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The Belt and Road Initiative

Reshaping Economic Geography in Central Asia?

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Abstract

This paper develops a computable spatial equilibrium model of Central Asia and uses it to analyze the possible effects of the Belt Road Initiative on the economy of the region. The model captures international and subnational economic units and their connectivity to each other and the rest of the world. Aggregate real income gains from the Belt Road Initiative range from less than 2 percent of regional income if adjustment mechanisms take the form of conventional Armington and monopolistic competition, to around 3 percent if there are localization economies of scale and labor mobility. In the latter case, there are sizeable geographical variations in impact, with some areas developing clusters of economic activity with income increases of as much as 12 percent and a doubling of local populations, while other areas stagnate or even decline.

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The Belt and Road Initiative:
Reshaping Economic Geography in Central Asia?*

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1. Introduction

The Belt and Road Initiative (BRI) is a project that seeks to foster improved connectivity between China and the rest of Asia, the Middle East and on to Africa and Europe. The initiative, launched in 2013, encompasses more than 65 countries, representing over 62 percent of the world's population; the potential scope for economic transformation is large. However, the benefits of building new infrastructure for every country affected by the initiative are highly uncertain, and the spatial incidence of effects may vary widely within each country. Building roads and railway links and reducing border times can facilitate trade, but the growth of industry in some regions may be at the expense of others. This paper focuses on Central Asia, and uses economic modeling techniques to explore the possible long-run implications of BRI projects in the region.

How might the BRI affect Central Asia? One goal of the BRI is to develop a transit route, designed to allow goods to be shipped across the region. This in itself does not necessarily lead to increases in local production or income. It does however provide new opportunities for local producers and workers. It may provide better access to markets for them, and better access to suppliers. The degree to which it does so will depend on numerous factors. First, the comparative advantage of the local economy; what is the initial endowment of the area in terms of primary factors of production and technologies? This determines the initial employment share of different sectors of the economy, and in turn, the potential of the area to reap the benefits of improved connections and access to suppliers and markets. Second, are the improved transport links having a larger direct effect on the import or the export costs of the affected area, and are these improvements boosting connections with the local region or with the rest of the world? A reduction in the price of imports directly increases real incomes, whereas a reduction in the cost of shipping exports can boost demand for local production. The relative size of these will influence the impact on the area. At the same time, lower trade costs within the region increase the potential for regional specialization of production; reduction in trade costs with the rest of the world increases exposure to external trade, and potential import competition. Third, to what degree is there potential for particular areas and industries in the region to reap economies of scale, particularly through the formation and growth of clusters of economic activity? Reducing regional transport costs will lead to higher returns if it allows productivity gains to be made through supporting increased geographical specialization. These returns however may be geographically unevenly distributed. Finally, since it is unlikely that impacts are spread evenly across countries, adjustment depends on the extent to which population in the country can move, growing some areas possibly at the expense of others.

This paper explores these issues using a computable spatial general equilibrium model of the region. To focus on the issues the model has a number of key features. First, the model is both international (covering 7 countries in or close to Central Asia and 4 'access points' through which they trade with the rest of the world) and subnational, capturing provinces and some cities within these countries. The international dimension allows us to consider changes in links to the outside world, and also the interactions between a set of neighboring countries; effects in one will not be independent of effects in others.[1] The sub-national dimension is important because many of the countries affected are large,

[1] This approach complements Lall and Lebrand (2019) who look at the impact of the BRI on each country in the region in more geographical detail, at the cell level; however they focus on each country individually,

and transport improvements will only affect particular areas. Stimulus to economic activity may be spatially concentrated so its effects – in aggregate and on regional inequalities – need to be modeled at quite a fine level of geographical detail.

Second, the model distinguishes between three sectors of activity in each economic geographical cell; (henceforth we refer to geographical units as cells). Two of these sectors have limited spatial mobility. The primary sector (accounting for around 25% of employment in the region) may have quite an elastic supply response, but is spatially anchored because of its dependence on land and natural resource inputs. Non-tradable services (accounting for around 39% of employment) are relatively immobile because they serve local demand. The third sector is a composite of manufacturing and tradable services, a sector that is relatively mobile, vulnerable to import competition, and with a potential to expand to serve export markets. We devote considerable attention to the implications of different supply responses by this sector. We look first at an 'Armington' modeling of the sector, where the number of 'varieties' (or firms) produced in a cell is held constant and constrains the supply response. We compare this with two other cases. One is monopolistic competition, giving entry and exit of firms (and varieties) in response to changes; this captures relatively 'footloose' activities and, since there are input-output linkages in the model, creates some (albeit weak) incentives for cluster formation. To this we also add localization economies, i.e. external economies of scale that are sector and location specific.[2] This captures the idea that some places may be able to gain productivity advantage by developing clusters of activity. In this last case the potential gains from the project are greatest, but it is difficult to predict which places will develop these clusters, so the results presented in this paper should be regarded as indicative of possibilities, rather than predictive of actual change.

The third distinctive feature of the model is to pay attention to the mobility of labor and the possibility of land-use change that enables cities to grow. Our starting case assumes that labor is immobile, tied to its initial cell and country. We then relax this, allowing labor to move between cells within countries (but not internationally) in response to changes in real wages. This additional source of economic flexibility generally magnifies the impact of the BRI on particular cells and is important in facilitating cluster formation. The largest benefits are derived (for some places, if not all) when labor is relatively mobile and when cities and other manufacturing sectors are enabled to grow without driving urban rents up too sharply.

The main experiment that we analyze is the change in connectivity due to infrastructure improvements from the Belt and Road Initiative. We consider a reduction in transport times across the region through the building and expansion of railway lines, using World Bank estimates from De Soyres et al. (2018). We also, in a penultimate section, add to this the effects of a package of other measures to reduce border crossing times.

The main conclusions we derive from the modeling are as follows. First, with limited supply response (monopolistic competition) the full economic gains are about 36% larger than the direct transport cost savings created by building the BRI infrastructure, amounting to a 1.9% increase in average real

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simulating changes to links outside the country. This paper combines a region-wide approach with internal country detail.

[2] 'Localization economies' is the term given to agglomeration economies which are both location and sector specific, and are also sometimes referred to as Marshallian economies.

income per capita in the region. This is associated with large increases in the value of trade, rising from 38% of GDP to 43% of GDP within the region and between the region and the rest of the world. Some cells and countries expand manufacturing production relative to the primary sector, and others do the reverse; the former is more likely for places with a relatively high initial share of employment in manufacturing, and for which the connectivity improvements brought about by the BRI are principally affecting export routes and are intra-regional, rather than links to the rest of the world. With a more elastic supply response – in particular localization economies and labor mobility – the aggregate gains are likely to be much larger, rising to 2.7% of initial GDP, nearly double the direct cost savings.

In both these cases, the effects are spatially uneven, with different cells in a country having widely different outcomes. In the absence of localization economies, labor mobility tends to equalize differences in GDP per capita; workers move to regions with more positive outcomes, this increase in labor supply tending to reduce wages. However, the presence of localization economies generally reverses this; as workers move into a cell so scale effects tend to raise productivity, creating a virtuous circle of growth. There are then large changes in economic geography, with some places experiencing large-scale manufacturing growth, per capita income increases of around 12%, and local population doubling. Such population increases seem large, until they are set against historical change in rapidly developing economies.

The results, particularly those concerning the exact places where development takes place, are sensitive to the description of the direct effects of the BRI; for example, western regions of China benefit much more in the combined infrastructure plus border improvements experiment than in the experiment with transport infrastructure alone. This dependence of results on the experiment is of course as it should be, but does alert us to the fact that the direct effects – which parts of the transport network have the largest improvement – are not known with any precision; a fortiori, the results from modeling their full economic impacts are indicative, not predictive.

This paper supplements other recent work written on the BRI. Lall and Lebrand (2019) also provide analysis of the spatially differentiated effects of the initiative, using similar data. They build an economic geography model, a development of work by Fajgelbaum and Redding (2014) in Argentina, which allows them to find the potential winners in terms of population and wages. They find that gains are concentrated in locations near to border points, and in urban centers. Higher levels of labor mobility help lower any potential impacts on spatial inequalities. Our paper complements this work, looking at the cells and countries as part of one wider trading system rather than as individual countries each facing an independent shock, and also providing a richer modeling of the supply side response of the economy to shocks. We draw heavily on de Soyres et al. (2018), who estimate the transport costs within and across the region, and how these may be affected by the Belt Road Initiative, including through improving rail infrastructure and reducing border times. From this they construct a detailed database of transport times pre- and post-BRI for cities across the region, and beyond. They use the data in a quantitative trade model assessing how the BRI may increase international trade flows. We use their analysis to construct our transport network and the experiments that we simulate.

This paper builds on work in several areas of economic literature. First, the model developed is essentially a quantitative economic geography model, with the location of population and economic activity endogenously determined across the economic space by the geography and underlying parameters and model structure. This field has rapidly grown in recent years, and a review of this literature and the types of analysis that can be performed is laid out in Redding and Rossi-Hansberg (2017). Many papers in this field look at the distribution of aggregate economic activity across space; in this paper we develop a model that allows three sectors of production to be distinguished, so capturing traditional comparative advantage as well as economic geography forces. Second, the paper also builds on work related to the impact of infrastructure on both trade and regional growth, including Donaldson (2018), Duranton et al. (2014) and Allen and Arkolakis (2019). Third, the impact of the BRI is modeled through a reduction in travel costs between pairs of cells both within and across national borders; we combine both internal trade and cross-country trade in a same setting. This builds on work that looks at how high transport times act as barriers to trade, and the relationship between travel times and trade costs including Djankov et al. (2010), Hummels and Schaur (2013), and Roberts et al. (2012). Finally, the paper also highlights the importance of internal migration in the level of spatial inequalities that result from the BRI, building on other work on within-country factor mobility and trade, including Redding (2016).

The paper continues as follows. In section 2, we outline the model, and in section 3 we discuss the data and the calibration process. Section 4 describes the BRI experiment and presents our central results. Section 5 extends the BRI experiment to include reductions in border delays, as well as infrastructure investments, and section 6 concludes.

2. The model

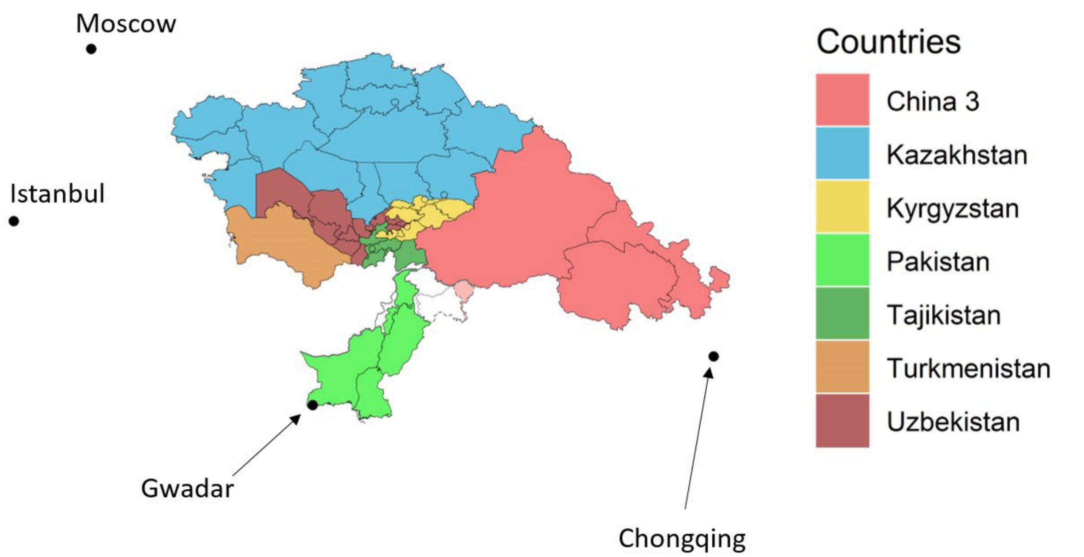
The model is described in full detail in appendix 2 and here we outline, in technical but largely non-mathematical terms, the structure of the model.

