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Spatial impacts of the creation of Brasília: A natural experiment

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Abstract

Using data spanning 70 years (1939–2008), we examine whether Kubitschek's planned creation of Brasília and its associated highway network had its intended effect of spreading development from Brazil's coast to its interior. Specifically, we test whether the spatial structure of the country's urban population and per capita GDP changed as a result of Brasília's inauguration in 1960. Uniquely amongst studies of Brasília's impacts, we use a 'spatial-difference-in-differences' approach, contrasting pre-Brasília with post-Brasília outcomes. We control for macroeconomic conditions, fixed city-specific factors, convergence forces, changing industrial structure and agglomeration impacts arising from proximity to São Paulo and Rio de Janeiro. We find a modest impact on population in the western coastal and western interior regions whose share of Brazil's urban population increased from 4.8% (1959) to 9.0% (2008); our spatial-difference-in-differences estimates show the impact to be statistically significant. We confirm per capita income convergence across regions, but we find no (descriptive or statistical) evidence of per capita income effects related to proximity to Brasília. Thus, even a massive development initiative such as Brasília's creation is estimated to have had only limited population impacts and zero per capita income impacts on the spatial structure of Brazil's economy outside of Brasília itself.

Keywords

Planned capital city, convergence, agglomeration, Brasília, Brazil

Introduction

Urban planning can be undertaken at a number of scales. Typically, these scales vary from city-region plans down to neighbourhood renewal projects. Our focus is at a much larger

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urban planning scale: the creation of a completely new capital city, Brasília, designed to affect national development outcomes. Brasília is an early example of the creation of a new capital city that was intended to create a new growth node for the country. Its creation was a planned response to the dominance of Brazil's two major cities, São Paulo and Rio de Janeiro, situated on the south-eastern coast. Our study, covering 70 years from 1939 to 2008 (i.e. pre- and post-Brasília) examines whether Brasília's creation and growth changed the nature of urban growth elsewhere in Brazil, particularly in the interior and northern regions of the country.

Impacts of Brasília's creation are of interest not just in their own right. It is a rare example of a natural experiment in urban systems that can shed light on spatial economic processes (such as the importance of agglomeration economies and of transport systems for city development) and on regional development processes more generally. Internationally, other historical and more recent cases involving the creation of a new capital city, often located away from the country's dominant population nodes, include: Abuja (Nigeria), Ankara (Turkey), Astana (Kazakhstan), Belpoman (Belize), Canberra (Australia), Dodoma (Tanzania), Islamabad (Pakistan), Lilongue (Malawi), Naypyidaw (Burma), New Delhi (India), Putrajaya (Malaysia), Washington DC (United States) and Yamoussoukro (Ivory Coast). Studies of some of these relocations (e.g. Kironde, 1993; Lovejoy, 1985; Moser, 2010; Robinson, 1973; Tranter, 1990) highlight that the prime motivations to shift the capital city (other than a common initiators' desire to leave a permanent personal legacy) include promoting national unity, and changing the spatial distribution of both population and wealth. However, it has been suggested that these latter economic objectives have not been realistic (Mabogunje, 1990) and we can find no evidence that other capital city relocations had a significant spatial economic impact. Similarly, the work of Davis and Weinstein (2002) shows that even an event as material as the allied bombings of Japan in Second World War had little if any impact on the evolution of the Japanese urban system. Prior analyses of the impacts of capital city relocation have relied largely on descriptive discussions of effects; ours is the first study to use difference-in-differences estimation in an econometric panel model to assess whether spatial effects did indeed arise from a shift of the capital city.

Brasília, in Brazil's Central Plateau, was established in 1960. It was created through the vision of President Juscelino Kubitschek, rather than from the natural development of an urban system such as those associated with Loschian or Christallian settlement patterns (McCann, 2013). Besides the creation of Brasília, Kubitschek's policies resulted in radial highways being built to connect Brasília to all parts of the country, while other highways were upgraded (DNIT, 2011). These highways potentially affected the development of municipalities located adjacent to the highways.

Studies that have examined economic effects of Brasília and its associated highways on development include: Bird and Straub (2014), da Mata et al. (2007), Dowall and Monkkonen (2007), IPEA (2010), Katzman (1975), Morten and Oliveira (2016), Serra et al. (2005) and Snyder (1964). Many of these studies adopt a descriptive approach. The studies most closely related to ours are those by da Mata et al. and by Bird and Straub. Both examine the effects on urban growth of proximity to the improved transport links created by the upgraded highway system. Da Mata et al. find negative effects on city population growth of transport costs and initial population size and positive effects of a higher ratio of manufacturing to services. Bird and Straub find that proximity to a highway had differing effects on urban outcomes based on whether a city is above or below certain thresholds, with agglomeration effects arising above the threshold and dispersion effects resulting if below. Thus, proximity to a highway does not have consistent effects on urban outcomes across urban areas. When effects are observed, the impacts tend to be more pronounced for population growth than for GDP per capita growth.

One issue with these two studies (and others) is that the period of analysis in each case is 1970–2000. However, Brasília was created in 1960 and even prior to this date, there may have been spatial development patterns that persisted beyond Brasília's creation. Indeed, Brasília was created in large part as a response to existing spatial development patterns that resulted in population and income growth being concentrated along the coast, particularly in and around Rio de Janeiro and São Paulo.[1] The coastal cities already had agglomeration advantages and had more developed transport routes than was the case in interior parts of the country. These patterns cannot be controlled for in studies that start only in 1970.

Ours is the first study to take account of the spatial development patterns that existed prior to Brasília's creation. We use a spatial-difference-in-differences approach (described in Theoretical framework and methodology section) to test if the nature of urban growth and development across Brazil changed after the inauguration of the new capital city in 1960. Specifically, we test whether Brasília's creation – and the creation of the radial highways that joined Brasília to all parts of the country – changed the spatial pattern of per capita income and population growth across 174 urban areas (cities) of Brazil. We also test whether agglomeration effects associated with proximity to São Paulo and Rio de Janeiro changed after the creation of Brasília. This contrast of post-Brasília relative to pre-Brasília spatial patterns in urban development is a unique approach that this paper takes compared with other studies of the development of Brazil's urban system. The next section of the paper presents a brief historical background to Brasília's creation; Theoretical framework and methodology section outlines the theoretical framework and estimation strategy; Data and descriptive statistics section describes our data and presents descriptive statistics regarding spatial population and per capita GDP trends; Empirical results and discussion section presents our statistical results; and the last section concludes.

