs such as human capital to become concentrated in select regions over the long-run – even if formal institutions eventually improve.

The notion that historical institutions can have long-lasting effects is not new. A large theoretical and empirical literature exists documenting numerous cases throughout history in which extraction negatively impacted long-run economic development. Human capital (Acemoglu et al, 2014), culture (Tabellini, 2010), and public goods provision (Dell, 2010) have all been cited as important channels through which historical institutions continue to matter. Most similar to this paper is Nunn (2007), who models a similar tradeoff between productive and unproductive activities in explaining the importance of historical extraction. This paper goes a step further, exploring how national institutions influence the persistence of shocks, and therefore the distribution of economic activity, *within* countries. In particular, it argues that in places that feature less economic activity, extractive institutions promote comparative advantages in unproductive activities that, as such, do not attract productive workers. In the context of a large shock, such as a natural disaster, this means that activities such as corruption and property theft made more attractive by weak institutions are present to reinforce the effects of the initial shock. It also means that, by weakening incentives underlying urban recovery in the short-run, weak central institutions may produce greater variation in development within countries.

Nevertheless, a link between the institutional environment experienced by a country or region and the persistence of population shocks therein has often been alluded to in existing empirical research on war, expulsion, and natural disaster. Mirroring Davis and Weinstein's (2002, 2008) finding that Japanese city size and composition were robust to the bombings of WWII, returning to their prewar distributions within decades, Miguel and Roland (2011) observe similar convergence in Vietnam. At the same time, they argue that differential convergence would be unsurprising in a larger sample of studies. In particular, the authors note that while postwar Japan was a market democracy and Vietnam a socialist regime, both had relatively strong political institutions, which would have aided in catch-up in both places. Similar points about the importance of preexisting institutions are made by Brakman et al (2004), who find swift convergence after WWII in West but not East Germany, as well as in surveys of the empirical literature by Redding (2010) and Nunn (2014).

Given this, it is perhaps unsurprising that much of the work on forced migration has shown, in contrast, strong persistence in the origin economy. For instance, Chaney and Hornbeck (2016) find delayed convergence following the expulsion of Moriscos from Spain in 1609, citing preexisting extractive institutions in Morisco areas as a potential source. Testa (2019) similarly finds Czech municipalities affected by expulsions of Germans after WWII to be worse off today relative to unaffected areas nearby, attributing these differences in part to the widespread property exploitation that took place of affected areas by settlers and local officials. Meanwhile, Nunn (2008) finds a negative relationship between exports of slaves and future economic performance in African countries, characterizing the slave trade as an extractive regime that gave rise to raiding and internal warfare in origin economies.

Such can also be found in the relatively smaller literature on non-political population shocks, such as natural disaster. In the case of earthquakes, Barone and Mocetti (2014) cite preexisting institutions as a source of differential effects, with corruption and declining social capital impeding recovery in poorly institutionalized places, while Anbarci et al (2005) similarly show poor collective action to exacerbate earthquake fatalities in places with greater inequality, and Belloc et al (2016) observe local institutional stagnation following earthquakes in medieval Italy in places where separation of relevant powers had previously been weak. Meanwhile, Acemoglu et al (2019) find that severe droughts paved the way for the Sicilian Mafia where institutions were weak, at the expense of subsequent local development.[1]

The remainder of the paper adds to this empirical literature by testing the predictions of the model. To do this, I consider the effects of large earthquakes on city population growth over time, using a dataset of all major earthquakes (i.e. 5 or greater magnitude on the Richter scale) and population size for 1860 world cities from 1973 to 2018. I first show that earthquakes tend to have a negative impact on city population growth, with this effect becoming large and growing over time when I account for a city's time-invariant earthquake risk. When I then split the sample on the basis of political institutions, I find this effect to be driven by cities located outside of stable democracies, in line with the predictions of the model. These findings complement an existing literature on the economic effects of earthquakes and other national disasters, to which they contribute an examination into the city-level population effects of earthquakes at a global level (Ahlerup, 2013; Cavallo et al, 2013; Boustan et al, 2017; Kirchberger, 2017).[2]

[1]Also see Maloney and Caicedo (2015) and Jedwab et al (2016) for examples of institutions as a source of heterogeneous effects in the persistence of pre-colonial American agglomerations and the Black Death, respectively, as well as Dell and Olken (2019) for evidence that within the extractive colonial Dutch regime in Java, agglomeration economies from sugar factories gave rise to countervailing long-run effects locally.

[2]A more similar empirical study is Kocornik-Mina (2019), who find persistent urban effects of floods.

2 The model

The economy in the model is composed of a share of non-atomic workers M_r in each region $r \in \{1, 2\}$. Workers are long-lived but myopic, and I focus for now on a single time period. Each worker begins a period with some endowment, which she may choose to transform into a *labor input*, h (e.g. human capital). If she does, then her labor input is combined with a firm's resources to produce goods, and she is compensated at the regional market wage rate w_r. In this scenario, she is said to be *engaged in production*. At any given time, the share of all workers living in region r *and* engaged in production is $m_r \leq M_r$.[3] Each region also has a fixed stock of *resources*, K, which are divided amongst $\lambda * m_r$ identically-producing firms indexed by ω.[4] In a given period, each region r firm has some amount $k_r \leq K/\lambda m_r$ of resources for use in production, to be defined shortly.

However, a worker may also choose to forgo engagement in production. In this scenario, she simply consumes resources directly – resources which might otherwise be used by firms as inputs in production. I refer to such behavior as *unproductive*, to the extent that it does not contribute to the local production process and as such comes at its expense. The relative payoffs from unproductive activities as compared to productive ones crucially depends on the formal institutional environment. The assumption that extractive or weak institutions decrease the relative payoffs from productive activities and give rise to unproductive behavior is long-standing in the political economy literature (Skaperdas, 1992; Nunn, 2007). In this model, the *quality of institutions* is exogenous to local economic activity and represented simply by the parameter β.

The productive environment

Production is subject to constant returns to scale within firms in resources and labor inputs. However, the model allows for *external* increasing returns (i.e. within regions) in regional labor inputs $H_r \equiv m_r h$. In this case, as relatively more productive activity locates in region r, region r firms can produce relatively more given the same labor inputs. This *agglomeration spillover* is represented by H_r^γ, where $\gamma \geq 0$ gives its magnitude.[5]

Besides agglomeration, heterogeneity across regions in firm-level productivity can also be attributed to differences in *natural advantages*. These locational benefits are given by the

[3]Thus the share of the world's workforce that is engaged in production is $m_r + m_{-r} \leq 1$, while the relative measure of workers in r engaged in production doesn't necessarily scale with but is constrained by M_r.

[4]For simplicity, K is immobile and regenerates each period.

[5]This term is common in the economic geography literature (Allen and Donaldson, 2018). For microfoundations, see Marshall (1920) and Duranton and Puga (2004). For empirical estimation, see Rosenthal and Strange (2004), Moretti (2004), Greenstone et al (2010), and Ellison et al (2010).

parameter a_r. Thus the overall productivity level for region r is given by:

$$A_r = a_r H_r^\gamma.$$

Altogether, this yields a firm-level CRS production function of:

$$f_r(\omega) = A_r k_r h_r(\omega),$$

where $h_r(\omega)$ gives a region r firm's demand for labor inputs. Hence, a firm's profit maximization problem can be given by:

$$\max_{h_r(\omega)} p a_r H_r^\gamma k_r h_r(\omega) - w_r h_r(\omega), \tag{1}$$

where prices p are set collectively by all regions with workers engaged in production.[6] Assuming zero profit, this implies a real income and thus consumption payoffs for productive workers in region r of:

$$\begin{aligned} V_r(h) &= a_r H_r^\gamma k_r * h \\ &= a_r k_r h^{1+\gamma} m_r^\gamma. \end{aligned} \tag{2}$$

How does the institutional environment matter?