Geography

The spatial foundations of the model are 52 geographical cells, covering the whole of 6 countries (Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan, Uzbekistan) and including 3 western provinces of China (which we will refer to as China-3). Some of the cells are quite large provinces (or oblasts) and others are specific cities; they are listed in appendix 1. In addition to these cells, the model contains 4 'access points' through which the region trades with the rest of the world, namely Moscow, Istanbul, Gwadar and Chongqing. The economies of the 52 cells are modeled in detail, while the 4 access points are modeled just as supply and demand functions for trade with rest of the world. The cells and access points are connected by a transport network and the experiments we consider are reductions in shipping times (and hence costs) in this network. Cells and access points are mapped in Figure 1.

Each cell has initial endowments of land and labor, as given by the data. Land is distinguished as rural and urban, and in our experiments, we allow this pattern of use to change, in particular urban land areas can expand or contract in response to changes in relative land rents in each. We assume a single type of labor, not distinguishing by skill level. In some of our experiments we hold the labor force of each cell constant, while in others we allow for varying degrees of labor mobility between cells within each country, but not internationally.

Figure 1: Map of countries, cells, and access points



Production and trade

There are three sectors of economic activity. Primary good production (agriculture and also mining): manufacturing and tradable services: non-tradable goods and services, including housing and retail. The first of these is spatially immobile because it uses rural land, and the last has very limited mobility, constrained by the size of local markets. Manufacturing and tradable services (which henceforth we will refer to collectively as manufacturing) is potentially 'footloose', and we explore different degrees of mobility. In each of these sectors there is some degree of product differentiation so that, in general, goods produced in each cell face demand curves from all cells and access points. Shipping occurs through the transport network, at iceberg costs per unit distance which are sector specific (e.g. near prohibitive for non-tradable services).

Primary sector: Production uses labor, rural land and intermediates (composites of goods from each sector entering through an input-output structure) combined in a Cobb-Douglas production function. Each cell produces a single 'variety', differentiated from production elsewhere. Differentiation is derived from a CES structure and creates iso-elastic demands for each cell's output, both as a final good and an intermediate, from all cells and access points. Two sorts of parameters describe the sector. The first is the factor shares, input-output relationships, demand elasticities and trade cost parameters, and these are listed in appendix 3. The other is cell-specific productivity parameters, denoted z_{si} where s indexes the sector and i indexes cells; these parameters are derived from calibration, such that employment and output levels for each cell match the data.

Manufacturing: Production is undertaken by distinct firms, each with its own variety. This follows the standard CES modeling of product differentiation again implying that, in general, each firm's output is sold in all markets, facing demand as both a final and intermediate good. Production uses labor, urban land and intermediates in a Cobb-Douglas production function. As in the primary sector, technology and demand parameters are listed in appendix 3. Cell specific productivities are derived from calibration to match the data; these are a combination of underlying cell level productivities plus, in one of the cases we study, localization economies, i.e. increasing returns to scale that arise from higher densities of manufacturing firms.

Our simulations explore the implications of different responses by manufacturing firms. The simplest case is that the number of firms in each cell is held constant, and shocks cause a response in the scale of operation of each firm. This is the Armington case where there is no entry, exit, or relocation of firms/ varieties. A second is case is monopolistic competition, where the number of firms in each cell changes in response to profit/ loss opportunities, in the standard Dixit-Stiglitz manner. This generates larger quantity responses than the Armington case, as we shall see. The third case is where we assume the presence of localization economies, so the productivity of firms in the cell-sector is increasing in the number of firms active in the same cell-sector. The calibrated cell-sector productivity parameter z_{si} is then split into two elements; a cell level productivity level, times an increasing function of the density of the sector's firms per person in the cell. As the manufacturing density grows in a cell, this tends to raise profits via this productivity effect, at the same time as the usual forces of product market competition and increasing factor prices tend to reduce profits. The equilibrium distribution of firms and output is determined as the outcome of these forces, and can support significant spatial clustering of activities.

Non-traded goods and services: This sector has the same basic production structure as manufactures, but with parameters set such that trade flows are very low. It follows that the scale of the sector is set principally by local demands, and that radical shifts in the location of production are not possible.

Access points: The 4 access points, Moscow, Istanbul, Gwadar and Chongqing, are cities at which goods and services can be traded with the rest of the world. At these points, imports can be bought at fixed world prices, and exports can be sold according to a highly elastic rest of world demand curve.

Households and population

The data give the initial population of each cell, which is scaled to match the size of the labor force in each city. Every household is assumed to consist of a representative individual who works in their cell of residence and supplies a fixed amount of labor. In our base experiments labor is assumed to be immobile; in some scenarios we relax this to allow partial labor mobility within each country (but not between countries) in response to changes in real wages (utility) across cells in a country.

Household income comes principally from the wage in the cell in which the household lives and works. Households also receive a lump sum transfer as land rents (and profits, if any) are distributed. We assume that each household in a country receives an equal share of the total rents and profits earned in that country. Given their income, utility maximizing households demand composite goods from the three sectors according to Cobb-Douglas preferences; demands for individual varieties come from CES sub-utility functions.

Trade

Goods and services move within and across countries. Within each country, these flows are determined by the relative demand and supply of goods in each cell together with iceberg trade costs. From the network data we derive iceberg trade cost factors τ_{ij}^{s}, i.e. the cost of shipping goods from sector s across the transport network from origin cell i to destination j. The experiment we study is a change in these costs. Internationally, in addition to network trade costs τ_{ij}^{s}, there are country origin-destination shift parameters, A_{ij}^{s}, which are sector specific, and capture national preferences for goods from other countries. For origins and destinations i, j both in the same country these take value unity. Between countries they may differ from unity but take a common value , A_{ij}^{s}, for trade between all origin cells i in one country and destination cells j all in one other; i.e. for each sector s this is a block matrix, with values of A_{ij}^{s} the same for any particular bilateral international trade.[3] The parameter applies both for final consumption and intermediate usage of such goods. These shift parameters are calibrated such that international trade flows match the trade flows in the data. They apply only to international flows, since we only have trade data internationally, and they calibrated on top of the trade barriers created by the transport network.

The initial international trade flows are defined by the data, in which national trade balances are non-zero. We assume that net imports are paid for by remittances from migrants or other capital flows; the base levels of remittances/ capital flows do not change with the experiments, and neither therefore do national trade balances.

Equilibrium and calibration

Given the transport network, endowments of labor and land, and parameters of the model (including productivity parameters z_{si} and country origin-destination shift parameters A_{ij}^{s}), the model generates, in each cell, prices for all goods, wages, and land rents such that markets clear. These prices shape the behavior of firms and the income levels and behavior of households, such that the associated levels of supply and demand are equal. The calibration sets values of productivity parameters z_{si} and country origin-destination shift parameters A_{ij}^{s} such that equilibrium employment in each sector and cell matches the employment data, per capita incomes match country level income data, and international trade flows match the trade data.

Simulations

The calibrated model is then 'shocked' with new transport times in the trade network, and firms and households adjust their decisions to optimally respond to the new geography of the region. We explore different degrees of response under combinations of five different assumptions which are, in summary:

(1) Direct effect: To quantify the scale of the shock we calculate transport cost savings at unchanged base level prices and quantities, i.e. take the transport cost reduction times the base value of exports from each cell to all other cells.[4] This allows us to observe the direct

[3] If cells are grouped by country then the matrix of values of A_{ij}^{s} is, for each s, a block matrix with common value $A_{ij}^{s} = A_{ck}^{s}$, for all $i \epsilon$ country c , $j \epsilon$ country k, and values unity on the block diagonal, i, j in the same country.

[4] This is an 'out of equilibrium' calculation, designed purely to quantify the size of the initial shock.

savings at the region wide level. Between each pair of cells, we take a mean of the reduction in costs of exports and imports as a simple measure of the extent to which a cell is directly affected by the change in transport costs.

(2) Armington supply response: Consumers and producers adjust behavior, but the number of varieties (firms) in each sector and cell is held constant.

(3) Monopolistic competition in manufacturing and non-tradable services sectors: Firms enter and exit in response to profit opportunities, so that equilibrium profits are zero. As usual in a Dixit-Stiglitz setting, this means that equilibrium firm size is constant.

(4) Labor mobility: While the total population of each country remains constant, households move between cells in response to changes in relative real per capita income across cells. We compare zero mobility with a high (but not 'perfect') level of mobility. Population movement has a significant effect on urban land rents, so we also allow land to convert from rural to urban in response to changes in relative urban-rural rents.

(5) Localization economies: Calibration gives sector-cell specific productivity parameters z_{si}. These are split into two multiplicative elements, the initial calibrated productivity parameter, and a part depending on the ratio of the number of firms in the cell to the base population in the cell. An increase in this ratio raises productivity. Further details of this and other relationships are given in appendix 2.

3. Data

The Belt and Road Initiative (BRI) aims to better connect China to the rest of Asia, Europe and Africa through the development of six major transport corridors. Our focus is on the impact of potential rail investments and of reductions in the time taken to cross borders in an area of Central Asia that spans the seven countries indicated in Figure 1. Each of these countries except Turkmenistan contains multiple cells, and these are listed in appendix 1. The model is calibrated to data on employment, population, land area, national accounts and trade. It also uses a network of current transport times and their projected changes. We discuss each of these sources of data in turn.

Employment: Employment data were gathered on a country by country level. For China, the data for the three Western cells, Gansu, Xinjiang, and Qinghai, come from the National Bureau of Statistics in China, http://www.stats.gov.cn. For Kazakhstan, the data come from the Agency of Statistics of the Republic of Kazakhstan http://stat.gov.kz, reported at the sector and province level. In Kyrgyzstan, employment data at the region and sector level are from the National Statistical Committee of the Kyrgyz Republic http://www.stat.kg/en/. In Uzbekistan, the sector and region employment data are from the State Committee of the Republic of Uzbekistan on Statistics, https://www.stat.uz/en/. For all these countries, we select data from 2016. In Tajikistan, regional data are calculated from the Labor Force Survey 2016, Statistics Agency of Tajikistan. In Pakistan, cell and sector data are from the Labor Force Survey 2014-2015 available from the Pakistan Bureau of Statistics http://www.pbs.gov.pk. In Turkmenistan, data are only available at the national level, broken into sectoral employment http://www.stat.gov.tm/. We therefore only have one location within the country in our analysis.

Population: Population data are from the Gridded Population of the World v4. GPWv4 depicts the distribution of human population across the globe. Source data are provided in 30 arc-second (~1 km) grid cells (CIESIN 2016).

Land area: Land areas are extracted from European Space Agency data, with land types reported in 300m square pixels. These are aggregated into our land areas. Rural land is defined as irrigated and rain-fed land, and mosaic cropland. Urban land includes all built areas (Defourny 2017).

***National Accounts**:* National Accounts data on Gross Value Added by sector are from United Nations accounts data for 2016 http://data.un.org . Total populations and GDP are given below in Table 1. There is large variation between the countries in the region, with per capita GDP nearly 10 times as large in Kazakhstan as it is in Tajikistan. The share of each sector in GVA is shown in Table 2 below. China-3 and Kazakhstan have the highest share of GVA in manufacturing, while primary sectors are relatively important in Turkmenistan and Tajikistan.

Table 1: GDP and Population of sample countries.

	GDP (Billion USD)	GDP per capita (USD)	Population (Millions)
China-3	280.5	5066	55.4
Kazakhstan	135.0	7585	17.8
Kyrgyzstan	6.6	1101	6.0
Pakistan	282.5	1580	178.8
Tajikistan	7.0	796	8.7
Turkmenistan	36.2	6712	5.4
Uzbekistan	67.8	2128	31.9

Table 2: Sectoral shares of GDP (percent)

	Primary	Manufacturing	Non-tradables
China-3	14.7	40.7	44.7
Kazakhstan	20.5	34.7	44.8
Kyrgyzstan	17.3	19.0	63.7
Pakistan	29.5	24.9	45.6
Tajikistan	29.4	23.3	47.3
Turkmenistan	37.0	28.0	35.0
Uzbekistan	21.8	33.2	45.0

Trade: Trade values are reported on a country to country basis, using value data from the BACI database of CEPII, 2016, www.cepii.fr (Gaulier and Zignago 2010). These data are split by sector into agricultural and mining trade (primary production) and manufacturing and services trade. For the countries we consider, the trade data report the value of total trade in business services to be just 1.4% of the value of total trade in manufacturing, and we combine this trade and business services (finance, insurance) with manufacturing. Over 95% of the services in our employment data are local services (housing, local utilities, retail etc.), and these constitute our non-tradable service sector.