Brasília's historical background

Brasília, the capital of Brazil, was created over a period of four years. Kubitschek advocated Brasília's building during an electoral campaign in 1955; its construction began in 1956 and the city was inaugurated in April 1960 (Kubitschek, 2000). Brasília was built within a forest area that lacked substantive economic activities, at a time when two-thirds of Brazil's territory was considered "empty" (Skidmore, 2010). The idea of transferring the capital from Rio de Janeiro to the interior dates back to 1716 and was present in Brazilian constitutions from 1891 onwards. Brazil's first two capital cities, Salvador and Rio de Janeiro, are located on the coast.[2] By contrast, Brasília's location was chosen to be in the country's Central Plateau in order to take advantage of unexploited natural resources and to spread development to the interior, thereby integrating the centre-west and northern regions into the national economy (Couto, 2001; Epstein, 1973). Kubitschek stated: "(t)he population nucleus created in that far away region would spill over as a stain of oil allowing the interior to open eyes for a great country's future" (Kubitschek, 2000: 7).

The state took on a prominent economic development role during Kubitschek's term (1956–1961) focusing especially on energy and highway infrastructure (Skidmore, 1967). Construction of the radial highways that emanate from Brasília began at the same time as Brasília's construction. Eight radial highways, spanning the compass and varying in length from 592 kilometers to 2047 kilometers, originate from Brasília. Initially, the quality of the highways was variable. For instance, the BR-010, constructed between 1958 and 1960, connects Brasília to Belém (in the northern state of Para). It provided the first land connection between Para and the rest of Brazil but initially comprised large stretches of dirt road. By contrast, the BR-040, connecting Brasília to Rio de Janeiro, extends a pre-existing road from Rio de Janeiro to Belo Horizonte which was paved by 1957. Other highways that link to the radial highways were built or upgraded at the same time. For instance, the 1500 kilometers BR-364 highway was built across the north-west Amazon in the 1960s. Initially constructed as a dirt road, the highway was paved in the 1980s as part of the Polonoroeste (''Northwest Pole'') project (Wade, 2011; World Bank, 2006). By 1992, Brazil had 161,503 kilometers of paved highways (9.7% of total highways) with paved highways linking Brasília to every region of Brazil.[3]

In 1960, the country's population was heavily concentrated along the coast.[4] The population of the area covered by present day Brasília was 69,000 in 1939 (albeit not constituting a single city), reaching 186,000 by 1959 (an annual growth rate of 5.1%). It grew to 1.76 million by 1985 (an annual growth rate of 9.0%). The annual growth rate slowed to 2.6% over 1985–2008, and by 2008, the urban area population had reached 3.2 million. In comparison, São Paulo and Rio de Janeiro remained the two largest cities in Brazil with populations of 19.9 million and 16.2 million, respectively, in 2008, compared with populations of 1.5 million and 2.2 million, respectively, in 1939 (Matlaba, 2012).

Theoretical framework and methodology

In order to model the effects of Brasília's creation on outcomes for other urban areas, we need a framework for assessing what development would have occurred in those cities in Brasília's absence. Our baseline theoretical framework (which we subsequently augment) is one of neoclassical per capita income convergence across cities. In the absence of other factors, per capita incomes are expected to increase at a faster rate in initially low per capita income regions as they become more capital intensive in production and adopt technologies utilised in higher per capita income areas (Barro and Sala-i-Martin, 1992).

We augment this framework with tests of two hypotheses regarding national spatial development. The first is that Brasília's creation and the lowering of transport costs through the accompanying highway developments had a significant impact on the spatial development pattern of Brazil. Citing a range of prior studies, Rosewell and Venables (2013) posit that if initial transport barriers are moderate, then reductions in inter-city transport costs should be a force for spatial economic convergence; however, if costs are initially very high (as they were in some parts of Brazil prior to 1960), then economic divergence may result as prior local activities relocate to the metropolis.[5] The latter case is commonly described by Wilhelm Launhardt's classic saying that ''the best protection for a backward region is a bad road'' (Cheshire et al., 2014).

The second hypothesis is that the spatial development pattern is driven significantly by agglomeration forces[6] centred on São Paulo and Rio de Janeiro. These agglomeration forces reflect greater amenities, plus higher productivity and wage premia (linked to specialization, competition and diversity spillovers) in large, globally connected cities. By contrast, rural regions tend to specialise in production of low value-added outputs that are exported to larger and diverse markets (McCann, 2013). Improved transport links for rural areas may enable increased production of these low value-added outputs facilitated by labour force and population growth without necessarily raising per capita incomes in those regions. Cities close to large agglomerations may benefit from the same economic factors that support the core city's growth (such as proximity to a major airport), and so may attract firms and people to produce commodities for which production costs are higher within the metropolis due to urban congestion and high land prices.

Our study of the spatial urban development impact of the planned creation of Brasília and its associated highways therefore accounts for a range of factors, including the agglomeration forces centred on São Paulo and Rio de Janeiro. We test the effect of Brasília's creation on per capita income growth and population growth across 174 Brazilian cities.[7] Our modelling approach complements qualitative analyses, such as the recent study of reperipheralization of the state of Roraima in northern Brazil resulting from the upgrading of the roadway between Manaus and the Brazilian border (Kanai and da Silva Oliveira, 2014).