Unlike typical two-region models of economic geography, this framework incorporates a strategic component in which workers may prefer to engage in unproductive activities. In contrast with production, which involves combining worker endowments with resources to create value for consumers, unproductive activities involve acquiring and consuming resources directly (i.e. every man for himself), which does not entail external economies of scale, while coming at the expense of the local productive sector, which does. This distinction between productive and unproductive activities is common in the literature on institutions and conflict (Acemoglu, 1995; Nunn, 2007). Real world examples might include corruption and rent-seeking, looting and other property crime, and free-riding on public goods.

I model such resource acquisition using a variant of the contest success function (Skaperdas, 1996). Unproductive workers consume resources that would otherwise be used in production, where the total amount of resources acquired by unproductive workers in region r is proportional to the relative prevalence of unproductive behavior in the regional economy:

$$\frac{M_r - m_r}{M_r} K,$$

[6] Since regions are in close proximity, I assume no trade costs or differences in market access.

where $M_r - m_r$ equals the share of all workers living in region r and engaged in unproductive activities. This leaves each region r firm with a final resource endowment of:

$$\begin{aligned} k_r^* &= \left(1 - \frac{M_r - m_r}{M_r}\right)\frac{K}{\lambda m_r} \\ &= \frac{K}{\lambda M_r}. \end{aligned} \tag{3}$$

Unproductive payoffs follow from this. Adopting the assumption that relative value from unproductive activities is derived inversely from the quality of institutions, consider the following payoffs from engaging in unproductive activities in region r:

$$\begin{aligned} V_r(u) &= \frac{1}{\beta}\frac{1}{M_r - m_r}\left(\frac{M_r - m_r}{M_r}\right)K \\ &= \frac{K}{\beta M_r}. \end{aligned} \tag{4}$$

Recall that β describes the quality of institutions, which I consider to be a deep parameter that is the same in both regions. In spite of this, unproductive behaviors may become widespread in one region and not the other, as one will see shortly. At the same time, because resources are fixed in each region and of use in both production and unproductive activities, they will serve as a relative congestion force in each region that prevents "black hole" equilibria, in which all workers locate in one region, from arising in the long-run.

2.1 Short-run equilibria

I assume that in the short-run, workers cannot move between regions but can move between productive and unproductive activities. For analytical simplicity, this choice is modeled as a binary decision. That is, an agent prefers to transform her endowment into a productive labor input if and only if

$$a_r \frac{K}{\lambda M_r} h^{1+\gamma} m_r^{\gamma} \geq \frac{K}{\beta M_r}. \tag{5}$$

For now, let $\gamma > 0$. Since agents are non-atomic, each takes m_r as given when deciding whether to deviate. Hence, worker behavior exhibits strategic complementaries around some critical threshold, $\widehat{m_r}$, above which the optimal $m_r^* = M_r$, the total share of workers in r.

Definition 1. A *high production short-run equilibrium* [HPSE] consists of all workers in a region r specializing in production ($m_r^* = M_r$).

Definition 2. A *low production short-run equilibrium* [LPSE] consists of all workers in a region r specializing in unproductive activities ($m_r^* = 0$).

Now consider the first result:

Proposition 1. *There exists a high production short-run equilibrium [HPSE] for each region r. In every HPSE:*

(i) There is a threshold relative amount of productive activity $\widehat{m_r}$ when $\gamma > 0$, above which the total share of workers in region r, M_r, prefer to specialize in production, $m_r^* = M_r$.

(ii) The share of the worker population located in r must be sufficiently large, $M_r \geq \widehat{m_r}$, where this equilibrium is locally stable in M_r whenever this inequality is strict.

(iii) $\widehat{m_r}$ is decreasing in a_r, h, and β and increasing in λ.

The remaining space below $\widehat{m_r}$ is characterized by a LPSE, in which all agents in region r forgo production and instead simply acquire and consume local resources (i.e. $m_r^* = 0$). Importantly, because productive activity entails within-region externalities, and because the relative measure of productive activity in one region is constrained by its relative population size, a temporary decrease (i.e. shock) in the share of the population located in that region has the potential to permanently shift it from a HPSE to a LPSE (i.e. $M_r < \widehat{m_r}$ implies $m_r < \widehat{m_r}$). However, this depends on the quality of formal institutions. When the quality of institutions β is sufficiently high, even large shocks will not generate incentives for workers to substitute toward unproductive activities in the affected region. This is important, as a population shock which cannot induce a shift from one short-run equilibrium to another within a region will also have no effect on the long-run equilibrium population distribution *across* regions, as we will see shortly.

Now let $\gamma = 0$, such that there are no agglomeration spillovers. This is relevant for understanding how sectors such as agriculture respond to population shocks in the short-run. As it turns out, population shocks cannot shift a region from one short-run equilibrium to another in the absence of agglomeration spillovers:

Remark 1. *In the absence of agglomeration spillovers, $\gamma = 0$, if a HPSE exists in region r for some M_r, then it exists for all M_r'.*

Hence, the propensity for a population shock to shift a regional economy from a HPSE to a LPSE depends not only on the quality of formal institutions but also on the presence of external increasing returns (i.e. $\gamma > 0$), which generate strategic complementarities in production choices within regions. In fact, absent agglomeration spillovers, economic activity will always tend toward its initial distribution as determined by fundamentals *regardless of institutions.* To show this, however, I must first introduce population dynamics, in the form of migration between regions over time.

2.2 Long-run equilibria

In the long-run, agents can move between productive and unproductive activities within regions as well as migrate between regions. Population dynamics are modeled as in the economic geography literature,[7] using a standard replicator dynamic:

$$\dot{M}_r = M_r(V_r - \overline{V}), \tag{6}$$

where $\dot{M}_r$ gives the change over time in the share of the population in region r, which depends on the relative size of the short-run payoffs in region r, and where $\overline{V} \equiv M_1V_1 + M_2V_2$ gives the national average payoffs. There is no cost to migration. However, since agents are non-atomic, short- and long-run incentives can interact to generate coordination problems which in turn constrain migration.

Suppose, for instance, that $m_r \geq \widehat{m_r}$ initially in each region r, such that both regions specialize in production (i.e. $m_r^* = M_r$ for all r). Then there exists some steady state $M_r \equiv M_r^*$ at which $\dot{M}_r = 0$ as long as $M_r^* \geq \widehat{m_r}$ for each region r. That is, when enough agents are coordinating on productive behavior in each region, $m_r \geq \widehat{m_r}$, there is some population distribution M_r at which both regions have high levels of production and no worker prefers to deviate from one region to other. From (2) and (6), this is the solution to:

$$\frac{a_1 K h^{1+\gamma}}{\lambda} M_1^{\gamma-1} = \frac{a_2 K h^{1+\gamma}}{\lambda} M_2^{\gamma-1}, \tag{7}$$

which implies for each region r:

$$M_r^* = \frac{a_r^{\frac{1}{1-\gamma}}}{a_r^{\frac{1}{1-\gamma}} + a_{-r}^{\frac{1}{1-\gamma}}}.$$

However, the local stability of this as a long-run equilibrium depends on γ.

Assume for now that $\gamma \in (0,1)$. When $\gamma \in (0,1)$, the lefthand side of (7) is strictly decreasing in M_r while the righthand side is strictly increasing. Then small changes in M_r will have only temporary effects, holding short-run equilibria fixed. However, by Proposition 1, the stability of this state also depends on the size of M_r relative to the threshold $\widehat{m_r}$ for each region, i.e. local stability in the short-run. I thus define the following:

Definition 3. A *symmetric high production long-run equilibrium* [HPLE] consists of (i) each region being in a HPSE ($m_r^* = M_r$ for all r), with (ii) a steady state share of workers located

[7] In this tradition, population dynamics are often framed in relative terms (i.e. regional shares), such that the size of the total population does not matter for the long-run analysis. For instance, see Krugman (1991), Davis and Weinstein (2008), and Allen and Donaldson (2018).

in each region, M_r^*, which is said to be *locally stable* in M_r if short-run equilibria are locally stable in M_r ($M_r^* > \widehat{m_r}$) and small changes in M_r are temporary ($\frac{\partial \dot{M}_r}{\partial M_r}|_{M_r=M_r^*} < 0$).

Now suppose that M_r and $\widehat{m_r}$ are sufficiently close. Then a large, negative shock to M_r in the short-run (e.g. from death or displacement) may result in a shift to a LPSE in region r, such that the steady state population distribution is no longer determined by (7).