The total value of trade – exports in particular – is relatively small compared to GDP, and notably so for some of the smaller countries in the region (Table 3). There are also large imbalances in terms of the trade levels, with the three Chinese regions and Kazakhstan having trade surpluses, and other countries having deficits (explained through the presence of large remittances and other transfers). Kyrgyzstan's imports amount to more than 70% of its GDP.

Table 3: Exports and Imports relative to GDP (percent)

	Primary exports	Manufacturing exports	Primary imports	Manufacturing imports
China-3	0	34	5	14
Kazakhstan	14	11	2	19
Kyrgyzstan	5	12	3	77
Pakistan	1	8	3	14
Tajikistan	5	7	4	48
Turkmenistan	17	2	0	13
Uzbekistan	2	9	1	13

Transport: Our measure of bilateral trade costs between cells (including access points) is based on travel times from De Soyres et al. (2018), who calculate the travel time between various pairs of cities in Central Asia. They use the current transport infrastructure network to compute shipping times before the BRI, and enrich this with planned projects related to the BRI to compute a post-BRI matrix of shipping times. They also compute a matrix of shipping times enhanced by additional reductions in border crossing times, resulting in three matrices covering 1,818 cities in 71 countries. We connect the main urban area in each cell of our study to the nearest city in their database, and calculate the optimal travel time, $time_{ij}$, expressed in days, through this location to all other cells in the data. This is done for three scenarios: pre the BRI, after the construction of infrastructure, and after the additional reduction in border times. We map transport times into transport costs τ_{ij}^{s} according to functional form , $\tau_{ij}^{s} = 1 + \lambda^{s} {time_{ij}}^{\theta}$ as in Alder (2017) and Roberts et al., (2012). Time is measured in days, and we set $\theta = 0.75$ reflecting similar assumptions elsewhere in the literature such as for rural goods in China in Roberts et al. (2012). λ^{s} varies by sector, highest for non-tradable services ($\lambda^{s} = 1.8$) which are produced and sold predominantly in the same location, lowest for manufacturing (which, while heavy to transport, is less time sensitive than agriculture $\lambda^{s} = 0.09$), and primary goods lying between the two ($\lambda^{s} = 0.18$).

For example, prior to the BRI, the shipment of goods between Urumqi in China and Almaty in Kazakhstan takes nearly 8 days, including border times, which is equivalent to an iceberg transport cost factor of 1.42 for manufacturing and 1.84 for primary goods. Shipment between Almaty and Astana, both in Kazakhstan, takes 1.1 days, equivalent to an iceberg transport cost factor of 1.09 for manufacturing and 1.19 for primary goods.

Other Parameters: Other parameters are taken from elsewhere in the literature and are reported in Appendix 3.

4. The BRI: Building infrastructure

Our main experiment considers the effects of building the BRI infrastructure and thereby reducing travel times within the region and with the rest of the world. Figure 2 shows the main rail improvements that will affect the region; the three corridors that will affect Central Asia include the new Eurasian Land Bridge, the China-Central Asia-West Asia corridor, and the North-South corridor. The reductions in transport times that occur as a result of building new rail infrastructure are reported in table 4 below, aggregated to the bilateral change at the national level (as unweighted averages of the fall in transport times between each pair of cells in the respective countries). Reductions in transport times to four access points with the rest of the world are reported below the line. Using the relationship between travel time and travel costs from the preceding section, this gives transport cost reductions for trade in manufactures ranging from no reduction (for e.g. Pakistan to Kazakhstan) to 19.5% of the value of trade (Kazakhstan – Turkmenistan). The reductions are clearly highly variable and in many cases large.

Figure 2: Map of Transport Improvements under the BRI.

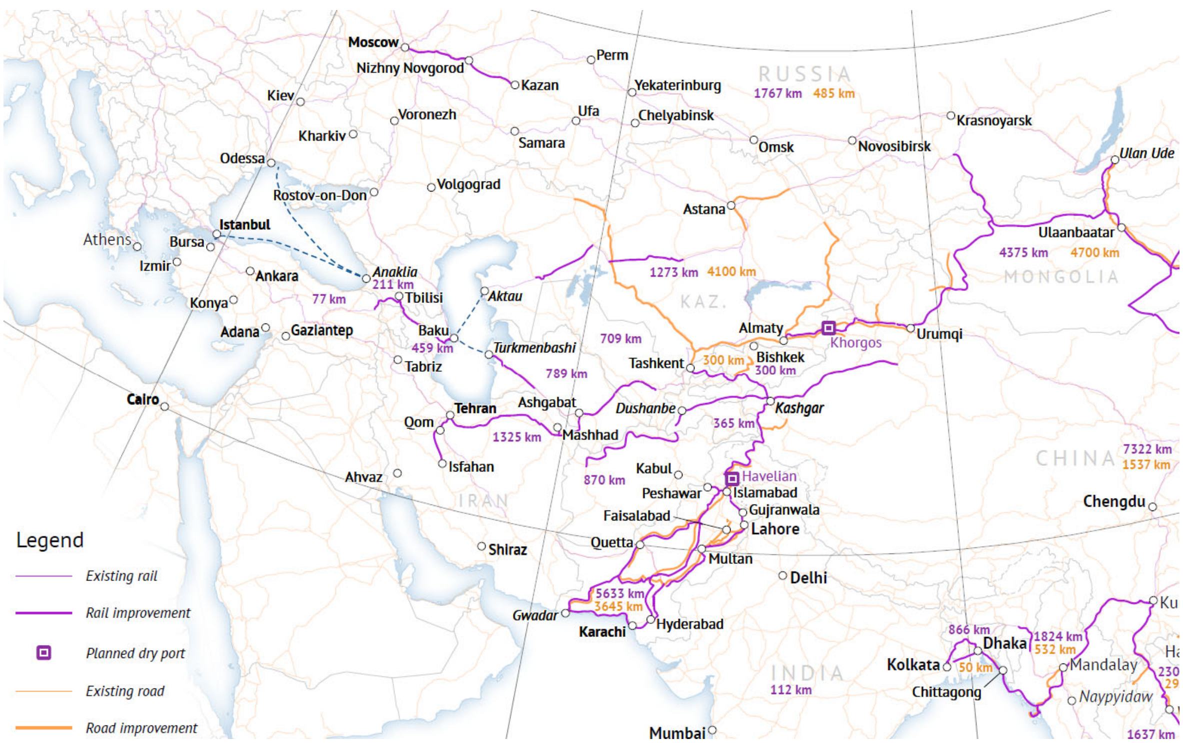


Table 4: Reduction in Average Transport Time, average from cells within country to cells in corresponding country.

	China-3	Kazakhstan	Kyrgyzstan	Pakistan	Tajikistan	Turkmenistan	Uzbekistan
China-3	0%	13%	46%	40%	0%	0%	8%
Kazakhstan	13%	17%	1%	0%	46%	63%	28%
Kyrgyzstan	46%	1%	0%	0%	33%	41%	37%
Pakistan	40%	0%	0%	32%	6%	7%	5%
Tajikistan	0%	46%	33%	6%	0%	4%	7%
Turkmenistan	0%	63%	41%	7%	4%	0%	13%
Uzbekistan	8%	28%	37%	5%	7%	13%	1%
Chongqing	0%	11%	41%	8%	0%	0%	8%
Gwadar	42%	0%	1%	28%	10%	11%	8%
Istanbul	21%	15%	11%	10%	0%	0%	19%
Moscow	12%	2%	0%	14%	0%	0%	15%

4.1 BRI and real incomes: National aggregates

What is the effect of applying these changes in transport times and hence costs, at the cell-to-cell level, on economic outcomes? We first report results aggregated up to the national level, and then discuss the richer picture that occurs at the cell level.

Although some of the trade cost reductions reported in Table 4 are large, they are applied to sometimes small volumes of initial trade. In aggregate, with no economic adjustment, the BRI infrastructure improvement yields direct cost saving equivalent to a 1.4% real income gain for the region. This is the value of the reduction in transport costs times the initial levels of trade. This measure assumes that there is no response whatsoever to trade or output in any cell or country and can be thought of as a summary measure of the extent to which the region as a whole is directly affected.[5]

Table 5 gives average real income gains of each country that follow from this reduction in transport times and subsequent economic responses. The first column (Armington) is a conservative benchmark case. In aggregate, the gains are only marginally greater than the direct effect, but there are noteworthy cross-country differences. Real income growth is particularly large for Kyrgyzstan, which faces a large fall in transport costs while being a net importer of manufacturing. This has two main consequences. First, the cost of Kyrgyzstan's imports falls substantially, leading to lower prices of imports and hence real income growth. Second, there is significant structural change. To understand this, it is helpful to look at the changes in sectoral production given in Table 6. Kyrgyzstan experiences a relatively large expansion in primary output and corresponding contraction of manufacturing

[5] In some following figures we will rank cells according to a measure of this direct effect. However, the direct effect has no real income interpretation at the country or cell level because we do not know (without using the model) the division of the cost saving between countries, i.e. the incidence of the cost reduction. In aggregate, for the region as a whole, it does have a real income interpretation as noted above.

production which faces import competition. This is in line with comparative advantage (as indicated by the production shares reported in Table 2) and hence contributes to the gain.

The effect is smallest for Turkmenistan and Uzbekistan, which also see growth in the primary sector, however with a far smaller reduction in the cost of their imports. Prices remain relatively static, and real income growth is small. China-3, Kazakhstan and Pakistan all experience growth in manufacturing, following reductions in their costs of exporting.

In the second column of Table 5, monopolistic competition allows manufacturing firms to enter, exit, and relocate in response to changes in their profitability. At the aggregate level this increases the real income gain to 1.9%, more than a third greater than the Armington effect. At the national level, the additional gain accrues principally to China-3, Kazakhstan, and Pakistan. These are all countries with a relatively large manufacturing base and, as is apparent from Table 6, they are countries that experience expansion of manufacturing output relative to primary (such countries flagged M in the tables). By contrast, Kyrgyzstan, Tajikistan and Turkmenistan experience contraction of manufacturing, and real income gains that are smaller in this monopolistic competition case than under the Armington assumption. Now the growth of manufacturing in other countries within the region has increased import competition, hurting the manufacturing sectors within these countries, which further specialize in primary good production.

Table 5: Real income gains by country.

	Real Income Growth		
	Armington	Monopolistic Competition	
	(1)	(2)	
China-3	1.2%	2.0%	M
Kazakhstan	1.6%	2.1%	M
Kyrgyzstan	4.9%	4.4%	
Pakistan	1.8%	2.3%	M
Tajikistan	1.7%	1.5%	
Turkmenistan	0.3%	0.0%	
Uzbekistan	0.8%	1.0%	
Aggregate	1.4%	1.9%	

Table 6. Growth in GVA, by sector

	Armington		Monopolistic Competition	
	Primary	Manuf.	Primary	Manuf.
	(1)	(2)	(3)	(4)
China-3	-2%	3%	-2%	4% M
Kazakhstan	3%	2%	3%	3% M
Kyrgyzstan	6%	-3%	7%	-6%
Pakistan	1%	3%	2%	4% M
Tajikistan	4%	0%	4%	-1%
Turkmenistan	2%	0%	3%	-1%
Uzbekistan	2%	1%	2%	2%

4.2: BRI and real incomes: Cell-level changes

The model operates at the level of the cell which gives a finer picture of the effect of the BRI. We summarize results in three scatter plots, figures 3-5. The horizontal axis of each is the direct effect of the decline in trade costs, and the vertical is the percentage change in real incomes. The direct effect is measured as an average of the reduction in the transport costs of export and of imports experienced by each country. The straight lines show the line of best fit from linear OLS regression for which the slope and R^2 are reported in the graphs.