Our panel model specification, estimated for 174 cities (subscripted r) across three time periods (subscripted t), is derived formally in the online appendix based on an augmented model of conditional per capita income convergence. The standard convergence model is augmented to include a gravity-type spatial interaction in which Brasília's presence and size affects another city r according to the two cities' respective populations and according to the distance between city r and Brasília ($dist\_B_r$). The standard gravity model suggests a loglinear effect of distance, and hence inclusion of $\log(dist\_B_r)$, but as a robustness check, we allow for a linear distance effect, $dist\_B_r$, also. Our model includes the potential influence of agglomeration economies that may be due to proximity of city r to either Rio de Janeiro or São Paulo. We allow for this effect through the inclusion of the variable, $dist\_RS_r$, being the distance between city r and the nearer of these two cities.[8]

Reflecting da Mata et al.'s (2007) finding that initial industrial structure may matter for Brazilian development, we include controls for shares of GDP in manufacturing and in agriculture/livestock at the start of each period. Growth fundamentals may vary across regions over time, so we add a set of regional dummies in which we group cities first in the following four regions: *North-East*,[9] *West*,[10] *South-East*[11] and *South*.[12] We further split the cities within each region into those that are within 100 kilometres of the coast (e.g. *North-East_Coast*) and others that are in the interior (e.g. *South-East_Interior*); *South-East_Coast* is the (omitted) base region category.[13] Coastal cities have traditionally dominated population and economic activity in Brazil. They are more likely to constitute nodes at the end of routes than are interior cities and this may lead to differing responses to the new highways connecting them to Brasília.[14]

Together, the manufacturing and agriculture share variables, plus the eight regional dummies and a full set of city fixed effects allow for differing initial conditions (reflecting, *inter alia*, initial population size and per capita income) and differing underlying growth trajectories for each city in our sample. While the city fixed effects capture all unobserved time-invariant city-specific growth determinants, we allow all other coefficients to vary over time. This approach reflects the hypothesis that the creation of Brasília, as well as other influences, may have affected spatial development patterns in different ways at different times (e.g. the importance of a large agriculture share on local development may have changed as agriculture became a more or less important part of the country's development over time).

With the inclusion of city and time fixed effects (λ_r and λ_t respectively), our panel regression model with time-varying coefficients can be expressed as (see the online appendix for the derivation)

$$\begin{aligned} \Delta \log(y_{r,t}) = {} & \beta_t \log(y_{r,t-T}) + \mu_t' \log(P_{r,t-T}) \\ & - \varphi_t' \log(dist\_B_r) - \theta_t' \log(dist\_RS_r) \\ & + \boldsymbol{\sigma_t share_{r,t-T}} + \boldsymbol{\pi_t region_r} + \lambda_r + \lambda_t + e_{r,t} \end{aligned} \tag{1}$$

where $y_{r,t-T}$ is per capita income (real GDP per capita) in city r at time t_T, T is the number of years spanned by each wave of the panel, $\Delta\log(y_{r,t})$ is the annual average growth rate in per capita income between year t_T and t, $P_{r,t-T}$ is the population of city r in year t_T,[15] $\boldsymbol{share}_{r,t-T}$ comprises two variables for the (log of) the manufacturing and agriculture shares of GDP, respectively, of city r in year t_T, and $\boldsymbol{region}_r$ is the set of regional dummies.

Our focus is on testing whether the coefficient on log($dist\_B_r$) is significantly different in the post-Brasília (post-1959) period than it was in the pre-Brasília (1939–1959) period. We hypothesise that the post-Brasília period may be characterised by differing spatial effects, respectively, representing Brasília's formative phase (the 26-year period to 1985) and its more established phase (the 23-year period to 2008).[16] These periods also reflect the initial construction and subsequent paving of the radial and other highways associated with Brasília's creation. We therefore split the data into three periods: 1939–1959, 1959–1985 and 1985–2008 (with the respective base years being 1939, 1959 and 1985). We test whether the coefficients on log($dist\_B_r$) and log($dist\_RS_r$) differ across sub-periods. Similarly, we test whether the regional, sectoral, population and convergence effects change following Brasília's creation.

For each of the variables that varies across regions and time (GDP per capita, population, and the manufacturing and agriculture shares in GDP), we estimate the time-varying coefficients directly in the panel regression by interacting the variable with the time fixed effect dummies. Each of $dist\_B_r$, $dist\_RS_r$ and $\boldsymbol{region}_r$ is time-invariant, so their level effects cannot be estimated within a panel regression that includes city fixed effects (λ_r); these city fixed effects capture all time-invariant observable and unobservable influences on city growth. However, it is the *change* in the effect of these distance and regional variables that is our research focus, i.e. we wish to test whether the creation of Brasília and the highways *changed* the pattern of urban development across Brazil post-1960 relative to the pre-1960 patterns. It is this focus that sets our study apart from studies that focus only on post-Brasília data. We estimate these changes by interacting the time-invariant variables with period difference dummies (as detailed in the online appendix). When presenting our econometric results in Table 5, any variable with a single date is the time-specific coefficient for that (time-varying) variable; any variable with a difference in dates is the coefficient for the change in effect of that (time-invariant) variable between the two listed dates.[17] This specification therefore takes account of any prior pattern of growth associated with distance to Brasília (and/or the newly constructed highways) that would have continued even if Brasília and the highways had not been built. In addition, we take account of prior patterns of regional growth and of prior effects associated with proximity to Rio de Janeiro and São Paulo. In addition to these controls, our specification controls for unobservable city characteristics (through λ_r), Brazil-wide macroeconomic developments (through λ_t), industrial structure (through the $\boldsymbol{share}_{r,t-T}$ variables) and the convergence and other effects associated with lagged population and per capita incomes.

This panel formulation represents a spatial-difference-in-differences (spatial-DID) approach. As in a standard DID setting, we compare outcomes before and after an exogenous shock. However, unlike a standard DID analysis, we do not have a bifurcated sample of treated versus control observations. Instead, each (city) observation is differentiated spatially through its (exogenous) distances from Brasília and Rio de Janeiro/São Paulo and by region. We analyse outcomes across these spatial differences before and after the shock of Brasília's creation, with the total change across all cities being the benchmark.