This brings me to a second case, in which a large, negative shock to e.g. M_2 occurs, shifting region 2 from a HPSE to a LPSE. In other words, in depleting region 2 of its productive workforce relative to region 1, a large negative population shock reduces its productive spillovers, thus making it relatively more appealing for those living in region 2 to engage in unproductive behavior, so long as institutions are sufficiently extractive. Furthermore, conditional upon engaging in unproductive activities, it also increases the consumable amount of resources *per capita* in region 2. In the long-run, this will trigger migration into region 2 by those who see opportunity in unproductive activities, but *not productive ones*. Assuming that such a shock did not also occur in region 1, the new steady states M_r will be the solution to:

$$\frac{a_1 K h^{1+\gamma}}{\lambda} M_1^{\gamma-1} = \frac{K}{\beta M_2}. \tag{8}$$

It can be shown that such a shock should leave region 2 at a permanently lower relative population level when $\gamma \in (0, 1)$, as in Figure 1. To do this, I first define the following:

Definition 4. An *asymmetric long-run equilibrium* [ALE] consists of (i) one region r being in a HPSE ($m_r^* = M_r$) and (ii) the other region $-r$ being in a LPSE ($m_{-r}^* = 0$), with (iii) a steady state share of workers located in each region, M_r^{**}, which is said to be *locally stable* in M_r if short-run equilibria are locally stable in M_r for region r ($M_r^{**} > \widehat{m_r}$) and small changes in M_r are temporary ($\frac{\partial \dot{M}_r}{\partial M_r}|_{M_r=M_r^{**}} < 0$).

Altogether, these results can now be summarized by the following proposition:

Proposition 2. *(i) There exists a locally stable symmetric high production long-run equilibrium [HPLE], with a unique interior steady state population $M_r^* \in (0, 1)$ when agglomeration spillovers are moderately strong, specifically $\gamma \in (0, 1)$, where $M_r^* = \frac{1}{2}$ if and only if $a_2 = a_1$, and where M_r^* increasing in a_r and decreasing in a_{-r}.*

(ii) There also exists a locally stable asymmetric long-run equilibrium [ALE], with a steady state population share in the productive (unproductive) region of $M_r^{**} > M_r^*$ ($M_{-r}^{**} < M_{-r}^*$), with M_r^{**} increasing in a_r, h, and β and decreasing in λ.

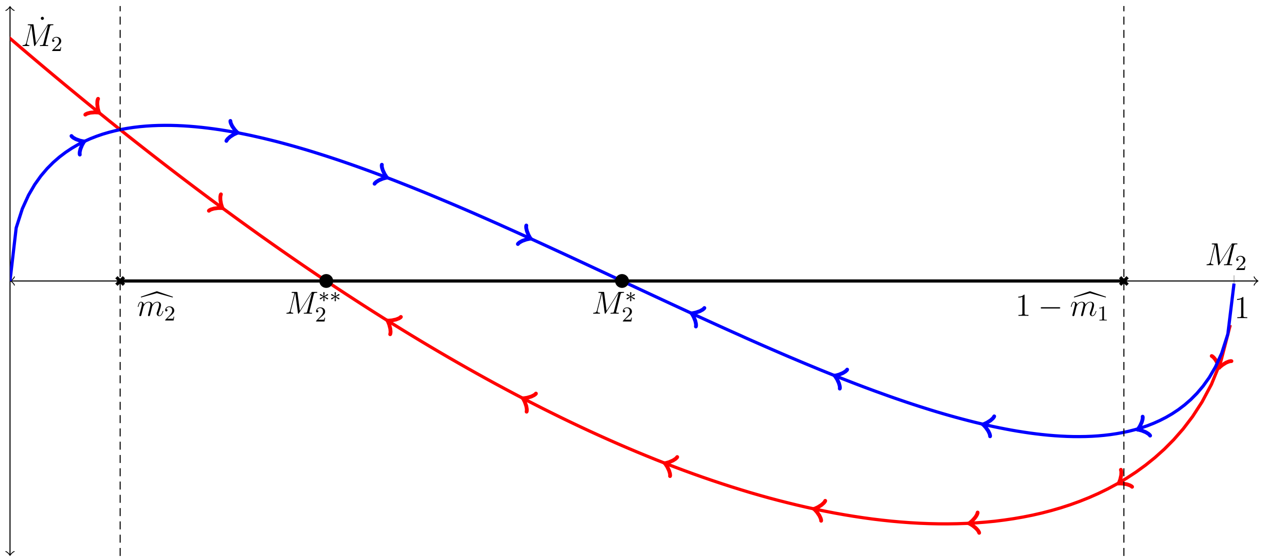

Figure 1: Symmetric high production (in blue) versus asymmetric (in red) long-run equilibria for $\gamma = 1/2$, $\beta = 10/3$, $a_1 = a_2 = K = h = \lambda = 1$.

Thus, a sufficiently large, negative population shock in one region (i.e. such that $M_r < \widehat{m_r}$) can permanently (i) shift its local economy from production to unproductive activity, (ii) lowering its relative population due to now relatively larger productive spillovers in the other region, (iii) leaving a population that is nonetheless positive to the extent that its resources may still be utilized in relatively unproductive ways, with such payoffs being determined by the quality of institutions (i.e. $\frac{\partial \widehat{m_r}}{\partial \beta} < 0$).[8]

In other words, given more extractive institutions, large-scale population loss tends to induce a shift toward unproductive activities in the affected region by those remaining as well as incoming migrants (e.g. property exploitation, corruption),[9] rendering it less productive and populated over the long-run. Stronger institutions, meanwhile, limit the extent to which being production becomes relatively unappealing following large shocks, such that agents are more likely to coordinate back to pre-shock patterns.

Lastly, let $\gamma \notin (0,1)$. We know that when $\gamma = 0$, short-run shocks of any size should have no bearing on short-run equilibria. Hence, sectors lacking agglomeration spillovers should see their workers return to their pre-shock distribution, as determined by either (7) or (8).[10]

Remark 2. *In the absence of agglomeration spillovers, $\gamma = 0$, population shocks have no*

[8] Thus if a shock also negatively affects K over the long-run in that region, even fewer would reside there.

[9] Alternatively, this could be thought of as corresponding to changes in local institutions or social norms.

[10] As a corollary to Propositions 1 and 2, note that if institutions become too extractive, then unproductive activities will become too appealing relative to productive ones, such that no HPLE or ALE can survive and both regions will be in LPSE as part of a globally stable symmetric low production long-run equilibrium [LPLE]. To see this, note that the derivative on $\widehat{m_r}$ and those on both steady states M_r^* and M_r^{**} are opposing in β. For sufficiently low β, $M_r \geq \widehat{m_r}$ can never occur, regardless of shocks.

long-run effect on the spatial distribution of productive activity.

In other words, in sectors like agriculture which lack external economies of scale, shocks have no permanent effects, regardless of institutions. Rather, the distribution of productive activity is determined solely by the fundamentals. If fundamentals vary across space, then activity will tend to locate more where they are stronger. If they are symmetric across regions (i.e. $a_2 = a_1$), then so will be the distribution of e.g. farmers, both before and after population shocks, assuming a HPLE to begin with.

What about when agglomeration spillovers are very strong, i.e. $\gamma > 1$?[11] As it turns out, when productive spillovers are sufficiently great, HPLE are *always* unstable:

Proposition 3. *When agglomeration spillovers are sufficiently strong, specifically* $\gamma > 1$*, then:*

(i) There exists a symmetric high production long-run equilibrium [HPLE].

(ii) It is always unstable in M_r*.*

Hence, the existence of a locally stable HPLE is sufficient but not necessary for uneven patterns of development to arise. Reminiscent of the new economic geography, when agglomeration spillovers are sufficiently strong, interior equilibria tend toward instability, in favor of unevenness over the long-run.[12]

The role of local development policy

Finally, note that in contrast with negative shocks, the model implies that the effects of temporary local development policies and positive population shocks associated with them (assuming an unproductive equilibrium to begin with) may actually be *more* likely to persist in the long-run in places with strong institutions. This is because while it takes a negative shock to m_r larger than $M_r - \widehat{m_r}$ to move a region from a productive equilibrium to an unproductive one, it takes a positive policy shock larger than $\widehat{m_r}$ to do the opposite. Hence, when β is large, only a small-scale coordinated effort (e.g. by some "city corporation") is needed to move a region from an unproductive equilibrium to a productive one: an investment need only attract a few to the region simultaneously before complementarities take over.