Figure 3 gives the Armington case, corresponding to the first column of table 5. Several points stand out. First, all cells experience an increase in real per capita income, and the range of gains is quite dispersed, from close to zero to around 7%. Second, as expected, there is a strong positive relationship between the direct effect and the full effect, with the direct effect accounting for 97% of the variance of the change in per capita income. Third, the cells that gain the most are in Kyrgyzstan, namely Osh city, Osh oblast, Naryn and Batken. While the direct effects reported on the x-axis are a mean of export and import weighted reductions in trade costs, Kyrgyzstan has the highest reduction in import costs, which fall by 11% at the country level (compared to 1-2% reductions elsewhere). This is driving the growth in real incomes in Kyrgyzstan.

Figure 4, monopolistic competition, allows for fuller adjustment in manufacturing, although holds labor immobile, fixed in its initial cell. Visually, the figure is similar to the previous, although the relationship between the direct reduction in trade costs and the real income growth is slightly less strong, with the former now explaining 84% of the variation in the latter. This is due to increased variation both within and across country, as the economy adjusts to the changing costs of trade. For example, while Kazakhstan's average per capita income growth is 2.1%, this ranges from a minimum cell level growth of 1.25% (Shymkent) to a maximum of 6.3% (Aqtau).

Figure 5 shows monopolistic competition with some (but not perfect) labor mobility between cells in each country. At the country aggregate level, the addition of labor mobility makes only very small differences to results (so was not reported in tables 2 and 3). But at the cell level, labor mobility narrows the variance in real income changes. People move into areas where the economy grows, dampening real wage growth in these cells by putting downward pressure on wages and upward pressure on demand for local services and rents. This results in lower variation between cells within countries. The slope of the regression line flattens somewhat, decreasing the difference in effect for those cells which gain the most versus those that gain the least. For example, in Kazakhstan the minimum remains Shymkent, but now at 1.6%, and the maximum Aqtau, at 4.25%. The population changes that bring about this leveling of per-capital incomes are – in proportionate terms – quite large in some places. The western oblasts of Kazakhstan (Aqtau, Atyrau and Aqtobe) experience population increases of respectively 25%, 12% and 11%. This is accompanied by declines in other areas in the country (a maximum decline of 4% in Shymkent). Of course, the decline is against a model assumption of constant total population; they are long run changes which will, in reality, be accompanied by changes in total national population.

The cell level detail enables a finer exploration of the reasons for the spatial variation in outcomes. Table 7 reports cross-cell regressions of outcome variables on the initial share of employment in manufacturing, and on direct trade cost changes, now split according to whether these are impacting imports (i.e. along routes through which a cell imports large values in the base period) or exports. Results are reported just for the case of monopolistic competition without labor mobility; they are qualitatively similar in other cases.

The results indicate that, first, the growth of manufacturing is positively correlated with the initial manufacturing share and with the decline in export trade costs, and negatively with the decline in import trade costs. The effects are significant and quantitatively important; a 1% fall in export trade costs leads to 4% increase in manufacturing output, as better connectivity enables countries to exploit regional advantage in manufactures. Second, the converse seems to be true for the primary sector; the initial share of manufacturing is negative and significant, as expected, and the decline in import trade costs is positively correlated with primary growth while a decline in export costs is negatively correlated with primary growth.

These asymmetric responses arise from the general equilibrium of the model, and the fact that the quantity response of manufacturing is more elastic than that of the primary sector. Monopolistic competition, with the consequent entry and exit of firms (and varieties), makes this sector more 'footloose' and more responsive to changes in trading opportunities. Thus, the results of Table 7 indicate that a cell receiving equal reductions in export and import costs could expect an expansion of manufactures and (small) contraction of the primary sector.[6] It also points to the importance of the reduction in trade costs being (at least) reciprocal, i.e. with export cost reduction not being overwhelmed by import cost reduction. These things matter because, as indicated in column 1 of Table 7, it is reductions in export trade costs and growth of manufacturing that are associated with relatively larger increases in real income.

The degree to which import or export routes are affected also depends on whether or not the improved transport links foster regional trade or that with the rest of the world. Table 8 splits the reductions in trade costs according to whether they are with other cells in the region of study, or with the Rest of the World (RoW) through one of the four access points. The importance of the fall in export

[6] Under the Armington case, the responsiveness of both sectors to the reduction in transport cost is more aligned; the equivalent regression shows that an equal reduction in export and import costs on average leads to a small positive expansion of both primary good and manufacturing production.

costs for manufacturing growth is particularly through links within the wider region, as better connectivity within the region allows for some clustering and higher manufacturing output growth. For real incomes in column one, however, whether the fall in trade costs is with the region or the rest of the world does not make a substantial difference.

Figure 3: Growth in real per capita incomes: Armington

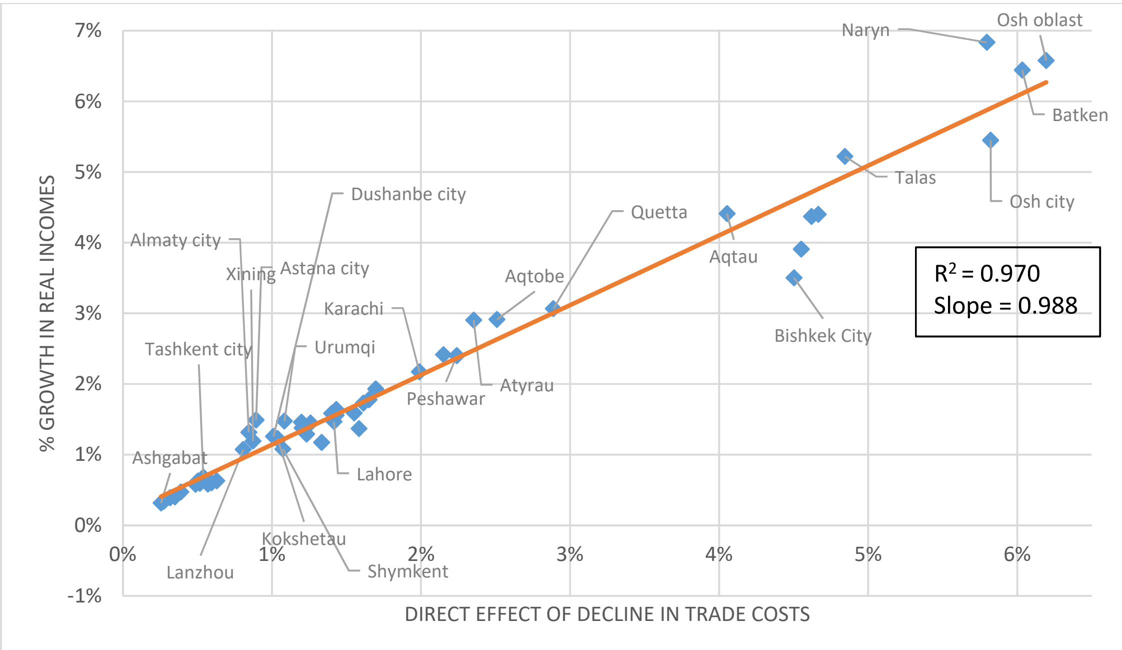


Figure 4: Growth in real per capita incomes: Monopolistic Competition, no labor mobility

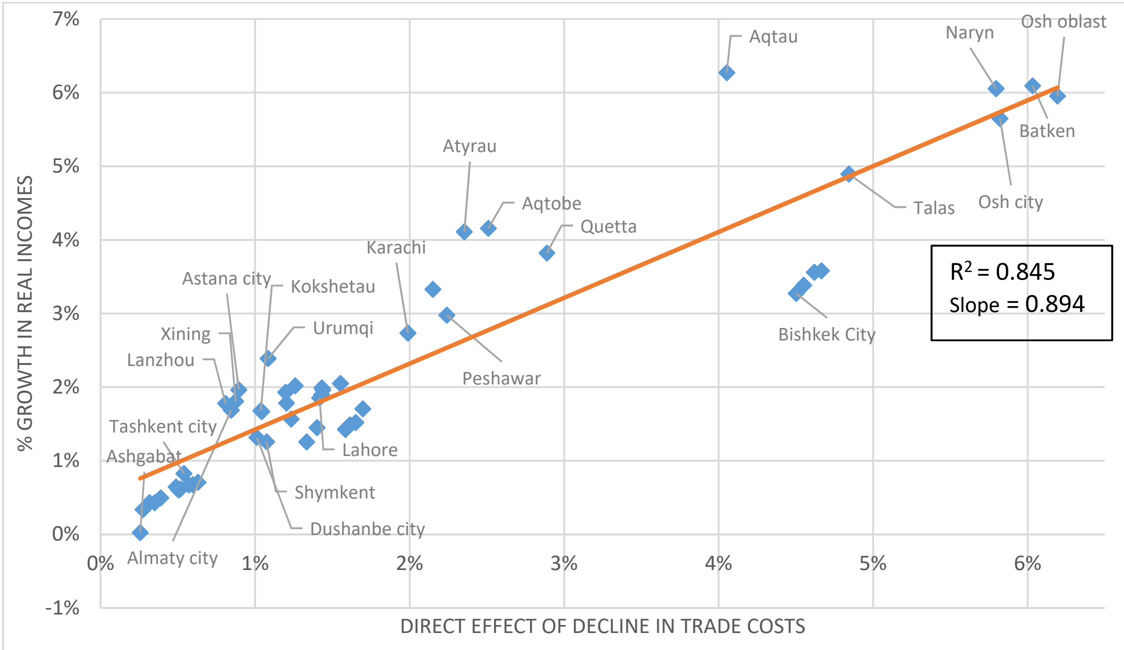


Figure 5: Growth in real per capita incomes: Monopolistic Competition and within-country labor mobility

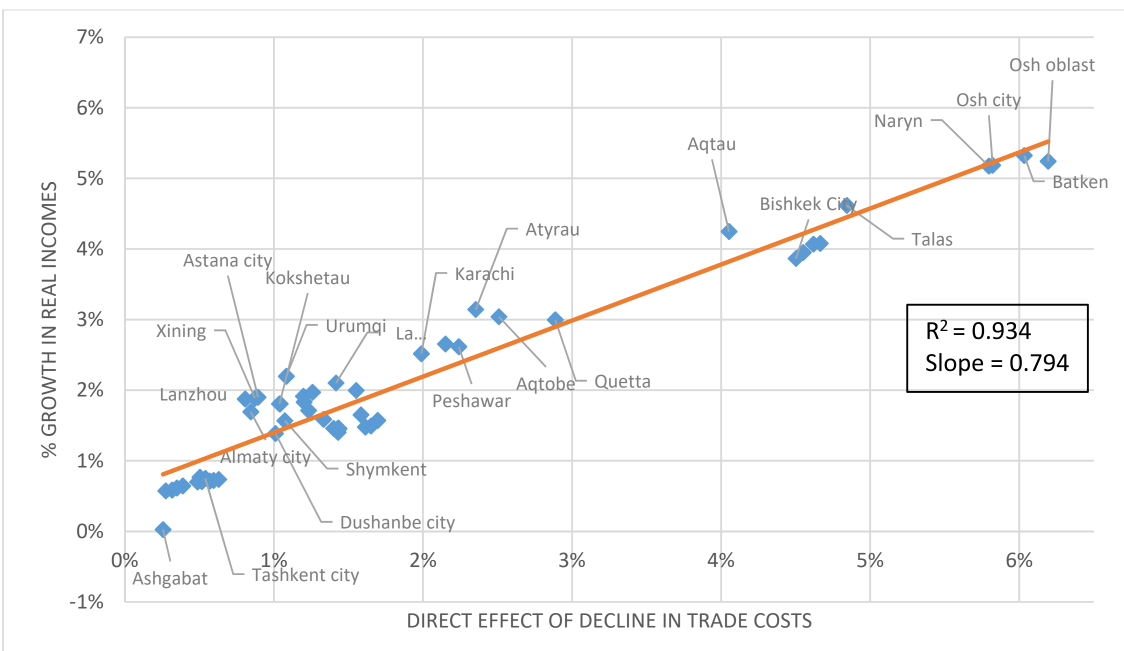


Table 7: OLS regression of impacts under Monopolistic Competition, on initial characteristics of cells and changes in trade costs