Four additional interpretation and econometric issues are addressed. First, in earlier work, we tested whether the *direction* of a city from Brasília had an impact over and above the variables included in equation (1), but found no material impacts. Second, the road distance of city r to Brasília ($dist\_B_r$) may not be econometrically exogenous. It is conceivable that roads were built more directly between Brasília and those cities that were expected to grow most strongly as a result of Brasília's creation (Bird and Straub, 2014; Morten and Oliveira, 2016). If this were the case, pooled OLS or fixed city effects estimates of the impact of log($dist\_B_r$) would be biased. However, we find that instrumenting log($dist\_B_r$) by the (exogenous) straight-line distance between city r and Brasília has no material effect on the results and endogeneity of road placement does not appear an issue for our analysis. Third, prior work (including Matlaba, 2012) tested for the presence of spatial error and spatial lag processes in these growth regressions, but almost no evidence of such patterns were found.[18]

The fourth econometric issue does, however, have to be dealt with explicitly. Equation (1) includes the lagged levels of the dependent variable within a panel regression containing city fixed effects. Pooled ordinary least squares (POLS) estimates with fixed effects therefore suffer from 'Nickell-bias' (Nickell, 1981), requiring that the lagged dependent variable be instrumented. We use long-lagged city data combined with regional growth rate information to form the instruments,[19] and present the IV estimates in Table 5. The various approaches to dealing with Nickell-bias depend on specific identification assumptions and results may not be robust to changes in these assumptions (Blundell and Bond, 1998). In the online appendix, to test robustness, we include unrestricted POLS estimates together with additional POLS estimates in which we restrict the coefficient on the lagged dependent variable (i.e. the beta-convergence parameter) to specific values (−0.02, −0.01 and 0.00, respectively) that are broadly consistent with prior cross-sectional estimates.

The discussion above has been in terms of the annual growth rate of GDP per capita as the dependent variable. A major regional development initiative may also impact positively on population without necessarily impacting on per capita incomes. For instance, a new transport link or proximity to a new city may lead to additional employment opportunities in certain types of industries and for low-skilled occupations but not for highly skilled occupations (Morten and Oliveira, 2016). Some higher skilled workers may relocate to the new capital from existing cities. New highways may also raise the amenity value of living in an affected city while enabling firms to offer lower wages, compensated (for the worker) by a rise in amenity values (Grimes, 2014). We therefore estimate each specification also with population growth as the dependent variable.[20]

Data and descriptive statistics

We use official data from Institute of Applied Economic Research (IPEA) and Brazilian Institute of Geography and Statistics (IBGE). The geographical unit of analysis (city r) is the functional urban area that we defined on the basis of data for all municipalities[21]; we do not test for effects in rural areas or within cities. The sample is 174 urban areas (that exclude Brasília, Rio de Janeiro and São Paulo[22]) for which we have consistent data over 1939–2008. We use aggregated municipality data for four variables. The first variable is total GDP in thousands of 2000 BR$. The two share variables (for manufacturing and agriculture/livestock respectively) are obtained from the same sources,[23] as is population; per capita GDP is the ratio of GDP to population. Distances are road distances in kilometres from each urban area to Brasília, and the minimum distance to either Rio de Janeiro or São Paulo.[24] Table 1 provides summary statistics and definitions for the variables.

In the upper half of Table 2, we tabulate the aggregated shares of urban area populations relative to total urban area populations for each of the eight regions (i.e. the four regions split by coast/interior) for each of 1939, 1959, 1985 and 2008.[25] Total urban area populations include the 174 cities in our analysis plus Rio de Janeiro and São Paulo; Brasília itself is

Table 1. Descriptive statistics and definitions.

Year	Variable	Mean	Standard deviation	Minimum	Maximum
All years	*dist_B*	1620	674	209	4275
All years	*dist_RS*	1430	1056	58	4756
1939	*GDP_pc*	0.9348	0.7795	0.1381	7.2154
1959	*GDP_pc*	1.8262	1.3955	0.2296	9.9656
1985	*GDP_pc*	5.5191	3.5561	0.8016	18.4825
2008	*GDP_pc*	6.4808	4.4434	0.9737	31.3662
1939	*Population*	99,458	93537	2179	776,203
1959	*Population*	153,771	156,362	3076	1,198,360
1985	*Population*	336,813	444,480	6965	3,162,213
2008	*Population*	539,733	722,583	18,789	5,105,179
1939	*Agriculture*	41.5%	22.0%	0.7%	84.8%
1959	*Agriculture*	30.0%	19.9%	0.1%	80.2%
1985	*Agriculture*	20.9%	15.5%	0.1%	57.1%
1939	*Manufacturing*	14.7%	11.8%	0.1%	47.9%
1959	*Manufacturing*	24.0%	16.4%	1.0%	87.9%
1985	*Manufacturing*	35.0%	17.1%	1.3%	78.2%

Variable definitions: *dist_B* is the current highway distance in kilometres from city r to Brasília; *dist_RS* is the minimum current highway distance from city r to either Rio de Janeiro or São Paulo; *GDP_pc* is real per capita GDP in city *r* (in '000 s of 2000BR$); *Population* is population in city *r*; *Agriculture* is the share of agriculture and livestock in city *r*'s GDP; *Manufacturing* is the share of manufacturing in city *r*'s GDP (note: 2008 data are not required for *Agriculture* and *Manufacturing*). In addition, region dummies are as follows: *North-East* is a dummy variable = 1 if city r is in the north-east region (=0 otherwise); *South* is a dummy variable = 1 if city *r* is in the southern region (=0 otherwise); *South-East* is a dummy variable = 1 if city *r* is in the south-east region (= 0 otherwise); *West* is a dummy variable = 1 if city *r* is in the north or centre-west regions (=0 otherwise); suffix dummies are interacted with the region dummies where: *Coast* = 1 if city *r* is within 100 kilometres of the coast (=0 otherwise); *Interior* = 1 if city *r* is > 100 kilometres from the coast (=0 otherwise). All statistics are for a consistent sample of 174 urban areas.

excluded since our focus is on whether Brasília's creation affected the urban structure elsewhere in the country.