[11] I opt to ignore the trivial case in which $\gamma = 1$ such that M_r is not well defined under equation (7).

[12] For more on alternative equilibria when $\gamma > 1$, see the Supplemental Material.

3 Empirical evidence

There exists a growing empirical literature exploring the short- and long-run impacts of shocks on the location of economic activity, with war, expulsion, disease, and natural disaster all serving as temporary shocks to relative city or region size (Davis and Weinstein, 2002; Testa, 2019; Jedwab et al, 2019; Kocornik-Mina et al, 2019). To the extent that population levels and growth trends do not return to pre-shock levels, as compared to places not exposed to the shock, it is taken as evidence in favor of multiple spatial equilibria and the importance of increasing returns for determining differences in development across space. At the same time, a sizable literature finds no such persistence in the aftermath of even very large shocks, supporting a more deterministic view of spatial development.

This paper proposes an interaction between increasing returns and a place's underlying formal institutions in determining its short- and long-run response to population shocks. In the model, pre-shock equilibria are robust to even large shocks when institutions are strong. To the extent that extractive institutions crowd out productive activities that generate increasing returns, however, the model sees multiple equilibria emerge, with shocked places experiencing a persistent relative decline in economic activity thereafter.

In this section, I test this prediction – thus providing new evidence relevant to this debate – using a new dataset of large earthquakes and 1860 world cities spanning nearly half a century in order to explore how large, temporary shocks to relative city size affect city growth in the short- and long-run, both overall and splitting the sample based on formal institutional qualities. I will first describe this data, before discussing estimation and results.

3.1 Data

To study the relationship between earthquakes and subsequent city growth, I use data on the location and annual population since 1950 of all world urban agglomerations with 300,000 residents or more as of 2018 – a total of 1860 cities in 153 countries – from the World Urbanization Prospects, as compiled by the UN's DESA/Population Division (2018). Data on city geography are derived using ArcGIS.

Data on major earthquake events from 1973 to 2017, including data on earthquake characteristics, come from the U.S. Geological Survey.[13] Prior to 1973, earthquake detection technology precluded reliable estimates of earthquake magnitude, and such is still the case for Richter magnitudes below 5 (Bentzen, 2019). The final sample has 7686 5+ magnitude earthquakes occurring within 100 km of major cities centers and 700 striking within 25 km. The full sample is plotted against the sample of cities in Figure 2.

[13] This database can be accessed at https://earthquake.usgs.gov/earthquakes/search.

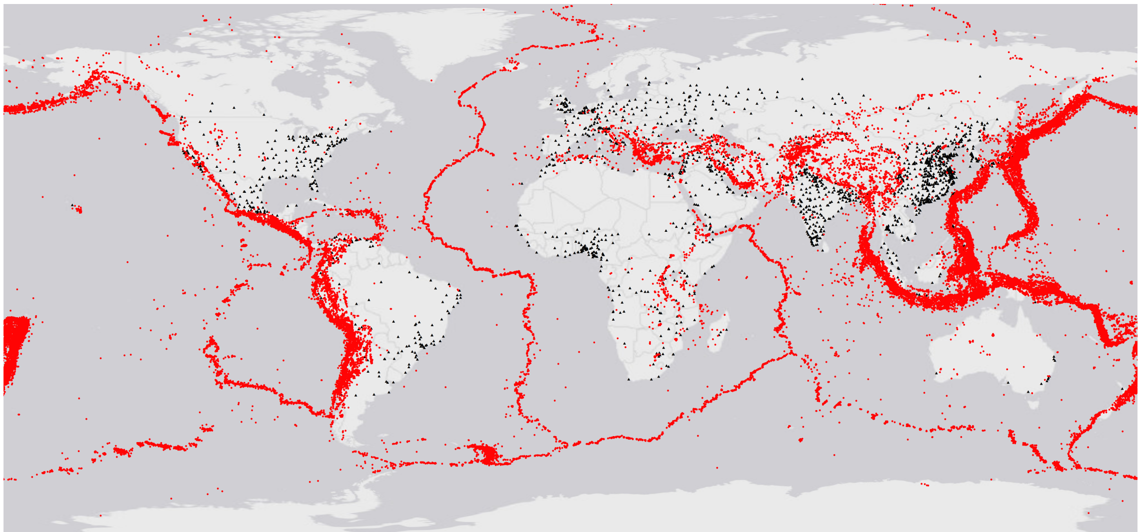

Figure 2: Earthquakes of Richter magnitude 5+ (in red) and major cities (in black), 1973-2017

Data on earthquake risk come from UNEP/GRID-Geneva (2015), which maps all parts of the world with at least a 10% probability of experiencing an earthquake with a Modified Mercalli intensity (MMI) greater than V (i.e. moderate strength) within the next 50 years, where MMI measures the effect of an earthquake at the surface.[14] I consider a city as being located in an earthquake risk area if such areas are within 50 km of its centroid. Under this definition, 895 or about half of cities in the sample are assigned to earthquake risk areas.

To measure formal institutions, I use Polity IV's POLITY index, which ranges from -10 to 10. By their definition, a democracy is a country with a score of 6 or greater. The advantage to using the POLITY index is that it consists of a long panel covering many years and countries. Only three cities in the full sample are not covered by POLITY. One concern, however, is that it provides a poor measure of political institutions, in part because it reflects contemporaneous political outcomes in addition to relatively "deep" institutional attributes (Glaeser et al, 2004). To deal with this concern, I develop a time-invariant indicator of institutions, in which a city is considered to be in a "stable democracy" if it has consistently been in a democracy under POLITY's definition for the entire sample period. To the extent that stable democracies have stronger institutions than autocracies as well as relatively unstable regimes (e.g. new or backsliding democracies), this should proxy for the deeper institutional qualities with which the theory concerns itself.[15]

[14] The four levels are >V, >VII, >VIII, and >IX. See Figure A.1 in the Supplemental Material for a heatmap of these areas, with darker orange corresponding to higher MMI scores with at least a 10% probability of being exceeded, recreated using raster data available at https://preview.grid.unep.ch.

[15] A few countries in the sample were colonial territories (Angola, Djibouti, Guinea-Bissau, Mozambique, and Papua New Guinea) in the first few years of the sample and lack POLITY scores in those years. Similarly, since Berlin was divided until the end of the Cold War, it only enters the POLITY sample upon German reunification. I consider all of such cases as having experienced democracy and nondemocracy at various

TABLE 1: SUMMARY STATISTICS, SUBGROUPS

Subsample	% City growth	Earthquake_{t-1}	Earthquake risk area	Stable democracy
Full sample	3.418	0.008	0.481	0.290
N= 83700	(3.265)	(0.091)	(0.500)	(0.454)
$\text{Earthquake}_{t-1} = 1$	2.867	–	0.969	0.280
N= 700	(2.289)		(0.175)	(0.449)
$\text{Earthquake}_{t-1} = 0$	3.423	–	0.477	0.290
N= 83000	(3.271)		(0.499)	(0.454)
Earthquake risk area = 1	3.403	0.017	–	0.285
N= 40275	(2.965)	(0.129)		(0.452)
Earthquake risk area = 0	3.432	0.001	–	0.294
N= 43425	(3.420)	(0.023)		(0.456)
Stable democracy	2.152	0.008	0.474	–
N= 24210	(2.392)	(0.090)	(0.499)	
Not stable democracy	3.937	0.008	0.484	–
N= 59355	(3.430)	(0.092)	(0.500)	

Standard deviations in parentheses. For a complete list of summary statistics, see Table A.1 in the Supplemental Material.