	Real Income Growth	Primary GVA Growth	Manufacturing GVA Growth
	(1)	(2)	(3)
Share of Employment in Manufacturing	0.00612	-0.0565**	0.164***
	(0.00643)	(0.0219)	(0.0464)
Decline Export Trade Cost	0.901***	-0.496*	3.932***
	(0.0830)	(0.252)	(0.598)
Decline Import Trade Cost	0.301***	0.414***	-0.750***
	(0.0220)	(0.0672)	(0.159)
Constant	-0.268	4.261***	-8.272***
	(0.307)	(0.963)	(2.211)
Observations	52	49	52
Adjusted R^2	0.898	0.617	0.622

OLS regression with all variables expressed as percentages. Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: OLS regression of impacts under Monopolistic Competition, on initial characteristics of cells and changes in trade costs

	Real Income Growth	Primary GVA Growth	Manufacturing GVA Growth
	(1)	(2)	(3)
Share of Employment in Manufacturing	0.00635	-0.0632***	0.182***
	(0.00680)	(0.0226)	(0.0466)
Decline Export Trade Cost with Region	0.940***	-1.501**	5.116***
	(0.251)	(0.738)	(1.719)
Decline Export Trade Cost with RoW	0.892***	-0.281	2.205**
	(0.148)	(0.443)	(1.016)
Decline Import Trade Cost with Region	0.268	1.286**	-0.647
	(0.195)	(0.572)	(1.332)
Decline Import Trade Cost with RoW	0.306***	0.280**	-0.628**
	(0.0379)	(0.113)	(0.259)
Constant	-0.273	4.424***	-8.808***
	(0.317)	(0.972)	(2.168)
Observations	52	49	52
Adjusted R^2	0.894	0.620	0.645

OLS regression with all variables expressed as percentages. Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.3: BRI and economic geography: Productivity and clustering

The changes reported above yield real income gains somewhat larger than direct effects and, if labor is mobile, some quite large changes in the distribution of population and economic activity. We now explore more radical possibilities in which localization economies are present in the manufacturing sector so that an increase in economic activity in a particular cell and sector has a positive effect on productivity in the cell-sector. We set the magnitude of these scale economies such that the elasticity of productivity with respect to the scale of output in the cell-sector has a mean value of 0.07 and a maximum value of 0.088, numbers at the mid-to-top end of the range of agglomeration economies that are found by empirical work, largely from studies in high income countries.[7] The presence of such effects means that there are benefits from clustering of firms in a particular place and as a consequence there may be multiple equilibria; firms derive advantage not solely from the fundamental characteristics of each place, but from the presence of other related firms.[8] In this world the actual equilibrium – and that selected by an economic model such as this – is likely to be path dependent and highly sensitive to small variations in initial conditions. This means that exact predictions of where clusters form are more than usual subject to doubt. However, development of clusters in some cells is a possible outcome of the improvement in connectivity, and merits the exploration that follows.

Table 9 reports real income effects at the country level; columns (1) and (2) are as in table 5, and columns (4) and (5) add the localization economies (increasing returns) without and with labor mobility. In the absence of labor mobility, real income gains are somewhat larger than in previous cases, exceeding Armington effects by 60%. Structural change is also greater (Table 8, comparing columns (1) and (2) with (3) and (4)).

Without labor mobility, the returns to scale created by clustering of firms is choked off by constraints on the supply of labor. The final column of table 9 relaxes this constraint (without removing it altogether) by allowing limited mobility of labor. The real income effect of the BRI becomes nearly twice as large as in the Armington setting. Structural change (Table 9 columns (5) and (6)) increases and Kazakhstan, China-3 and Pakistan in particular are beneficiaries with 5-8% growth in manufacturing and a 2.4-5.6% increases in real income.

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[7] The elasticity is variable, because of the functional form employed, see appendix 1. In the literature, Rosenthal and Strange (2004) suggest a consensus range of elasticities of agglomeration between 3% and 8%; our relatively high levels capture the fact we are only considering agglomeration effects in manufacturing, and allow us to highlight the variation coming from potential increasing returns to scale. A detailed meta-analysis is provided by Melo et al. (2009). Recent work suggests that the elasticity is somewhat higher in lower and middle income countries (Glaeser and Xiong 2017).

[8] For analytical investigation of these effects see Fujita et al. (1999).

Table 9: Real income gains by country.

	Armington	Monopolistic competition	Increasing returns	Increasing returns & labor mobility
		Real Income Growth		
	(1)	(2)	(3)	(4)
China-3	1.2%	2.0%	2.4%	2.4%
Kazakhstan	1.6%	2.0%	2.5%	5.6%
Kyrgyzstan	4.9%	4.4%	3.9%	5.1%
Pakistan	1.8%	2.3%	2.5%	2.7%
Tajikistan	1.7%	1.5%	1.2%	0.9%
Turkmenistan	0.3%	0.0%	-0.2%	-0.3%
Uzbekistan	0.8%	0.9%	1.1%	1.5%
Aggregate	1.4%	1.9%	2.1%	2.7%

Table 10. Growth in GVA, by sector

	Monopolistic competition		Increasing returns		Increasing returns & labor mobility	
	Primary	Manuf.	Primary	Manuf.	Primary	Manuf.
	(1)	(2)	(3)	(4)	(5)	(6)
China-3	-2%	4%	-2%	5%	-2%	5%
Kazakhstan	3%	3%	2%	4%	5%	8%
Kyrgyzstan	7%	-6%	8%	-9%	8%	-5%
Pakistan	2%	4%	2%	5%	2%	5%
Tajikistan	4%	-1%	5%	-2%	8%	-9%
Turkmenistan	3%	-1%	3%	-1%	3%	-1%
Uzbekistan	2%	1%	2%	2%	3%	0%

Clustering and localization economies occur at the cell level, and population movement is between cells within countries. It is therefore at the cell level that the story appears most clearly, as shown in figures 6 and 7 (shown on smaller vertical scales than preceding scatter plots). With increasing returns and labor mobility, cells in manufacturing areas of Western Kazakhstan experience increases in real incomes in excess of 10%. Driving this is large growth of manufacturing, which doubles in size in Aqtobe, Aqtau, and increases to four times its initial output in Qostanay in Kazakhstan. This occurs alongside population growth, enabling scale economies to be realized. Similar, though smaller, transformations occur in Quetta in Pakistan and Osh city in Kyrgyzstan.

This is also clear in the Table 11, which shows the correlation between the falls in trade costs and real income growth under Armington, Monopolistic Competition, and Increasing Returns with Labor Mobility. First, while base manufacturing shares have little impact on income growth in the Armington setting (and in fact, a slight negative one), once increasing returns to scale are considered, cells with higher manufacturing employment shares are better able to reap the benefits of declines in trade costs. Second, the impact of reductions in import costs remains similar in the three settings, influencing prices and boosting real incomes. Third, however, the reduction in export trade costs has increasing impact on real income growth across the three settings; when there are increasing returns to scale the falls in the cost of transporting exports to destinations allow cells to specialize, growing clusters of manufacturing, and hence boosting productivity and output.

An important further implication of this setting is that labor mobility *widens* intra-country income differentials, rather than narrowing them as we saw in the discussion of figures 4 and 5. Thus, continuing to take cells in Kazakhstan as an example, with increasing returns and no labor mobility, Aqtau's real income increase is 8% and Shymkent's is 1%. With labor mobility, these become 12% and 2%. Booming places experience both population growth and further income growth because of the effects of localization economies and increasing returns to scale in their productive sectors, this outweighing the effects of falling labor-to-land ratios. This amplification of effects is consistent with the equilibrium being stable, although if labor was even more mobile than we have assumed, this would be an unstable situation; further mobility would follow, sucking population into centers and depopulating other areas.[9]

While the message that clustering may occur and bring with it gains is robust, we emphasize that identifying the precise places where this happens is not robust. Quite small initial differences between places may give the initial advantage that allows the cluster to form and grow: the data used in this model is not accurate enough to predict this with confidence, and local policy measures not captured in the model will influence outcomes. Furthermore, some cities lose population; this is a consequence of our assumption that total population in each country is fixed: over the time scale of this long-run experiment aggregate population growth will likely mean that all cells gain population.

[9] The equilibrium is stable. To understand this, think of two relationships on relative real wage (ω, vertical axis) and relative population (λ, horizontal axis) space. The migration relationship is upward sloping, as a higher ω draws in population. With non-increasing returns the wage relationship is downward sloping, as more labor (higher λ) encounters diminishing returns. Localization economies and increasing returns to scale mean that the wage relationship becomes upward sloping, but the equilibrium remains stable if it is less steep than the migration relationship. This is the case described; a shift in the wage relationship (due to the BRI shock) now gets amplified by labor mobility. If the direction of intersection of the relationships was reversed (as would be the case with perfect labor mobility giving a horizontal migration relationship) then the equilibrium would be unstable.

Figure 6: Growth in real per capita incomes: Increasing Returns and Labor Mobility.

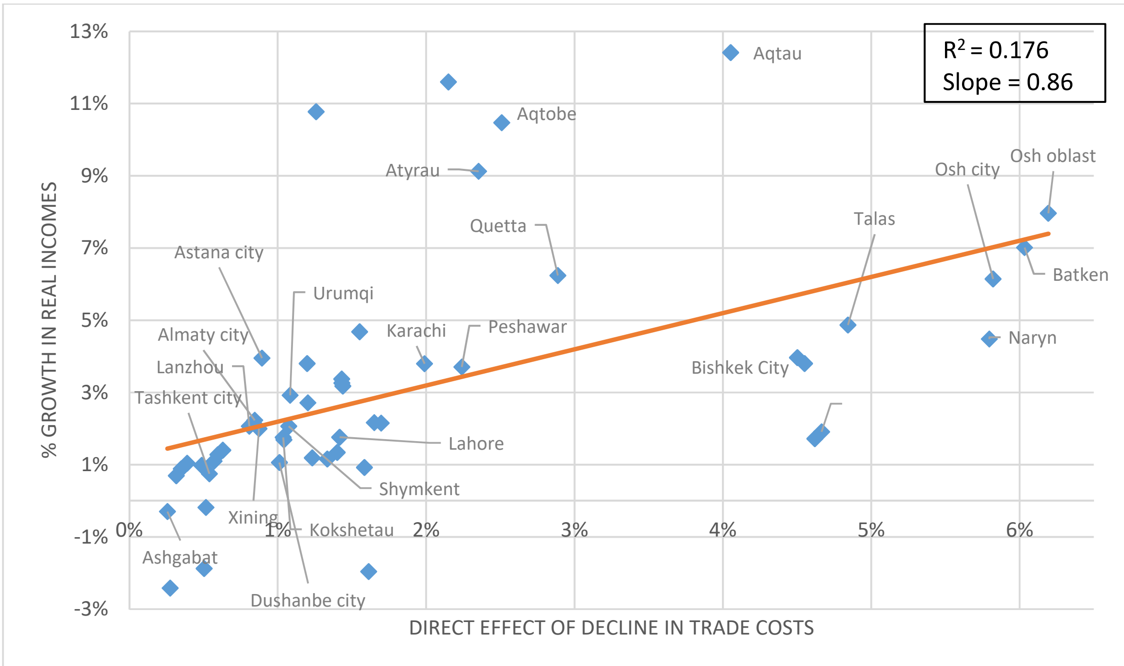


Figure 7: Change in cell population, Increasing Returns and Labor Mobility.