If Brasília's creation had the intended effects on Brazil's development, we would expect a rise in the share of population in the interior regions and in *West_Coast* and *North-East_Coast* relative to the population in *South-East_Coast* and *South_Coast* following Brasília's creation. From 1959 to 2008, the population share of the four interior regions fell from 31.5% to 28.4%, while the share of the two southern coastal regions rose from 45.0% to 46.3%. Thus, the raw aggregated data do not indicate a marked population shift towards the interior away from the southern coast after Brasília's creation. However there are indications of a shift westward. The two western regions (*West_Interior* and *West_Coast*) increased their population share from 4.9% and 4.8% in 1939 and 1959, respectively, to 7.4% in 1985 and to 9.0% in 2008.

The lower half of Table 2 tabulates mean GDP per capita in urban areas within each region expressed as a ratio of mean GDP per capita across all 176 urban areas. Three trends are apparent. First, we observe strong signs of convergence: relative per capita incomes fall in the most prosperous region, *South-East_Coast* (which includes Rio de Janeiro and São Paulo), while relative per capita incomes in all other regions increase. Second, most of this convergence occurred over the 1959–1985 period with much less evidence of convergence over 1985–2008.[26] Third, we see strong persistence in the rankings of relative per capita GDP, with the same rankings across the eight regions in 2008 as was the case in 1959. Thus, apart from a strong pattern of convergence in regional incomes over 1959 to 1985 and some

Table 2. Regional population and GDP per capita trends.

	1939	1959	1985	2008
Population (regional share of population across 176 urban areas, excluding Brasília)				
North-East_Coast	0.223	0.198	0.188	0.190
North-East_Interior	0.094	0.086	0.067	0.062
South_Coast	0.132	0.117	0.107	0.110
South_Interior	0.063	0.068	0.046	0.041
South-East_Coast	0.275	0.333	0.362	0.353
South-East_Interior	0.162	0.150	0.155	0.155
West_Coast	0.041	0.037	0.051	0.064
West_Interior	0.008	0.011	0.023	0.026
Total all urban areas[a]	0.998	1.000	0.999	1.001
GDP per capita (ratio of mean GDP per capita across 176 urban areas, excluding Brasília)				
North-East_Coast	0.524	0.495	0.635	0.581
North-East_Interior	0.227	0.221	0.243	0.288
South_Coast	0.918	0.833	1.147	1.163
South_Interior	0.769	0.637	0.781	0.832
South-East_Coast	1.902	1.755	1.326	1.317
South-East_Interior	0.849	0.863	1.117	1.165
West_Coast	0.603	0.584	0.662	0.681
West_Interior	0.740	0.611	0.762	0.828

[a]Regional shares in each column may not add to 1.0 due to rounding.

westward shift in population, the raw regional data do not indicate a marked change in the spatial structure of Brazil's development following Brasília's inauguration.

Another way of examining the raw data is by distance, either to Brasília or to the large conurbations (the nearer of Rio de Janeiro or São Paulo). In the first half of Table 3, we divide cities into groups based on their highway distance to Brasília. The closest group (≤750 kilometres) includes 13 cities and each other group includes between 16 and 32 cities. We present the mean growth rate over each period for each distance category for both population and GDP per capita. The second half of the table presents the same information based on distance to the nearer of Rio de Janeiro or São Paulo.[27]

From the first half of the table, we see that the population of cities close to Brasília (≤750 kilometres distant) grew faster over 1959–1985 than did any other group of cities over that period. However, this was also the case over 1939–1959, so we must take these pre-existing patterns of growth into account, otherwise we could draw misleading conclusions about the effects of Brasília's creation on population growth trends. To do so, Table 4 presents the Table 3 data in a difference-in-differences form. The first column of the table presents the distance category's population growth rate minus the aggregate growth rate (for the 174 cities) over the first post-Brasília period (1959–1985) less that category's growth rate minus the aggregate growth rate over the pre-Brasília period (1939–1985). Similarly, column 2 presents the difference-in-differences growth rate for the second post-Brasília period (1985–2008) relative to the first post-Brasília period (1959–1985). Columns 3 and 4 provide the same information with respect to GDP per capita growth.

Table 4 indicates virtually no change in the growth rates of either population or GDP per capita for the cities nearest Brasília in the first post-Brasília period, albeit there is some modest rise in population growth in the next closest distance for that period. However, the difference-in-differences population growth of cities that are within 1250 kilometres of

Table 3. Population and GDP per capita growth rates (% p.a.) by distance (174 urban areas).

	Population			GDP per capita		
Distance to Brasília	1939–1959	1959–1985	1985–2008	1939–1959	1959–1985	1985–2008
≤750	3.0	4.0	2.0	3.6	4.1	0.9
751–1000	1.6	3.1	2.0	4.4	4.8	0.4
1001–1250	2.7	3.6	2.0	4.6	3.4	0.3
1251–1500	1.8	3.0	2.3	4.0	5.2	1.0
1501–1750	2.5	2.8	2.2	3.8	5.1	1.2
1751–2000	2.0	2.4	2.0	4.1	4.3	0.8
2001–2250	2.3	2.8	1.8	3.0	3.8	0.3
>2250	2.2	3.2	2.8	2.7	4.2	0.1
Distance to Rio/SP[a]						
≤750	2.2	3.4	2.1	4.3	4.2	0.8
751–1000	2.9	2.6	1.5	4.2	4.8	1.0
1001–1250	2.3	2.5	1.9	3.3	4.3	−0.1
1251–1500	1.8	1.3	1.3	2.5	4.0	−0.7
1501–1750	1.7	3.4	2.2	4.0	5.4	−0.7
1751–2000	1.3	2.8	2.3	3.9	5.7	0.1
2001–2250	1.6	2.0	1.8	4.8	3.2	1.3
>2250	2.5	3.4	2.3	3.0	3.9	0.8
TOTAL (174 cities)	2.2	3.1	2.1	3.8	4.3	0.6

[a]Distance to the nearer of Rio de Janeiro or São Paulo. All distances are in kilometres.