In secondary specifications, I also interact the treatment with a time-invariant indicator of a city's wealth: its country's income classification in 1990, midway through the sample, as determined by the World Bank in their World Development Indicators (2019) catalog.[16] Countries with gross national income per capita below $2465 USD in 1990 are considered low or lower middle income, with the remainder of countries being upper middle or high income. I refer to cities in these two groups as low and high income, respectively.

3.2 Estimation

To estimate the immediate (i.e. following year) and longer-run impact of strong earthquakes on city population growth, I adopt a distributed-lag approach that controls for a finite number of lags on the explanatory variable (Dell et al, 2012), using panel regressions of the following form:

$$\Delta Pop_{it} = \sum_{s=1}^{L} \gamma_s Quake_{i,t-s} + \theta_i + \mathbb{Y}_t + \varepsilon_{it}, \tag{9}$$

where ΔPop_{it} is a city's rate of population growth between year $t-1$ and year t; $Quake_{i,t-s}$ is a dummy equal to one if an earthquake of 5+ magnitude on the Richter scale struck within 25 km of a city centroid in year $t-s$ for $s = 1, 2, ...$ up to some fixed number of lags L;

times and code them as zeroes. I also derive two alternative institutional measures: one that uses a cutoff POLITY score of zero, and one that allows institutions to vary if the state in which the city resided changed (e.g. Prague resided in Czechoslovakia, a communist autocracy, through 1992, after which it resided in the Czech Republic, a parliamentary republic). Results are robust to instead using these measures, as shown in Table A.6 in the Supplemental Material.

[16]See http://databank.worldbank.org/data/download/site-content/oghist.xls for this data.

θ_i are city fixed effects; and $\mathbb{Y}_t$ are year fixed effects.[17] Regressions are robust to including various city and earthquake interactions, including a wealth indicator. ε_{it} is an error term clustered at the country level, as treatment assignment is often correlated beyond the city level (Abadie et al, 2017). For instance, the same earthquake may affect multiple cities, while seismicity may be spatially correlated along tectonic structures spanning multiple cities.[18]

Spatial correlation may also give rise to heterogeneous effects. In particular, cities regularly at risk of experiencing earthquakes are likely to be different in relevant ways from those that do not. For instance, they may be more prepared to deal with an earthquake, with better infrastructure and more funds allocated toward post-earthquake recovery, which could attenuate population effects (Neumayer et al, 2014). Since I am interested in the effects of exogenous and unexpected shocks to city size, I also run all specifications with an earthquake "risk area" dummy, which I interact with $Quake_{i,t-s}$ for all s. This estimates separately the effects of earthquakes on relative city growth in high-risk areas and in cities where one would constitute a relatively truer shock.

3.3 Results

Table 2 examines the effect of earthquakes on city population growth, first without interactions or lags as a baseline. Column (1a) shows that a one-off earthquake of 5+ magnitude is associated with a 0.1 percentage point decrease in a city's rate of population growth the following year. While this estimate is statistically significant, it lacks economic significance. Introducing lags in columns (1b-d) sees this immediate effect estimated to be smaller still, likely reflecting some autocorrelation among lags, while retaining some statistical significance. Then, in the years following an earthquake, decreases in city population growth trend toward zero, losing their significance. Hence, when one utilizes the full sample of cities without differentiating among them, the effect of a large, one-time earthquake shock on relative city growth appears to be very temporary and small at best.

The remainder of Table 2 includes the earthquake risk area interaction term, estimating

[17] An earlier version of this paper interacted year fixed effects with region dummies as the baseline, finding similar albeit smaller and less precise effects. Given the rarity of major earthquakes, this relied on very little within variation for a relatively large set of regressors, which raised some concern regarding the estimation of standard errors. I therefore refocused the main empirical model in favor of greater parsimony, while now also including a comparison of various alternative year fixed effects specifications below.

[18] Of the 153 countries in the sample, only 64 (and only 13.5% of cities) experienced any major earthquake at all, yet among those 64, 40 saw more than one strike within 25 km of a major city between 1973 and 2017. Meanwhile, all years experienced such earthquakes, with a median of 15 per year, a mean of 15.6, and a standard deviation of 4.6 across years. This is consistent with Tosi et al (2008), who show that while the distribution of seismicity across time is random at a global level, some areas are more prone to activity than others over the long-run (i.e. those near tectonic structures), with local temporal correlations existing within specific, < 1 year space-time domains (i.e. due to migrating aftershocks along tectonic structures).

Table 2: Effects of earthquakes on relative city growth

	Annual city population growth$_t$ (%)			
	No lags	1 lag	2 lags	3 lags
	(1a)	(1b)	(1c)	(1d)
Earthquake$_{t-1}$	-.106 (.046)**	-.096 (.044)**	-.084 (.047)*	-.081 (.046)*
Earthquake$_{t-2}$	–	-.082 (.056)	-.070 (.056)	-.056 (.058)
Earthquake$_{t-3}$	–	–	-.052 (.061)	-.034 (.061)
Earthquake$_{t-4}$	–	–	–	-.005 (.065)
Cumulative effect	-.106 (.046)**	-.178 (.098)*	-.207 (.151)	-.175 (.204)
Adj. R^2	.113	.115	.122	.122
	With earthquake risk area dummy interaction			
	(2a)	(2b)	(2c)	(2d)
Earthquake$_{t-1}$	-.949 (.457)**	-.680 (.215)***	-.451 (.139)***	-.391 (.135)***
Earthquake$_{t-2}$	–	-.925 (.466)**	-.697 (.228)***	-.453 (.180)**
Earthquake$_{t-3}$	–	–	-.995 (.412)**	-.765 (.234)***
Earthquake$_{t-4}$	–	–	–	-.981 (.456)**
Cumulative effect	-.949 (.457)**	-1.605 (.620)**	-2.143 (.692)***	-2.590 (.823)***
Earthquake$_{t-1}$×Earthquake risk area	.875 (.459)*	.606 (.215)***	.377 (.146)**	.318 (.144)**
Earthquake$_{t-2}$×Earthquake risk area	–	.875 (.416)**	.649 (.238)***	.407 (.201)**
Earthquake$_{t-3}$×Earthquake risk area	–	–	.978 (.411)**	.757 (.244)***
Earthquake$_{t-4}$×Earthquake risk area	–	–	–	1.012 (.456)**
Cum. interact.×Earthquake risk area	.875 (.459)*	1.480 (.626)**	2.004 (.710)***	2.494 (.867)***
Adj. R^2	.113	.115	.122	.122
Observations	83700	81840	79980	78120
Cities	1860	1860	1860	1860
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Robust standard errors are clustered by country, with ***, **, and * denoting significance at the 1%, 5%, and 10% levels, respectively. An earthquake is considered to have hit a city if it struck within 25 kilometers for that city's centroid in the previous year. A city is considered to be in an earthquake risk area if there is a 10% probability of it experiencing an MMI event greater than V in the next 50 years at any point within 50 km of its centroid.

the effects of earthquakes in high- and low-risk cities separately. Evaluating effects in cities that historically experience few earthquakes, in which they are arguably more likely to serve as an exogenous shock to city size, column (2a) shows the effect in (1a) to be driven by these, with this coefficient being much larger at about -1 percentage point. Moreover, when I introduce lags here, a different trend emerges from before: the years following a one-off earthquake see persistent if not increasing population decline, suggestive of a circular feedback process ongoing in these cities as their relative sizes move to new equilibria.[19] This trend persists if I add additional lags, albeit with increasing standard errors, as shown in Table A.2 in the Supplemental Material.[20] In contrast, high-risk cities hardly respond at all and exhibit swift convergence back to pre-earthquake population levels with little cumulative effect, suggestive of a preparedness or pervasive belief that city size will be robust.

The second exercise I perform with the data seeks to test the model's key prediction: that the relative amount of economic activity will be less robust to shocks in places with weaker or more extractive institutions. If the logic of the model is correct, one would expect the effects of earthquakes on relative city size to be driven by the cities located outside of stable democracies, in autocracies as well as relatively unstable regimes.