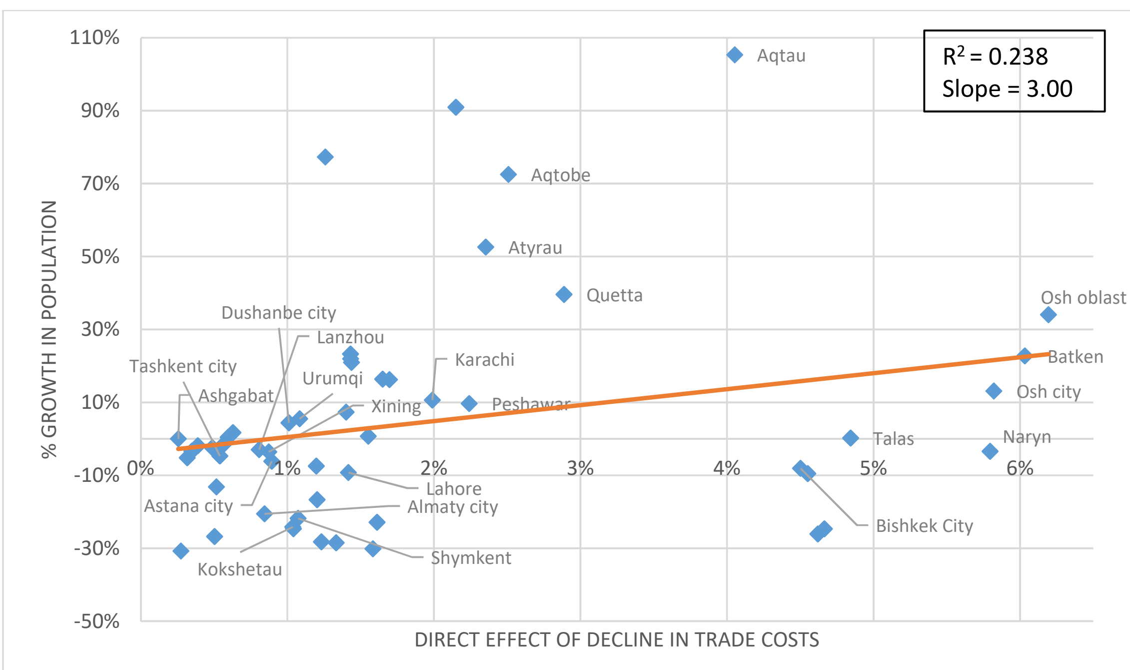


Table 11: OLS regression of impacts on real income growth under different settings, on initial characteristics of cells and changes in trade costs.

	Real income growth		
	Armington	Monopolistic Competition	IRS and Labor Mobility
	(1)	(2)	(3)
Share of Employment in Manufacturing	-0.00923*	0.00612	0.0459*
	(0.00506)	(0.00643)	(0.0245)
Decline Export Trade Cost	0.512***	0.901***	2.628***
	(0.0653)	(0.0830)	(0.316)
Decline Import Trade Cost	0.356***	0.301***	0.236***
	(0.0173)	(0.0220)	(0.0838)
Constant	0.491**	-0.268	-3.216***
	(0.241)	(0.307)	(1.167)
Observations	52	52	52
Adjusted R^2	0.941	0.898	0.629

OLS regression with all variables expressed as percentages. Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5. The BRI: Infrastructure improvements and border effects

A large component of transport times between countries in Central Asia and with the rest of the world is the time spent at borders. De Soyres et al. (2018) produced separate estimates of changes in border delays based on reductions in importing and exporting times from the 'trading across borders' section of the World Bank's Doing Business Database. [10] Table 12 combines these estimates with those of the preceding section to give combined reductions in transport time. The table indicates that the estimated reduction in border times yield greater average time saving than do the physical investments alone (the simple average of numbers in table 12 is a 39% reduction in travel times, as compared to a 15% average reduction in the previous experiment, the average of numbers in table 4). Furthermore, there are considerable differences in the geographical pattern of these changes. For example, reduced border delays bring Kyrgyzstan very large reductions in transport times, with many falling by over 60%. China-3 has lower travel times with Pakistan and improved access to the rest of the world through Gwadar.

[10] For any border, the data on "Border Compliance" and the total delay is assumed to be the sum of export time from the exporting country and the import time from the importing country. Documentary compliance is not included as it does not relate to travel time. All data are available at http://www.doingbusiness.org/data/exploretopics/trading-across-borders.

Table 12: Reduction in Average Transport Time, infrastructure improvement and border effects: from cells within country to all cells in corresponding country.

	China-3	Kazakhstan	Kyrgyzstan	Pakistan	Tajikistan	Turkmenistan	Uzbekistan
China-3	0%	42%	63%	67%	41%	31%	45%
Kazakhstan	42%	17%	37%	27%	61%	71%	51%
Kyrgyzstan	63%	37%	0%	43%	61%	64%	64%
Pakistan	67%	27%	43%	32%	27%	24%	27%
Tajikistan	41%	61%	61%	27%	0%	36%	46%
Turkmenistan	31%	71%	64%	24%	36%	0%	45%
Uzbekistan	45%	51%	64%	27%	46%	45%	17%
Chongqing	0%	35%	56%	59%	36%	27%	45%
Gwadar	63%	23%	40%	28%	31%	28%	31%
Istanbul	48%	34%	36%	16%	21%	16%	37%
Moscow	52%	36%	37%	34%	26%	23%	38%

We have run the model for this larger experiment, and briefly report and comment on selected results. A summary comparison of the two policy experiments, under four adjustment scenarios, is given in figure 8a (infrastructure alone) and 8b (infrastructure plus lower border costs). The combined experiments gives direct effects more than twice as large, at 3.4% versus 1.4% (aggregate, right hand block of 8a and 8b), and full effects (with increasing returns and labor mobility) over three times as large, amounting to a 8.8% increase in per capital income for the region as a whole.

Within this aggregate effect on the region there are substantial differences in national impacts. These are due to details of changes in the transport network and are hard to generalize about; the Armington setting shows that Kyrgyzstan experiences an income gain of 12.8%, compared to 4.8% in the infrastructure only scenario, and other countries experience substantial relative changes in their income growth. Once full adjustment occurs, with increasing returns to scale and labor mobility, a few things stand out. First, Kyrgyzstan is a large beneficiary. As a central country in this BRI network, it gains from a fall in transport costs with every major trading partner, both within the region and in the rest of the word. The Armington setting gives income growth of 12.8%; with full adjustment, this is 38% higher at 17.7%. The scale of this direct effect induces a substantial economic shift; despite being a major manufacturing importer initially, cities within Kyrgyzstan, particularly Osh, develop as economic clusters and see increases in both productivity and manufacturing output. The creation of these clusters generates increasing returns to scale and begins to allow the country to establish itself as a local manufacturing hub. Other provinces within the country with slightly lower levels of base manufacturing employment shares see growth driven by increased primary good production.

The initial manufacturing centers in the above analysis - China-3, Kazakhstan, Pakistan, and to a lesser extent Uzbekistan - continue to do well. China-3, already a sizable economy within the region, has a direct increase in income under the Armington setting of 5.5%, over four and a half times that in the infrastructure scenario. Combined with the initial large manufacturing base, China-3 can exploit these large falls in trade costs to reap income growth of 12.4%, enhancing pre-existing productive clusters. Kazakhstan, Uzbekistan, and Pakistan also observe high income growth, though not at the same rate as China-3. These countries have large manufacturing bases and are able to reap the benefits of lower trade costs throughout the region. They do however simultaneously experience increased import competition from China-3, Kyrgyzstan and the rest of the world. As a result, the size of the income growth, though still large, does not reach the levels obtained by Kyrgyzstan.

Finally, those countries with little in the way of manufacturing, Tajikistan and Turkmenistan, experience lower income growth than under the direct Armington case when we allow for full economic adjustments. Tajikistan, though faced with one of the largest falls in transport costs, leading to income growth of 6.2% under the Armington case, cannot convert this into growth in manufacturing. Simultaneously, primary goods can be imported at far lower prices, which while offering lower prices to consumers also competes against local production, lowering economic growth to 1%, only marginally more than under the infrastructure scenario alone. For Turkmenistan performance is even worse. With little in the way of manufacturing and a less competitive economy, the reduction in trade costs leads to a substantial fall in incomes. Reduced trade costs are not sufficient in themselves to boost the local economy, and import competition may in fact damage incomes when the initial productive capacity is lower compared to that in potential trading partners.

Figure 8a: Real income gains by country: infrastructure improvements

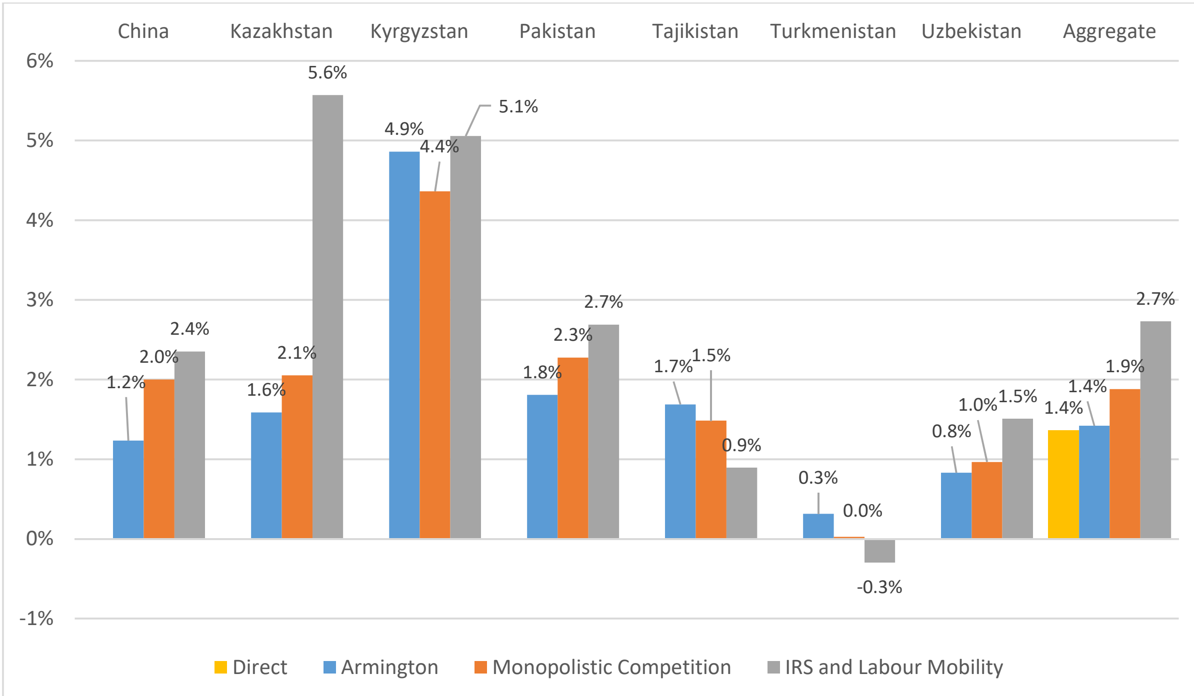
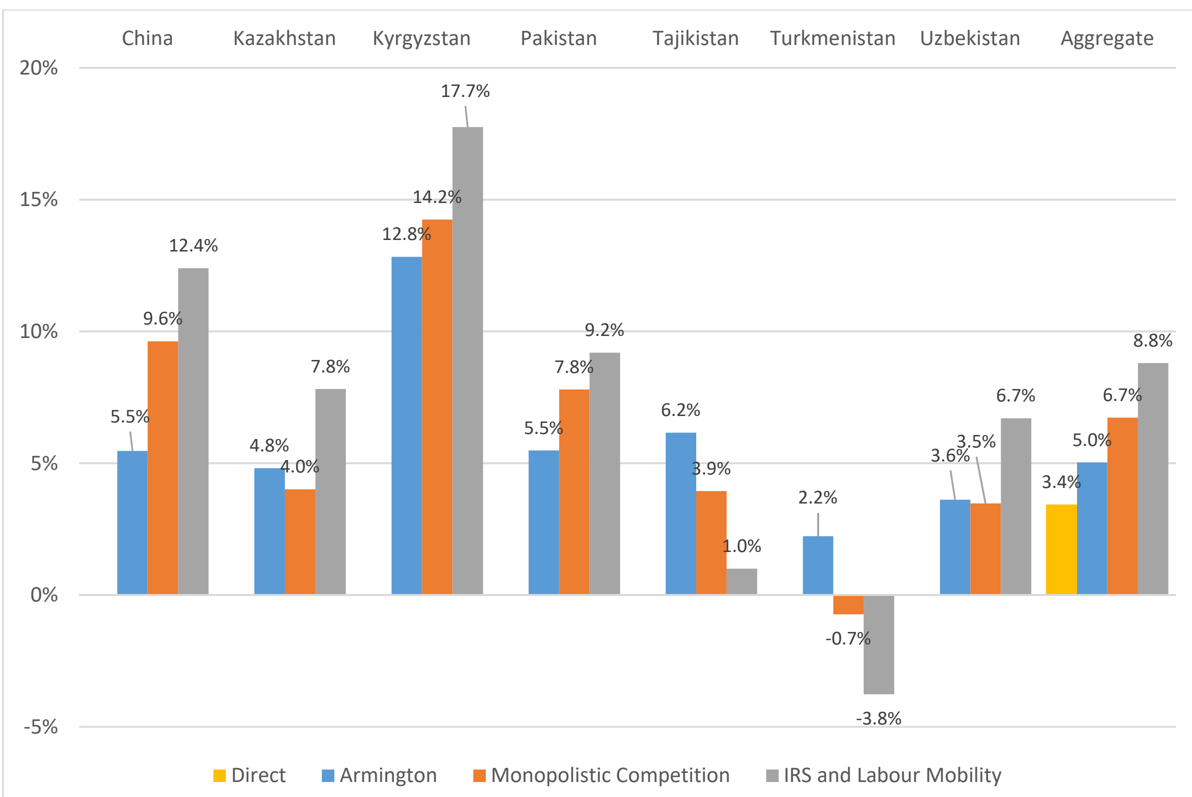