Table 4. Difference-in-differences growth rates (% p.a.) by distance (174 urban areas).

	Population		GDP per capita	
Distance to Brasília	1959/85–1939/59	1985/08–1939/59	1959/85–1939/59	1985/08–1939/59
≤750	0.1	−1.0	0.0	0.5
751–1000	0.6	−0.1	−0.1	−0.7
1001–1250	0.0	−0.6	−1.7	0.6
1251–1500	0.3	0.3	0.7	−0.5
1501–1750	−0.6	0.4	0.8	−0.2
1751–2000	−0.5	0.6	−0.3	0.2
2001–2250	−0.4	0.0	0.3	0.2
>2250	0.1	0.6	1.0	−0.4
Distance to Rio/SP[a]				
≤750	0.3	−0.3	−0.6	0.3
751–1000	−1.2	−0.1	0.1	−0.1
1001–1250	−0.7	0.4	0.5	−0.7
1251–1500	−1.4	1.0	1.0	−1.0
1501–1750	0.8	−0.2	0.9	−2.4
1751–2000	0.6	0.5	1.3	−1.9
2001–2250	−0.5	0.8	−2.1	1.8
>2250	0.0	−0.1	0.4	0.6

[a]1959/85–1939/59 is the distance category's growth rate minus the TOTAL growth rate over 1959–1985 less that category's growth rate minus the TOTAL growth rate over 1939–1959; and analogously for 1959/85-1939/59.

Table 5. Estimation of equation (6); instrumental variables; 174 urban areas.

Dependent variable Distance specification	[1] GDP per capita log distance	[2] GDP per capita linear distance	[3] Population log distance	[4] Population linear distance
ln(GDP_pc): 1939	−0.029***	−0.028***	−0.002	−0.002
ln(GDP_pc): 1959	−0.011	−0.011	0.001	0.002
ln(GDP_pc): 1985	−0.042	−0.041	0.001	0.004
ln(Population): 1939	0.004	0.004	−0.036***	−0.036***
ln(Population): 1959	−0.007	−0.006	−0.038***	−0.039***
ln(Population): 1985	−0.001	−0.000	−0.042***	−0.042***
[ln](dist_B): 1985-1959	−0.001	−0.001	−0.004*	−0.007*
[ln](dist_B): 2008-1985	−0.000	0.001	−0.001	−0.003
[ln](dist_RS): 1985-1959	0.003	0.002	−0.003*	0.002
[ln](dist_RS): 2008-1985	−0.001	−0.001	−0.002	0.002
sh(Agriculture): 1939	0.017	0.017	0.013*	0.012*
sh(Agriculture): 1959	0.039*	0.037*	−0.014	−0.013
sh(Agriculture): 1985	−0.004	−0.004	−0.060**	−0.057**
sh(Manufacturing): 1939	0.029	0.030	0.037***	0.030**
sh(Manufacturing): 1959	−0.003	−0.007	0.013	0.014
sh(Manufacturing): 1985	−0.001	−0.002	−0.003	−0.002
North-East_Coast: 1985-1959	−0.005	−0.003	0.009	0.001
North-East_Coast: 2008-1985	−0.011	−0.011	0.005	−0.000
North-East_Interior: 1985-1959	−0.005	−0.004	0.007	−0.001
North-East_Interior: 2008-1985	−0.017	−0.016	0.002	−0.002
South_Coast: 1985-1959	0.002	0.005	0.002	−0.002
South_Coast: 2008-1985	−0.002	−0.004	−0.000	−0.003
South_Interior: 1985-1959	−0.004	−0.002	−0.003	−0.007**
South_Interior: 2008-1985	−0.001	−0.002	−0.003	−0.006*
South-East_Interior: 1985-1959	−0.001	−0.000	−0.003	−0.005*
South-East_Interior: 2008-1985	−0.004	−0.004	−0.002	−0.004
West_Coast: 1985-1959	−0.002	−0.001	0.026***	0.016***
West_Coast: 2008-1985	−0.012	−0.011	0.020***	0.013**
West_Interior: 1985-1959	−0.005	−0.004	0.020***	0.013**
West_Interior: 2008-1985	−0.000	0.000	0.012**	0.006
Observations	522	522	522	522
No. of urban areas	174	174	174	174
Urban Area fixed effects	Yes	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes	Yes
R^2	0.35	0.35	0.08	0.08

***$p < 0.01$; **$p < 0.05$; *$p < 0.10$ (using robust standard errors). Dependent variable is annualised GDP per capita growth (columns [1] and [2]) and annualised population growth (columns [3] and [4]); *ln(GDP_pc): 1939* is log of GDP per capita in 1939 (the base year for the 1939–1959 period), and similarly for other years; *ln(Population)* is log of population; *sh(Agriculture)* is share of agriculture and livestock in GDP; *sh(Manufacturing)* is share of manufacturing in GDP [services is the base category]; *dist_B: 1985-1959* is the difference in the impact of distance to Brasília over 1959–1985 relative to its effect over 1939–1959 (and similarly for 2008–1985); *dist_RS* is the distance to the nearer of Rio de Janeiro or São Paulo, (columns [1] and [3] use ln(dist_B) and ln(dist_RS) while columns [2] and [4] use linear distance variables); *North-East, South, South-East, West* are regional groupings: a *Coast* suffix indicates ≤100 kilometers of the coast, *Interior* is >100 kilometers from the coast [*South-East_Coast* is the base region]; a constant and variables for missing manufacturing and agriculture shares are included but not reported. Lagged dependent variables have been instrumented using instruments as per footnote 19.