The estimates in Tables 3 and 4 suggest this to be the case. Looking first at short-run effects, columns (3) in Table 3 show negative and statistically significant effects for such cities in low-risk areas, where earthquakes constitute an arguably exogenous shock, with larger coefficients in comparison to both full sample and stable democracy sample estimates. In particular, estimates show an initial decrease in city population growth of about 1.3 percentage points observed in association with a nearby earthquake for low-risk cities outside of stable democracies, versus a small decrease of about 0.2 percentage points for stable democracies, suggesting overall effects are likely being driven in large part by the former. Meanwhile, cities in higher risk areas again exhibit comparatively small effects.

Similar patterns are observed upon the inclusion of lags, as shown in Table 4. Outside of earthquake risk areas, long-run effects mirror those in Table 2 for cities not located in stable democracies, with negative and increasing effects over time for a four-year cumulative effect of over -3 percentage points. This mirrors the findings in Barone and Mocetti (2014) on a more global scale. In contrast, coefficients are notably smaller and statistically insignificant for cities in stable democracies. Differences in these estimates become statistically significant after a couple of years, with a difference in cumulative effects that is significant at the 1%

[19] Another reason for relatively small instantaneous effects is that any interpolation used to derive population counts between official reports would have averaged pre- and post-earthquake counts. Hence, measured effects may be largely capturing cases in which there *was* persistence (enough to be measurable years later).

[20] This finding mirrors Ager et al (2019), who find persistent changes to the spatial distribution of economic activity in the American West following the 1906 San Francisco Earthquake.

Table 3: Short-run effects of earthquakes by polity subsample

	All		Stable democracy			
			Yes		No	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Earthquake_{t-1}	-.949	-.876	-.186	.110	-1.289	-1.199
	(.457)**	(.433)**	(.042)***	(.088)	(.618)**	(.551)**
$\text{Earthquake}_{t-1} \times$Risk area	.875	.839	.130	.110	1.182	1.116
	(.459)*	(.438)*	(.087)	(.132)	(.609)*	(.549)**
$\text{Earthquake}_{t-1} \times$High income	–	-.137	–	-.428	–	-.195
		(.087)		(.097)***		(.122)
Adj. R^2	.113	.113	.043	.043	.144	.144
Observations	83700	83655	24210	24210	59355	59355
Cities	1860	1859	538	538	1319	1319
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Income interaction?	No	Yes	No	Yes	No	Yes

Robust standard errors are clustered by country, with ***, **, and * denoting significance at the 1%, 5%, and 10% levels, respectively. An earthquake is considered to have hit a city if it struck within 25 kilometers for that city's centroid in the previous year. A city is considered to be in an earthquake risk area if there is a 10% probability of it experiencing an MMI event greater than V in the next 50 years at any point within 50 km of its centroid. The difference in effects in (2a) and (3a) is 1.1 (0.62), which is significant at the 10% level. The differences in cumulative effects for low- and high-income countries in (2b) and (3b) are 1.31 (0.56) and 1.08 (0.62) with significance at the 5% and 10% levels, respectively. Note that splitting the sample is equivalent to interacting the institutions indicator with all time-varying regressors in the pooled sample, including income. Results are robust to pooling the sample but omitting this latter interaction (i.e. leaving only an unconditional income interaction). In particular, differences become 1.17 (0.57), with significance at the 5% level.

level in the main specification. For cities located in earthquake risk areas, long-run effects again appear to converge to zero within a few years, with minimal cumulative effect.

One concern is that stable democracy may correlate positively with wealth. Since reactions to earthquakes likely vary in rich versus relatively poor countries, it is possible that controlling for income classification could account for differences associated with formal institutions above. Columns (b) in Tables 3 and 4 include this interaction, with baseline coefficients reflecting effects of earthquakes on relative city size in low income countries. As it turns out, cities in higher income countries tend to exhibit somewhat *larger*, more negative effects.This potentially reflects the economic ease of migration in response to negative shocks in such places, relative to cities in lower income countries.

Results are also robust to including other city-earthquake controls. Potentially important interactions include earthquake depth and Richter magnitude, earthquake month, and a city's distance from the nearest other major city. For instance, Bosker et al (2017) show that spatial interdependencies between cities can impact the effects of shocks, while Richter magnitude and quake depth tend to increase and decrease the surface effects of earthquakes, respectively, and earthquake month may influence to what extent effects are present the following year. Short- and long-run effects with these interactions included can be found in Tables A.4 in the Supplemental Material.

Table 4: Dynamic effects of earthquakes by polity subsample

	All		Stable democracy		Not stable democracy	
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Earthquake$_{t-1}$	-.391 (.135)***	-.332 (.152)**	-.158 (.076)**	.147 (.065)**	-.458 (.158)***	-.433 (.167)***
Earthquake$_{t-2}$	-.453 (.180)**	-.398 (.183)**	-.196 (.112)*	.075 (.058)	-.528 (.231)**	-.509 (.237)**
Earthquake$_{t-3}$	-.765 (.234)***	-.700 (.219)***	-.240 (.164)	-.067 (.129)	-.936 (.234)***	-.836 (.182)***
Earthquake$_{t-4}$	-.981 (.456)**	-.907 (.426)**	-.218 (.153)	-.059 (.130)	-1.462 (.547)***	-1.337 (.473)***
Cumulative effect	-2.590 (.823)***	-2.338 (.803)***	-.812 (.504)	.096 (.284)	-3.384 (.802)***	-3.115 (.689)***
Earthquake$_{t-1}$×Risk area	.318 (.144)**	.304 (.156)*	.044 (.056)	.056 (.132)	.375 (.184)**	.192 (.192)*
Earthquake$_{t-2}$×Risk area	.407 (.201)**	.402 (.208)*	.108 (.108)*	.129 (.106)	.465 (.289)	.462 (.295)
Earthquake$_{t-3}$×Risk area	.757 (.244)***	.733 (.227)***	.233 (.117)*	.267 (.071)***	.903 (.242)***	.833 (.193)***
Earthquake$_{t-4}$×Risk area	1.012 (.456)**	.975 (.427)**	.207 (.116)*	.219 (.077)***	1.485 (.532)***	1.386 (.457)***
Cum. interact.×Risk area	2.494 (.867)***	2.414 (.839)***	.593 (.263)**	.672 (.254)**	3.228 (.875)***	3.043 (.777)***
Earthquake$_{t-1}$×High income	–	-.160 (.082)*	–	-.465 (.135)***	–	-.109 (.128)
Earthquake$_{t-2}$×High income	–	-.173 (.090)*	–	-.436 (.124)***	–	-.131 (.130)
Earthquake$_{t-3}$×High income	–	-.144 (.096)	–	-.296 (.140)**	–	-.245 (.132)*
Earthquake$_{t-4}$×High income	–	-.127 (.105)	–	-.245 (.104)**	–	-.223 (.174)
Cum. interact.×High income	–	-.603 (.308)*	–	-1.441 (.486)***	–	-.708 (.476)
Adj. R^2	.113	.122	.057	.057	.151	.151
Observations	78120	78078	22596	22596	55398	55398
Cities	1860	1859	538	538	1319	1319
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Income interaction?	No	Yes	No	Yes	No	Yes

Robust standard errors are clustered by country, with ***, **, and * denoting significance at the 1%, 5%, and 10% levels, respectively. An earthquake is considered to have hit a city if it struck within 25 kilometers for that city's centroid in the previous year. A city is considered to be in an earthquake risk area if there is a 10% probability of it experiencing an MMI event greater than V in the next 50 years at any point within 50 km of its centroid. The difference in cumulative effects in (2a) and (3a) is 2.57 (0.94), which is significant at the 1% level. For a breakdown by year, see column (2) of Table A.5 in the Supplemental Material. The differences in cumulative effects for low- and high-income countries in (2b) and (3b) are 3.21 (0.74) and 2.48 (0.87), respectively, both significant at the 1% level. Note that splitting the sample is equivalent to interacting the institutions indicator with all time-varying regressors in the pooled sample, including income. Results are robust to pooling the sample but omitting this latter interaction (i.e. leaving only an unconditional income interaction). In particular, differences become 2.90 (0.75), with significance at the 1% level.