Figure 8b: Real income gains by country; infrastructure improvements and border effects



6. Conclusions

The BRI offers Central Asia the prospect of large improvements in connectivity, linking places within the region to each other as well as improving connections to the rest of the world. The tools of international economics and economic geography provide ways of thinking about the effects of such improvements, and this paper applies these tools in a quantitative model of the region.

An exercise of this type faces many uncertainties, of which two are particularly critical. The first is that the BRI is a series of different projects, some infrastructure, others to do with logistics handling and border controls, and all combining to reshape a complete transport network. The direct impacts of these changes on travel times and wider measures of transport costs are hard to estimate. A reduction in tariffs or the construction of a particular segment of road or rail may be a fairly clearly defined policy change, but this is not so in the case of the package of measures involved in the BRI. Our work has built on the work of de Soyres et al. (2018) which, while thorough and careful in its construction, leaves many questions open due to the large degree of uncertainty about the BRI itself.

The second uncertainty is the ability of economies in the region to respond to these changes in connectivity. This is particularly important since some areas in the region will experience changes in connectivity that go well beyond the usual economics framework of marginal change. The research literature, particularly in economic geography, suggests that such non-marginal changes may have large impacts. In the presence of economies of scale and agglomeration, places that experience an increase in activity may achieve productivity growth, and this will amplify change as clusters of economic activity develop. The present paper is innovative in so far as it captures these effects by including localization economies in the manufacturing sector. Doing this raises modeling issues concerning the best way to model localization economies, the possibilities that equilibria may become unstable (a problem we solve by only allowing limited labor mobility), and the inherent unpredictability about the exact location of clusters of activity. It means that the results we present are illustrative rather than predictive, but we think it important to explore these mechanisms which are widely believed to be present.

To place our results in context, the paper presents a series of scenarios describing different economic environments and adjustment possibilities. We start with a conservative approach in which few factors are mobile, meaning that adjustment rapidly runs into diminishing returns; direct benefits of around 1.4% of GDP (in aggregate across the region) get somewhat amplified by economic adjustment, up to around 1.9% of GDP.

We then go beyond this to increase the scale of possible response, letting more things be mobile (firms and, to some extent, workers) and adding increasing returns to scale and agglomeration economies to some productive sectors. This produces much larger quantity responses, and takes aggregate real income gains up to around 3% of GDP, with gains for some countries exceeding 5% and for some cells exceeding 10%. Gains are still larger in the combined experiment of infrastructure plus time savings at borders. Within this aggregate change, there is very substantial heterogeneity, within as well as across countries. The top performing cells in the entire region see per capita real income gains of as much as 21%, coupled with a tripling of the local population; the worst performing experience small real income declines and lose a substantial fraction of their population. Importantly, labor mobility, which without increasing returns to scale served to limit regional inequalities, can now serve to increase regional inequalities. Whereas in a traditional model labor mobility reduces inequality, with increasing returns, booming regions with growing populations benefit from rising productivity and a virtuous circle of growth.

The model developed in this paper does not offer certain predictions about where such changes will occur, but it does point to the possibility that the BRI could be a catalytic force for reshaping the economic geography of the region. Whether – and where – it does so will depend on numerous other aspects of the economic environment and economic policy, not least policy makers' responses to regionally divergent growth paths.

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Appendix 1: Cell (region/oblast) listing

Country		***Region/oblast***		***City***	
1100	China	1	Gansu	10	Lanzhou
1110	China	1	Qinghai	11	Xining
1120	China	1	Xinjiang Uygur	12	Urumqi
2100	Kazakhstan	2	Aqtobe	10	Aqtobe
2110	Kazakhstan	2	Atyrau	11	Atyrau
2120	Kazakhstan	2	East Kazakhstan	12	Staro-Semipalatinskiy
2130	Kazakhstan	2	Jambyl	13	Taraz
2140	Kazakhstan	2	Mangystau	14	Aqtau
2150	Kazakhstan	2	North Kazakhstan	15	Petropavlovsk
2160	Kazakhstan	2	Pavlodar	16	Pavlodar
2170	Kazakhstan	2	Qaraghandy	17	Qaraghandy
2180	Kazakhstan	2	Qostanay	18	Qostanay
2190	Kazakhstan	2	Qyzylorda	19	Qyzylorda
2200	Kazakhstan	2	South Kazakhstan	20	Shymkent
2210	Kazakhstan	2	West Kazakhstan	21	Uralskiy Prigorodnyy
2220	Kazakhstan	2	Aqmola	22	Astana_city
2221	Kazakhstan	2	Aqmola	22	Astana
2230	Kazakhstan	2	Almaty	23	Almaty_city
2231	Kazakhstan	2	Almaty	23	Almaty
3100	Kyrgyzstan	3	Batken	10	Batken
3110	Kyrgyzstan	3	Jalal-Abad	11	Jalal-Abad
3120	Kyrgyzstan	3	Karakol	12	Karakol
3130	Kyrgyzstan	3	Naryn	13	Naryn
3140	Kyrgyzstan	3	Talas	14	Talas
3150	Kyrgyzstan	3	Bishkek	15	Bishkek
3151	Kyrgyzstan	3	Bishkek	15	Bishkek_city
3160	Kyrgyzstan	3	Osh	16	Osh
3161	Kyrgyzstan	3	Osh	16	Osh_city
4100	Pakistan	4	Baluchistan	10	Quetta
4110	Pakistan	4	N.W.F.P.	11	Peshawar
4120	Pakistan	4	Punjab	12	Lahore
4130	Pakistan	4	Sind	13	Karachi
5100	Tajikistan	5	Gorno-Badakhshan	10	Khorugh
5110	Tajikistan	5	Khatlon	11	Qurghonteppa
5120	Tajikistan	5	Leninabad	12	Khujand
5130	Tajikistan	5	Dushanbe	13	Dushanbe_city
5131	Tajikistan	5	Dushanbe	13	Dushanbe
6100	Turkmenistan	6	Ashgabat	10	Ashgabat
7100	Uzbekistan	7	Andijon	10	Andijon
7110	Uzbekistan	7	Bukhoro	11	Buxoro
7120	Uzbekistan	7	Ferghana	12	Fargona
7130	Uzbekistan	7	Jizzakh	13	Jizzax
7140	Uzbekistan	7	Karakalpakstan	14	Nukus
7150	Uzbekistan	7	Kashkadarya	15	Qarshi
7160	Uzbekistan	7	Khorezm	16	Urganch
7170	Uzbekistan	7	Namangan	17	Namangan
7180	Uzbekistan	7	Navoi	18	Navoiy
7190	Uzbekistan	7	Samarkand	19	Samarqand
7200	Uzbekistan	7	Sirdaryo	20	Bekobod
7210	Uzbekistan	7	Surkhandarya	21	Termiz
7220	Uzbekistan	7	Tashkent	22	Angren

7230	Uzbekistan	7	Tashkent City	23	Tashkent
Access points					
8100	*Chongqing*	*8*	*Chongqing*	*10*	*Chonqing*
9100	*Gwadar*	*9*	*Gwadar*	*10*	*Gwadar*
10100	*Istanbul*	*10*	*Istanbul*	*10*	*Istanbul*
11100	*Moscow*	*11*	*Moscow*	*10*	*Moscow*

Appendix 2: The Model

Geography

There are n = 56 geographical cells (subscript *i, j* from 1…*n*), split across 52 cells in 7 countries, (subscript *c* = 1…7), plus an additional 4 access points for the rest of the world. Countries, cells and access points are listed in appendix 1.

Each cell i has an area $\overline{K}_i$, divided into urban and rural land $\overline{K}_i = \overline{K}_{Ui} + \overline{K}_{Ri}$. It is connected to all other cells in the system, as well as the rest of the world, via a transport network. This transport network gives a transport cost matrix between every pair of cells (n x n).

The 4 access points, Moscow, Istanbul, Gwadar and Chongqing, are cities at which goods and services can be traded with the rest of the world. At these points, imports can be bought at fixed world prices, and exports can be sold according to a highly elastic rest of world demand curve discussed below.

Production

There are three productive activities: Primary good production (agriculture and mining); manufacturing and tradable services: non-tradable services, including housing and retail.

Primary Goods: Primary goods (agriculture and mining), sector s = 1, are produced using a Cobb-Douglas production function, using intermediates, rural land, and labor. Primary producers in cell i supply goods at price $\mathrm{p_{1i}}$ per unit with $\mathrm{p_{1i}} = \mathrm{w_i^{\alpha_w}}(\prod_{i\in[1,3]} \mathrm{P_{si}}^{\alpha_i}) r_{Ri}^{\alpha_r}/\mathrm{z_{1i}}$, where the right hand side is unit costs, with $\mathrm{w_i}$ the wage in cell i, P_{si} the CES price index for sector s in cell i, $\mathrm{r_{Ri}}$ the rural land rent and $\mathrm{z_{1i}}$ the cell-sector specific productivity parameter. Exponents (input shares) sum to unity, $\alpha_w + \alpha_1 + \alpha_2 + \alpha_3 + \alpha_r = 1$.

Demand for primary products (s = 1) produced in cell i, is $\mathrm{x_{1i}} = \sum_j \mathrm{p_{1i}}^{-\sigma_1} A_{ij}^1 {\tau^1}_{ij}{}^{1-\sigma_1} \mathrm{E_{1j}} \mathrm{P_{1j}}^{\sigma_1 - 1}$, where E_{1j} is total expenditure on primary in cell j, ${\tau^1}_{ij}$ the sector-specific bilateral iceberg trade cost, and A_{ij}^1 is a utility parameter expressing the preference for i's agriculture in location j. The CES price index is $\mathrm{P_{1i}} = \left[\sum_j A_{ij}^1 (\mathrm{p_{1j}} {\tau^1}_{ij})^{1-\sigma_1}\right]^{1/1-\sigma_1}$.