Brasília is negative in the second post-Brasília period. Stronger DID effects are observed for the development pattern of cities in relation to distance from the two largest conurbations. Cities that are 751–1500 kilometres from Rio de Janeiro and São Paulo suffer a relative decline in population in the first post-Brasília period, while cities that are 751–2000 kilometres from the conurbations suffer a relative GDP per capita decline in the second post-Brasília period. Population and income effects, however, are minor for cities within 750 kilometres of those conurbations.[28]

Other than the convergence effects and some westward shift in population, the descriptive data in Tables 2 to 4 do not indicate material changes in the spatial urban structure of Brazil following Brasília's creation. However, these analyses do not control for other factors. In the next section, we present econometric estimates for per capita GDP and population growth impacts of Brasilia that control for other factors, based on equation (1).[29]

Empirical results and discussion

GDP per capita growth

Columns 1 and 2 of Table 5 present our instrumental variable (IV) estimates of equation (1), where the dependent variable is GDP per capita growth. Column 1 uses log distances while column 2 uses linear distances. The convergence parameter is consistently negative as expected, although it is statistically significant only in the first period.[30] The only other significant variable is the 1959 agriculture share which has a positive association with GDP per capita growth over 1959–1985. We find no impacts of the distance, regional or population variables on GDP per capita growth.

Tables 6 and 7 in the online appendix present POLS results with the convergence parameter initially unrestricted and then restricted (to −0.02, −0.01 and 0.00, respectively). The unrestricted estimates are presented both for the 174-city sample and a 176-city sample that includes Rio de Janeiro and São Paulo. The results are broadly consistent with those of the IV estimates in Table 5. The IV results are also consistent with our observations from the raw data in which regional GDP per capita trends show no systematic pattern of adjustment other than via the convergence process. Thus, proximity to the newly created capital city does not appear to have affected the pattern of per capita income growth across Brazil's cities in either period following Brasília's inauguration.

Population growth

Columns 3 and 4 of Table 5 present the IV estimates for population growth (Tables 8 and 9 of the online appendix present the analogous POLS results to those of Tables 6 and 7). We find strong evidence of population growth convergence for all three periods, i.e. smaller cities grew faster than did larger cities. Furthermore, the convergence parameters (on ln(Population)) are very similar (or slightly increasing) over the three intervals indicating that the population convergence process is as strong (or stronger) after the creation of Brasília as prior to its creation. Using both distance specifications, we find that a high agriculture share had a positive effect in the pre-Brasília period (1939–1959) but a negative effect in the post-Brasília periods (especially the second post-Brasília period). This result is consistent both with the push by Kubitschek after 1960 to reduce the dominance of primary industries in the economy and with a global trend reduction in agriculture's share of GDP as countries develop. The manufacturing share had a positive effect in the initial period but not in the latter two periods when state policy was aimed towards greater industrialisation. This may indicate that the industrialisation process did not necessarily favour cities with large existing manufacturing bases.

We find evidence (at the 10% significance level) of positive population growth effects of proximity to Brasília in the first post-Brasília period (1959–1985).[31] For the second post-Brasília period, we find no additional significant proximity effects but the estimated coefficient on distance is again negative so the lift in the population growth rate of cities close to Brasília at least appears to be sustained throughout the period. We also find positive population growth effects at the regional level for each of *West_Interior* and *West_Coast* across both post-Brasília periods (albeit not significant for *West_Interior* using linear distances in the second post-Brasília period). These findings are consistent with those shown by the raw data in Table 2. Thus, even after controlling for prior growth trends, macroeconomic factors, city-specific fixed factors, industrial shares and convergence forces, we find that the population growth rates of cities that were proximate to Brasília and/or were in the two western regions increased following Brasília's establishment.

Conclusions

We have tested whether Kubitschek's vision of spreading development from Brazil's coast to its interior through the creation of Brasília and its associated highway network had the intended effect. We use data spanning from 1939 (21 years prior to Brasília's inauguration) to 2008 (48 years post-inauguration) to examine whether the spatial structure of the country's urban population and per capita GDP changed following Brasília's creation. We hypothesise that if this natural experiment had its intended effects, we would observe greater relative growth in GDP per capita and population for cities proximate to Brasília and/or in areas serviced by the new highway network. Thus, we would observe faster growth of cities in interior, and especially western, regions relative to the pre-existing dominant coastal cities.

Our formal tests adopt a spatial-difference-in-differences approach through the inclusion of city and time fixed effects and comparison of post-Brasília with pre-Brasília growth trends. The formal tests control for macroeconomic developments, city-specific fixed factors, convergence effects, regional effects, changing industrial structure and agglomeration impacts arising from proximity to the two largest conurbations, São Paulo and Rio de Janeiro.

Descriptive statistics indicate some increase in population of the two western regions, and show convergence of per capita income across regions. Our formal econometric tests confirm these descriptive results. We find significant population increases in the two western regions across both post-Brasília periods. Income and population convergence is also observed. However, we find no descriptive or econometric evidence that Brasília's creation had any effect on city per capita incomes; neither proximity to Brasília nor regional location significantly impacts city per capita GDP in either the first or second post-Brasília periods (relative to the pre-Brasília period). Our results are unique amongst studies of Brasília's impacts in that we account for the population and per capita GDP trends that existed prior to Brasília's creation. Failure to take account of these pre-existing trends could give misleading indications of Brasília's growth impacts.

Whether the outcomes of Kubitschek's experiment are consistent with his vision of spreading development from Brazil's coast to its interior is a matter of interpretation. We find that the population structure did move westward – even after accounting for pre-existing trends and other control variables. By 2008, 9.0% of Brazil's population lived in western coastal and western interior regions compared with 4.8% in 1959, an increase in the western population share of almost one percentage point per decade. Per capita incomes in the west or in the interior more generally, however, did not increase any more than could be expected through the observed income convergence process. Thus, the west became more populous both absolutely and relatively but no richer in relative per capita terms as a result of Brasília's creation. It is possible that certain enclaves, for instance those near a highway node, may have experienced income benefits (or costs) of a specific infrastructure project as found in some prior studies. However, these effects were not sufficient to impact on the general spatial structure of city outcomes across Brazil.

From a broader development perspective, this large-scale natural experiment illustrates the magnitude of the task confronting policy-makers who wish to change the spatial economic and population structure of a country. Faced with agglomeration and other forces, even a massive development initiative of the scale undertaken by Kubitschek is estimated to have had limited population impacts outside of Brasília itself and approximately zero per capita income impacts on the spatial structure of Brazil's urban economy.