Another important assumption is the choice of year fixed effects. Current results in split sample regressions by definition let year fixed effects vary by institutional qualities, akin to interacting the institutions indicator with year fixed effects in a pooled sample regression. This is not an unreasonable assumption, given that cities in stable democracies and those elsewhere exhibit sizably different growth rates in a given year. Across alternate fixed effects specifications, point estimates are substantively similar while precision varies. To examine this, I pool the sample, interacting the institutions indicator with the main regressors while varying assumptions on year fixed effects. Differences in treatment effects across institutional groups with three lags are statistically significant at the $< 5\%$ level in specifications with (i) year$\times$institutions, (ii) year$\times$income group, and (iii) year$\times$institutions and year$\times$income fixed effects, and lose statistical significance under (iv) non-interacted year fixed effects as well as upon including (v) year$\times$region fixed effects,[21] although the latter specification must estimate a large number of parameters using very little within variation, given the rarity of earthquakes throughout space and time. Precision in the non-interacted specification increases with the inclusion of controls, such as an income-treatment interaction, while the latter sees some significance return when standard errors are clustered by city. These alternative fixed effects specifications can be found in Table A.5.

Other extensions and robustness exercises, such as (i) the use of alternative indicators of institutional quality and earthquake risk, (ii) the clustering of standard errors instead at the city level as a check against small cluster sets in sample subgroups, and (iii) the examination of heterogeneous effects within the subsample of cities not in stable democracies,[22] are also featured in the Supplemental Material. Across all specifications, the size of overall effects appears to be driven in large part by exogenous earthquake shocks striking poorly institutionalized places, in support of the theory above.

That being said, more research is needed. It remains to be seen whether the effects observed here are indeed rooted in shifts toward unproductive behavior in the aftermath of earthquakes – such as corrupt behavior on the part of local officials or property crime in the absence of strong enforcement, which in turn prolong the effects of the initial shock – or some other unobservable factor correlated with institutions. Whereas the evidence provided here is reduced form, future work should examine the precise channels through which earthquakes

[21] Regions used are Africa, Asia, Oceania, Europe, and the Americas.

[22] When I split the sample of cities not in stable democracies further into those in stable nondemocracies (POLITY< 6 for all years) and those in neither stable democracies nor stable nondemocracies (i.e. unstable polities), the same patterns persist in both samples, as shown in Tables A.7. To the extent that effects reflect the importance of formal institutions, this affirms the presumption that transitioning and young democracies do not necessarily have strong underlying deep institutional qualities. Consistent with this, differences persist but shrink somewhat when the stable democracy POLITY cutoff is lowered to being above 0, as shown in Table A.6. However, due to limited observations as subgroups increase, I do not emphasize these estimates.

affect city size in such places. External validity is also threatened by sample limitations. Even using the largest available sample, strong earthquakes are very rare in urban areas and more so upon imposing subgroups, limiting external predictive power. Thus, despite the conformity of observed effects with both the theory and existing research, interpretative caution must nonetheless be advised. Lastly, earthquakes may have features that differ in important ways from those of other shocks and disasters. Future research should examine the urban effects of earthquakes on a case-by-case basis, as in Ager et al (2019), as well as those of other types of natural disasters, as in Boustan et al (2017).

4 Conclusion

Why do some shocks to local development permanently impact the spatial distribution of economic activity, while others do not? This paper considers the role of formal institutions in explaining these differential effects. In the model, extractive institutions decrease the return on productive relative to unproductive activities. In the presence of increasing returns to productive activity within regions, a sufficiently large, negative shock to one region's labor force can serve as a tipping point, inducing its workers to substitute into unproductive activities. Thereafter, new migrants will also prefer to engage in unproductive activities, resulting in regional asymmetries in population and production levels over the long-run. This suggests that extractive institutions may magnify the importance of increasing returns for long-run local development, while long-run equilibria may be more robust to large negative shocks where there are strong institutions to help coordinate the reemergence of production. An empirical examination into the effects of large earthquakes on population growth in 1860 world cities finds evidence consistent with these predictions.

I conclude with a few remarks. First, it is important to note that the choice between productive and unproductive activity is, in reality, not binary. Rather, the prevalence of the latter will depend on its relative return as determined by the institutional environment (i.e. β). As institutions improve, it seems likely that even unproductive regions would become more developed. Nor is this stylized model sufficient to explain all differences in development observed within countries. A richer model is needed to capture the nuanced interactions between institutions, agglomeration spillovers, natural geography, infrastructure, etc. That being said, this model illustrates in simple terms how formal institutions can influence the importance of increasing returns in the face of large, negative population shocks. In particular, it suggests that spatial equilibria may be more subject to influence by negative shocks in places and times in which institutions are weak, becoming more robust as they improve.

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Proof of Proposition 1

Proof. Suppose

$$V_r(h) = V_r(u) \Leftrightarrow a_r \frac{K}{\lambda M_r} h^{1+\gamma} m_r^{\gamma} = \frac{K}{\beta M_r}, \tag{10}$$

where m_r gives the relative measure of productive workers in region r. Hence, any arbitrarily small positive perturbation to m_r will induce

$$a_r \frac{K}{\lambda M_r} h^{1+\gamma} m_r^{\gamma} > \frac{K}{\beta M_r}, \tag{11}$$

such that the remainder of workers shift to production iteratively, until the total share of workers in r are all engaged in production and $m_r = M_r \equiv m_r^*$. I define the m_r that solves (10) to be:

$$\widehat{m_r} \equiv \left(\frac{\lambda}{\beta a_r h^{1+\gamma}} \right)^{\frac{1}{\gamma}},$$

above which all workers in region r prefer to specialize in production over unproductive activities.

Because $M_r \geq m_r$ by definition, it follows that $M_r \geq \widehat{m_r}$ must hold for this equilibrium to be feasible. If instead $\widehat{m_r} > M_r$, then $\widehat{m_r} > m_r$ always. □

Proof of Remark 1

Proof. In a HPSE, $m_r^* = M_r$, and

$$a_r \frac{K}{\lambda M_r} h^{1+\gamma} M_r^{\gamma} \geq \frac{K}{\beta M_r}.$$

Suppose $\gamma = 0$. Then this condition becomes $\beta a_r h \geq \lambda$, which is invariant to M_r. Hence, when $\gamma = 0$, if a HPSE exists in region r for some population share M_r, then it also exists for all M_r'. □

Proof of Proposition 2

Proof. Let $\gamma \in (0, 1)$. Suppose $M_r > \widehat{m_r}$ and $m_r^* = M_r$ in each region r, such that there is a locally stable HPSE in each region. Then

$$\begin{aligned} \dot{M}_r &= M_r(V_r(h) - \overline{V}(h)) = M_r(1 - M_r)(V_r(h) - V_{-r}(h)) \\ &= M_r(1 - M_r)(a_r \frac{K}{\lambda} h^{1+\gamma} M_r^{\gamma-1} - a_{-r} \frac{K}{\lambda} h^{1+\gamma} M_{-r}^{\gamma-1}), \end{aligned} \tag{12}$$

where $M_{-r} = 1 - M_r$. By inspection, $V_r(h)$ is strictly decreasing in M_r for all M_r, while $V_{-r}(h)$ is strictly increasing in M_r for all M_r. Furthermore, $\lim_{M_r \to 0} V_r(h) = \infty$ and $\lim_{M_r \to 0} V_{-r}(h) = a_{-r}\frac{K}{\lambda}h^{1+\gamma}$, while $\lim_{M_r \to 1} V_r(h) = a_r\frac{K}{\lambda}h^{1+\gamma}$ and $\lim_{M_r \to 1} V_{-r}(h) = \infty$. Hence, $\dot{M}_r = 0$ if $V_r(h) = V_{-r}(h)$, where $V_r(h) = V_{-r}(h)$ if and only if

$$M_r = \frac{a_r^{\frac{1}{1-\gamma}}}{a_r^{\frac{1}{1-\gamma}} + a_{-r}^{\frac{1}{1-\gamma}}} \equiv M_r^* \in (0,1)$$

for regions r and $-r \neq r$, and $\frac{\partial \dot{M}_r}{\partial M_r}|_{M_r = M_r^*} < 0$. Hence, if $m_r^* = M_r$ and $M_r^* > \widehat{m_r}$ in each region r, then there is a locally stable HPLE, with a unique interior steady state population $M_r^* \in (0,1)$ when $\gamma \in (0,1)$.