The value demand for each of the inputs into production can be expressed as follows:

Labor demand by sector 1 in cell i: $\mathrm{L_{1i}} = \alpha_w \mathrm{p_{1i}} \mathrm{x_{1i}}/\mathrm{w_i}$

Rural land demand by sector 1 in cell i: $\mathrm{K}_{Ri} = \alpha_r \mathrm{p_{1i}} \mathrm{x_{1i}}/\mathrm{r}_{Ri}$

Intermediate demand by sector s for sector 1 in cell i: $e_{1i}^s = \alpha_s \mathrm{p_{1i}} \mathrm{x_{1i}}/\mathrm{P_{si}}$

Manufacturing and Local Services: The two other sectors, manufacturing and local services, $s = 2, 3$ respectively, are produced under monopolistic competition with differentiated products as modeled by Dixit-Stiglitz.[11] The number of firms from sector s in cell i is n_{si}. Each firm choose inputs and sales to maximize profits. Production uses labor, intermediates, and urban land. The local producer price is given by $\mathrm{p}_{si} = \mathrm{w_i^{\alpha_{sw}}}(\prod_{k\in[1,3]} \mathrm{P_{ki}}^{\alpha_{sk}}) r_{\mathrm{Ui}}^{\alpha_{sr}}/\mathrm{z}_{si}$ with $\alpha_{sw} + \alpha_{s1} + \alpha_{s2} + \alpha_{s3} + \alpha_{sr} = 1$ for $s = 2, 3$.

[11] The Armington case holds the number of varieties produced in each country constant. Products are differentiated by location of production but since the number of varieties in each location is fixed, manufacturing and local services behave like agriculture.

Demand in cell i is $\mathrm{x_{si}} = \sum_j \mathrm{p}_{si}{}^{-\sigma_s} A^s_{ij} \tau^s{}_{ij}{}^{1-\sigma_s} \mathrm{E}_{sj} \mathrm{P}_{sj}{}^{\sigma_s - 1}$ and the local CES price index $\mathrm{P}_{si} = \left[\sum_j A^s_{ij} \mathrm{n}_{sj} (\mathrm{p}_{sj}\, \tau^s{}_{ij})^{1-\sigma_s}\right]^{1/1-\sigma_s}$. At equilibrium firms make zero profits selling output quantity $\mathrm{x}_{si} = 1$. Value demands for each input are as follows:

Labor demand by sector s=2,3 in cell i: $\mathrm{L}_{si} = \alpha_w \mathrm{p_{si}} \mathrm{n}_{si} \mathrm{x_{si}} / \mathrm{w_i}$

Urban land demand by sector s=2,3 in cell i: $\mathrm{K}_{U\mathrm{si}} = \alpha_r \mathrm{p_{si}} \mathrm{n}_{si} \mathrm{x_{si}} / \mathrm{r_{Ui}}$

Intermediate demand by sector k for sector s=2,3 in cell i: $e^k_{si} = \alpha_k \mathrm{p_{si}} \mathrm{n}_{si} \mathrm{x_{si}} / \mathrm{P_{ki}}$

$\mathrm{z_{si}}$ is the productivity of sector s in cell i. This is composed of two elements, a base location-sector-specific level of productivity multiplied by a scale factor. For the initial analysis, we calibrate to find z_{si}. Further details are outlined in the simulation section below.

Population

The total population of each country is given exogenously as $\bar{L}_c$. For all cells $i \epsilon$ country c, the local population L_i is given by the data and $\bar{L}_c = \sum_i L_i$. In the simulations with labor immobility each L_i is held constant. With labor mobility L_i can change but $\bar{L}_c$ is held constant. Details are outlined in the simulation section below.

Households work in their cell of residence and supply a fixed amount of labor (one household = one worker) and consume the three different goods and services. Their income in cell i is a combination of two components: the wage w_i, and m_i, which is a lump-sum transfer capturing the distribution of country-wide land rents and profits, assumed to be equally distributed across households in each country.

Households have Cobb-Douglas preferences over sector composite goods and indirect utility function $u_\mathrm{i} = (w_i + m_i)/(\prod_{s\in[1,3]} \mathrm{P_{si}}^{\beta_i})$ with expenditure shares $\beta_1 + \beta_2 + \beta_3 = 1$. Total income in cell i is equal to $M_i = (w_i + m_i)L_i$, and total household expenditure on each sector s is therefore $e^{HH}_{si} = \beta_s M_i$.

Trade

Goods and services move between cells within and across countries consistent with each cell's supply, demand, and trade costs. Within each country, these flows are determined by the relative demand and supply of goods in each location and trade costs, $\tau^s{}_{ij}$.

Across country the pattern of trade is shaped also by country origin-destination preference parameters, A^s_{ij}; these take a common value A^s_c for goods produced and consumed in the same country (i.e., where i, j are in the same country c). Across international borders these preference parameters take the form: $A^s_{ij} = A^s_{ck}$, the same for all $i \epsilon$ country c , $j \epsilon$ country k . Thus, for each sector there are distinct n x n preference matrices, but the variation is only between countries so, if nc denotes the number of countries, A^s_{ij} has just nc x nc distinct values. The values are found in the calibration process.

Transport times between each pair of cells allows us to estimate trade costs. We assume a relationship between the two of the form , $\tau_{sij} = 1 + \lambda^s time_{ij}{}^{\theta}$ with $\theta = 0.75$ and λ^s varying by industry.

The initial international trade flows are defined by the data. In the data national trade balances are non-zero, so net imports are assumed to be paid for by net remittances from emigrants living elsewhere; the fixed base level of remittances does not change with the experiments, and neither therefore do national trade balances.

Equilibrium

Within each cell, labor, land, and all three goods/services markets must clear.

For labor in each cell i, $L_i = \sum_{s\in[1,3]} L_{si}$. The total value demand in cell i for sector s output is $\mathrm{E}_{si} = e_{si}^1 + e_{si}^2 + e_{si}^3 + e_{si}^{HH}$, which must equal the value produced in the cell net of any exports out of the cell and imports into the cell. Land market clearing within each cell is given by $\overline{K}_{Ri} = K_{1i}$, $\overline{K}_{Ui} = K_{Ui} = \sum_{s\in[2,3]} K_{Usi}$ and $\overline{K}_i = \overline{K}_{Ui} + \overline{K}_{Ri}$. Together these market clearing conditions determine $\mathrm{r_{Ri}}$, $\mathrm{r_{Ui}}$, $\mathrm{w_i}$, $\mathrm{P_{1i}}$, $\mathrm{P_{2i}}$, and $\mathrm{P_{3i}}$.

Lump sum transfer payments, m_i , are determined through splitting total land rents nationwide equally among all the population within the country, regardless of where they live, such that, for cells $i \epsilon$ country c, $m_i = \sum_{i\in c}(\overline{K}_{Ui}\mathrm{r_{Ui}} + \overline{K}_{Ri}\mathrm{r_{Ri}})\ /\overline{L}_c$.

Calibration

The model's equilibrium is calibrated to the base data set by choice of productivity parameters, z_{si}, and country origin-destination shift parameters, A_{ij}^s. The z_{si} are calibrated to match observed employment levels in each sector-cell and per capita income levels across countries. A_{ij}^s are calibrated to match the international trade data.

The calibration proceeds in three main steps. First, we calibrate relative z_{si} within each country, so that equilibrium employment in each sector and cell matches the employment data. Second, the absolute levels of z_{si} in each country are scaled to match income per capita at a country level. Finally, we calibrate preference parameters A_{ij}^s such that the share of country *i* output being sold in country *j* is consistent with international trade data.

Simulations

The calibrated model is 'shocked' with new transport time matrices, and firms and households adjust their decisions to optimally respond to the new connectivity of the region. We look at four different levels of economic response

(1) The direct trade value of the transport cost reduction. We take the base value of exports of each cell according to the destination and calculate the reduction in costs in shipping the same amount of goods and services that results from the decreased travel times. No demand or supply response occurs.

(2) Armington assumption; the number of firms/ varieties of products produced in each cell is held constant. Output per firm adjusts, as do equilibrium prices and demands.

(3) Monopolistic competition in manufacturing production, where the number of firms in each cell in sectors 2 and 3 adjusts in response to profit opportunities until equilibrium is restored

(4) Monopolistic competition with increasing returns to scale in manufacturing (localization economies) and some intra-country labor mobility.

In setting (4), under increasing returns, z_{si}, the calibrated productivity of sector s in cell i is composed of two elements. First, a base productivity of sector-cell, $\bar{z}_{si}$, and second, an additional component which represents potential increasing returns to as a function of the density of firms in the sector-cell (denoted by $\bar{n}_{si}$) and taking the form $z_{si} = \bar{z}_{si}(1 + \alpha(n_{si}/\overline{L}_i))^\rho$. The density of firms in expressed as a density per population in the cell in the base period, capturing the effective size of the space in which the firm is located.

If, following the transport investment, the number of firms increases (or decreases), then returns to scale change productivity, where $\rho > 0$ if there are increasing returns. We assume that $\rho > 0$ only in setting (4) and in sector 2. Parameters α and ρ are chosen such that areas with average firm density are 20% more productive than comparable areas with no firms, and that the cell will the mean value $n_{si}/\overline{L}_i$ has an elasticity of productivity with respect to the number of firms equal to 0.08, these two restrictions implying parameter values $\alpha =$ 6.67 and $\rho =$ 0.093. This translates into a point elasticity of productivity with respect to the number of firms that ranges from 0 in cells with no initial manufacturing to a maximum of 0.088.

Labor mobility is captured by assuming that $L_i = \bar{L}_i {u_i}^{\mu} / \left(\sum_{j \in c} L_j {u_j}^{\mu} / \sum_{j \in c} L_j \right)$, where $\bar{L}_i$ is the base exogenous population in the cell pre any scenario, coming directly from the data. $\mu = 0$ implies labor is completely immobile within the country, as in settings (1) to (3). $\mu = \infty$ would imply perfect labor mobility. The total national population must equal the sum of all cell populations within the country $\bar{L}_c = \sum_{i \in c} L_i$. Results with labor mobility are computed with $\mu = 10$.

In settings (2) - (4), the amount of urban land is able to adjust in response to changes in the urban-rural rent differential, so that $K_{Ui} = \bar{K}_{Ui}((\mathrm{r_{Ui}}/\bar{r}_{\mathrm{Ui}})/(\mathrm{r_{Ri}}/\bar{r}_{\mathrm{Ri}}))^{\nu}$. We set $\nu = 0.5$.

Appendix 3: Parameters

The assumed parameters in the model are listed in the table below. Each sector of production employs intermediates, land, and labor. Primary good production relies on rural land, whereas manufacturing and non-tradeable services rely on urban land (the latter has the highest value share of land in production, as this sector includes real estate and therefore all housing production). Primary good production is the most labor intensive of sectors/

Transport costs are calculated using a linear relationship from the transport time (in days) $\tau_{ij} = 1 + \lambda^s {time_{ij}}^{\theta}$, as in Alder (2017) and Roberts et al., (2012). Costs are highest from non-tradeable services which are produced and sold predominantly in the same location, and lowest for manufacturing, for which longer travel times do not lead to much loss in terms of the value of the good. θ is chosen at 0.75 , reflecting similar assumptions elsewhere in the literature such as for rural goods in China in Roberts et al. (2012). There are other ways of modeling the impacts of transport times on transport costs, such as through an exponential model in Lall and Lebrand (2019).

The GVA data from the UN National Accounts, and the consequent Gross Output values calculated from input-output matrices, combined with the net trade flows from each country, gives a total value of output of each sector consumed within each country. From these, national consumption value shares for each sector, $\beta_1, \beta_2, \beta_3$, are calculated.

Parameters

	Primary Goods	Manufacturing	Non-Tradeable Services
Input Shares			
Primary Goods α_1	0	0.2	0.1
Manufacturing α_2	0.1	0.2	0.1
Non-Tradable Services α_3	0.1	0.1	0.1
Land α_r	Rural 0.25	Urban 0.1	Urban 0.3
Labour α_w	0.55	0.4	0.4
Transport Costs			
λ^s	0.18	0.09	1.8
θ	0.75	0.75	0.75
Elasticities			
CES consumption σ_s	6	6	6
Export demand η_s	10	10	10
Returns to scale, ρ	0	0 (0.2 IRS)	0
Mobility; μ = 0 (immobile) or 10 (mobile)		Urban Land Supply elasticity, $\nu = 0.5$	