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Notes

1. See http://www.zonu.com/brazil_maps/Brazil_Population_Administrative_Divisions_Economic_Regions_Map_2.htm for a 1977 map showing Brazil's population densities and regions in 1960.
2. See http://www.dholmes.com/master-list/brasil.gif for a map of Brazil's states and their capital cities.
3. Sources: http://www.photius.com/countries/brazil/economy/brazil_economy_highways.html (ITA); and http://www.dnit.gov.br/planejamento-e-pesquisa/planejamento/evolucao-da-malha-rodoviaria/ (DNIT); each accessed 15 March 2014.
4. See the map referred to in footnote 1.
5. Empirical studies that examine impacts of new transport networks on local outcomes using natural experiments or instruments include Banerjee et al. (2012), Duranton and Turner (2012), and Ghani et al. (2012).

6. For analyses of agglomeration forces, including transportation effects, see e.g. Fujita and Thisse (2002), Disdier and Head (2008); and de Groot *et al.* (2009).
7. We exclude Brasília from the analysis since it is the 'shock' variable and we also exclude São Paulo and Rio de Janeiro in the core regressions as we are essentially interested in the impact of the distance between city r and Brasília vis-à-vis distance between city r and the two prime agglomeration hubs in Brazil. We do, however, report in an on-line appendix robustness tests of our results in which we include these latter two cities and find that their inclusion makes very little difference to our estimates.
8. In earlier work, we included distances to each of the two cities separately, but multicollinearity between these two distance variables made it difficult to distinguish their separate effects.
9. Cities in the *North-East* comprise cities in the following states: Maranhao, Piaui, Ceara, Rio Grande do Norte, Paraiba, Pernambuco, Alagoas, Sergipe, Bahia. See the map cited in footnote 2 for the location of states referred to in this and subsequent footnotes.
10. To ensure sufficient cities in each regional grouping, the cities in *West* include those in both the North and the Centre-West, comprising the following states: Mato Grosso do Sul, Mato Grosso, Rondonia, Acre, Amazonas, Roraima, Para, Amapa, Toncantins, Goias.
11. Cities in the *South-East* comprise cities in the following states: Minas Gerais, Espinto Santo, Rio de Janeiro, São Paulo.
12. Cities in the *South* comprise cities in the following states: Parana, Santa Catarina, Rio Grande do Sul.
13. The number of cities in each of our eight regions are: *North-East_Coast*, 36; *North-East_Interior*, 23; *South_Coast*, 24; *South_Interior*, 21; *South-East_Coast*, 15; *South-East_Interior*, 33; *West_Coast*, 16; *West_Interior*, 6.
14. We do not take account separately of internal nodes; consideration of the localized effect of such nodes for development could be a subject of future research.
15. Inclusion of this variable, which arises from our embedded gravity model, enables us to test whether the effects of population size on city growth changed after the creation of Brasília and the highways.
16. The exact choice of years is driven by data availability.
17. For example, *sh(Agriculture): 1985* is the coefficient on the agriculture share in 1985; while *West_Interior: 2008-1985* is the change in the West-Interior region's coefficient from 1985 to 2008.
18. Given their lack of materiality, none of these results is reported here. Details of earlier estimates relating to these issues are available from the corresponding author.
19. For example, the instrument for GDP per capita in 1939 for city r ($y_{r,1939}$) situated within region R is calculated as: $y^{IV}_{r,1939} = y_{r,1920} * \left[\frac{y_{R,1939}}{y_{r,1920}}\right]$. The use of the relevant regional growth rate overcomes the problem that our periods are of different lengths. This approach assumes that no city dominates its own regional growth rate and also assumes that the deep lag on own GDP per capita is sufficient to remove endogeneity concerns.
20. Data availability constraints (e.g. an absence of data on skills composition) mean that we include the same explanatory variables in the population growth specification as in the per capita income growth specification.
21. Details about the construction of the dataset are contained in Matlaba (2012) and Matlaba *et al.* (2013).
22. A comparison of columns 1 and 2 in each of Tables 6-9 in the on-line appendix shows that our results are not affected if we add Rio de Janeiro and São Paulo (i.e. Brazil's two largest cities) to the sample.
23. Share data are missing for 12 cities. These values are set to zero and a dummy variable for missing shares is included in each regression.
24. The distance data come from websites: http://www.transportes.gov.br/bit/inrodo.htm; http://www.aondefica.com/, and http://www.estradas.com.br/new/header_sites/mapas.asp. The distance of each of Rio de Janeiro and São Paulo from itself is set at 1 kilometre when we form the log distance variables.

25. We take the shares relative to the sum of all urban areas (rather than of the Brazilian total) to avoid potentially misleading trends driven by urbanisation across the country through this period.
26. This pattern would be consistent with a greater role for agglomeration economies in the latter period which may serve to stifle the convergence process.
27. Since we include information relative to Rio de Janeiro and São Paulo we do not include these cities in Tables 3 and 4. Corresponding tables that include Rio de Janeiro and São Paulo are included as Tables 3A and 4A in the on-line appendix.
28. Less consistent trends are shown in on-line Appendix Tables 3A and 4A due to the size of Rio de Janeiro and São Paulo both of which are included in the 751–1000 km distance category from Brasília (and the ≤750 km category from Rio/SP).
29. The exact equation that we estimate is given as equation (6) in the on-line appendix.
30. The finding of convergence is consistent with prior research findings, for instance by Silveira-Neto & Azzoni (2006), and Resende (2011). Our IV estimates for the convergence parameter are smaller in absolute value than in our unconstrained POLS estimates, reflecting the correction for Nickell bias.
31. The coefficient on distance to Brasília is negative so that cities closer to Brasília grew faster. Given inclusion of regional dummies, the distance variables pick up proximity effects to Brasília and Rio de Janeiro/São Paulo within regions. The regional dummies pick up the effects across regions (relative to *South-East_Coast*).

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