(ii) Suppose there is a sufficiently large negative population shock in one region, say 2 (without loss of generality), such that (11) no longer holds and $m_2^* = 0$. However, suppose $M_1 > \widehat{m_1}$ and $m_1^* = M_1$ still. Then

$$\dot{M}_1 = M_1(1 - M_1)(V_1(h) - V_2(u)) = M_1(1 - M_1)\left(a_1\frac{K}{\lambda}h^{1+\gamma}M_1^{\gamma-1} - \frac{K}{\beta(1 - M_1)}\right). \quad (13)$$

By inspection, $V_1(h)$ is strictly decreasing in M_1 for all M_1, while $V_2(u)$ is strictly increasing in M_2 for all M_2. Furthermore, $\lim_{M_1 \to 0} V_1(h) = \infty$ and $\lim_{M_1 \to 0} V_2(u) = K/\beta$, while $\lim_{M_1 \to 1} V_1(h) = a_1\frac{K}{\lambda}h^{1+\gamma}$ and $\lim_{M_1 \to 1} V_2(u) = \infty$. Hence, $\dot{M}_1 = 0$ if $V_1(h) = V_2(u)$; $V_1(h) = V_2(u)$ for a unique $M_1 \equiv M_1^{**} \in (0,1)$; and $\frac{\partial \dot{M}_r}{\partial M_1}|_{M_r = M_1^{**}} < 0$. Hence, if $m_1^* = M_1$, $m_2^* = 0$, and $M_1^{**} > \widehat{m_1}$, then there is a locally stable ALE, with a unique interior steady state $M_1^{**} \in (0,1)$ when $\gamma \in (0,1)$.[23]

Next, it is straightforward to show that the steady state population share in a productive (unproductive) region will be greater (lower) in a ALE than in a HPLE: $M_1^{**} > M_1^*$ and $M_2^{**} < M_2^*$.

Suppose to the contrary that $M_1^{**} \leq M_1^*$. When $M_1 = M_1^*$,

$$a_1\frac{K}{\lambda}h^{1+\gamma}M_1^{*\gamma-1} = a_2\frac{K}{\lambda}h^{1+\gamma}(1 - M_1^*)^{\gamma-1}. \quad (14)$$

If $M_1^{**} \leq M_1^*$, then when $M_1 = M_1^*$ holding all else fixed,

$$a_1\frac{K}{\lambda}h^{1+\gamma}M_1^{*\gamma-1} \leq \frac{K}{\beta(1 - M_1^*)} \Leftrightarrow \dot{M}_1 < 0. \quad (15)$$

[23]Note that a black hole equilibrium in which M_1 goes to 1 does not exist here, since the limit of $\dot{M}_1$ as M_1 goes to 1 is $-K/\beta$.

Together (14) and (15) imply that when $M_1 = M_1^*$, if $M_1^{**} \leq M_1^*$ then

$$a_2 \frac{K}{\lambda} h^{1+\gamma}(1-M_1^*)^{\gamma-1} \leq \frac{K}{\beta(1-M_1^*)} \Leftrightarrow M_2^* \leq \widehat{m_2}.$$

However, by Definition 3, $M_r^* > \widehat{m_r}$ for all r in any locally stable HPLE. Hence, $M_1^{**} > M_1^*$ by contradiction, and $M_2^{**} = 1 - M_1^{**} < 1 - M_1^* = M_2^*$ by symmetry.

To check comparative statics for M_1^{**}, implicitly differentiate $V_1(h) - V_2(u) = 0$ with respect to each variable of interest. Doing so yields:

$$a_1 : \frac{1}{\lambda} h^{1+\gamma} M_1^{**\gamma-1} + (\gamma-1)\frac{\partial M_1^{**}}{\partial a_1} a_1 \frac{1}{\lambda} h^{1+\gamma} M_1^{**\gamma-2} = \frac{\partial M_1^{**}}{\partial a_1} \frac{1}{\beta(1-M_1^{**})^2},$$

$$h : (1+\gamma) a_1 \frac{1}{\lambda} h^{\gamma} M_1^{**\gamma-1} + (\gamma-1)\frac{\partial M_1^{**}}{\partial h} a_1 \frac{1}{\lambda} h^{1+\gamma} M_1^{**\gamma-2} = \frac{\partial M_1^{**}}{\partial h} \frac{1}{\beta(1-M_1^{**})^2},$$

$$\lambda : -a_1 \frac{1}{\lambda^2} h^{1+\gamma} M_1^{**\gamma-1} + (\gamma-1)\frac{\partial M_1^{**}}{\partial \lambda} a_1 \frac{1}{\lambda} h^{1+\gamma} M_1^{**\gamma-2} = \frac{\partial M_1^{**}}{\partial \lambda} \frac{1}{\beta(1-M_1^{**})^2},$$

$$\beta : (\gamma-1)\frac{\partial M_1^{**}}{\partial \beta} a_1 \frac{1}{\lambda} h^{1+\gamma} M_1^{**\gamma-2} = -\frac{1}{\beta^2(1-M_1^{**})} + \frac{\partial M_1^{**}}{\partial \beta} \frac{1}{\beta(1-M_1^{**})^2},$$

which imply $\frac{\partial M_1^{**}}{\partial a_1}, \frac{\partial M_1^{**}}{\partial h}, \frac{\partial M_1^{**}}{\partial \beta} > 0$ and $\frac{\partial M_1^{**}}{\partial \lambda} < 0$ when $\gamma \in (0,1)$. □

Proof of Remark 2

Proof. By Remark 1, population shocks cannot shift a region from one short-run equilibrium to another when $\gamma = 0$. Hence, if the steady state population distribution M_r^* is determined by (12) or (13) prior to a population shock, then all else fixed, it will also be determined by (12) or (13) after a shock, respectively, when $\gamma = 0$. □

Proof of Proposition 3

Proof. (i) Let $\gamma > 1$. Suppose $M_r > \widehat{m_r}$ and $m_r^* = M_r$ in each region r, such that there is a locally stable HPSE in each region. Then

$$\begin{aligned}\dot{M}_r = M_r(V_r(h) - \overline{V}(h)) &= M_r(1-M_r)(V_r(h) - V_{-r}(h)) \\ &= M_r(1-M_r)(a_r \frac{K}{\lambda} h^{1+\gamma} M_r^{\gamma-1} - a_{-r} \frac{K}{\lambda} h^{1+\gamma}(1-M_r)^{\gamma-1}), \quad (16)\end{aligned}$$

By inspection, $\dot{M}_r = 0$ if $V_r(h) = V_{-r}(h)$, where $V_r(h) = V_{-r}(h)$ if and only if

$$M_r = \frac{a_r^{\frac{1}{1-\gamma}}}{a_r^{\frac{1}{1-\gamma}} + a_{-r}^{\frac{1}{1-\gamma}}} \equiv M_r^* \in (0,1)$$

for regions r and $-r \neq r$ for all $\gamma > 1$. Hence if $M_r > \widehat{m_r}$ and $m_r^* = M_r$ in each region r, then there is an HPLE with a unique interior steady state population $M_r^* \in (0,1)$ when $\gamma > 1$.

(ii) However, note that for $\gamma > 1$, $V_r(h)$ is strictly increasing in M_r for all M_r and $V_{-r}(h)$ is strictly decreasing in M_r for all M_r. Furthermore, $\lim_{M_r \to 0} V_r(h) = 0$ and $\lim_{M_r \to 0} V_{-r}(h) = a_{-r}\frac{K}{\lambda}h^{1+\gamma}$, while $\lim_{M_r \to 1} V_r(h) = a_r\frac{K}{\lambda}h^{1+\gamma}$ and $\lim_{M_r \to 1} V_{-r}(h) = 0$. Hence, $\frac{\partial \dot{M}_r}{\partial M_r}|_{M_r = M_r^*} > 0$, such that any HPLE is unstable when $\gamma > 1$. □