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Oyu Tolgoi: Impacts of Mining on Economic Outcomes in Mongolia

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Oyu Tolgoi: Impacts of Mining on Economic Outcomes in Mongolia

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Abstract

This paper represents an analysis of the impacts of Mongolia's Oyu Tolgoi copper mine on various first and second-order outcomes in the mine's province, Umnogovi. These outcomes include infrastructure, health, education, and income metrics at the individual and household levels. Findings are mixed: relative to the control group, residents of the mine's province exhibit a decrease in overall health and respiratory problems, increases in centralized water infrastructure and spending on medical treatment, increases in rates of treatment sought and vocational education, and increases in wages, remittance, and labor hours. Concurrently, the mine's province is also associated with a relative increase in digestive problems, slower growth rates in the number of internet users, a decrease in secondary education completion rates amongst 18 to 20-year-olds, and an increase in the number of children under 12 without any formal education.

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1. Introduction

The Oyu Tolgoi copper deposit, located in Umnogovi *aimag* (South Gobi province) of southeastern Mongolia, is the largest known undeveloped copper reserve in the world. The existence of copper at the site has been known since the Bronze Age, but it was only in the 1980s and 1990s that numerous geological surveys and investor law revisions made private development of the resource possible. In 1999, a local geologist employed by Canadian mining company Ivanhoe Mines Ltd. discovered copper and other metals in economically-viable proportions. The mine has since quickly developed into one of the largest mining operations in the world, producing 157,400 tons of copper, 114,000 ounces of gold, and 974,000 ounces of silver in 2017 (Ergo Strategy Group 2018).

In this paper I utilize the establishment of the Oyu Tolgoi mine to study the impacts of natural resources on various socioeconomic outcomes. In addition to employing household surveys, I draw upon my research in the field to compare the development of these outcomes in Umnogovi province to that of other provinces not directly impacted by the mine. In so doing I aim to demonstrate the mine's causal effect on aspects of economic wellbeing of people located within its proximity, which I define to be the province in which the mine is located: Umnogovi province.

Since mining began at Oyu Tolgoi, anecdotal evidence suggests Umnogovi has changed drastically. This study empirically investigates changes in infrastructure, health, education, and income outcomes in response to the mine's establishment, which to the best of my knowledge have largely been unexplored. Infrastructurally, I find that the mine is associated with an increase in the occurrence of ger (yurt) residence, centralized water systems, and a decrease in the number of internet users per household. The mine

has also been associated with several changes to the overall health of Umnogovi: a decrease in the prevalence of health problems, decreasing proportions of respiratory problems, increasing proportions of digestive problems, higher amounts paid for medical treatment, and higher rates of medical intervention sought. Educationally, the mine is associated with significant decreases in the high school graduation rate of young adults, an increase in the incidence of children without any formal education, and an increase in the prevalence of vocational education amongst adults. There appears to be no significant impact on the proportion of adults with a secondary education or higher degree. Oyu Tolgoi also shows correlation with higher real wages earned, higher levels of remittance received by Umnogovi residents, as well as an increase in labor hours worked.

The study of these changes and how the Oyu Tolgoi operation may be causing them is important for several reasons. Firstly, the mine has enormous implications for the expansion of the Mongolian economy. A landlocked economy, this country has depended upon animal husbandry for productivity for much of its history. In more modern times, the mining sector, an associated rise in commodity prices, and import demand (mainly from China) have driven growth in the Mongolian economy. The country has become increasingly dependent upon natural resources for its growth, the mining sector being responsible for 43% of fiscal revenues in 2008 and 85% of exports in 2009 (Muff et al. 2016). In a 2011 study, the National University of Mongolia projected that GDP per capita would be 34% higher by 2020 through the development of the mine than if the project had not existed and economic growth held constant (Fisher et al. 2011).

Secondly, the mine has wider implications as a case study in the management of natural resources. Much of the existing work on the topic of natural resources (discussed

in Section 3) demonstrates that an endowment of natural resources actually slows growth or even reverses it; other studies show that such endowments, when managed appropriately, do in fact translate into increased growth for their host countries. Oyu Tolgoi is a particularly critical case to add to this body of work not only due to its immense size, but also the country in which it is located. Mongolia is a recent democracy, having experienced its revolution in 1992 after the collapse of the Soviet Union. Tinged with influences both communist and democratic, the country has struggled to establish itself in international markets. Political corruption remains pervasive (Harutyunyan, Neziri-Vela, and Saba 2019). This is a setting in which there has been very little research on the influence of natural resources on development. Studying the economic impacts of the Oyu Tolgoi mine, especially in its initial stages, will have crucial policy implications that will guide the management of such a key asset. A success story in Mongolia could serve as a unique model for developing countries in similar situations.

Thirdly, the mine's value makes it significant on a global scale. The successful extraction of the site's resources would have enormously meaningful benefits to the world economy. Currently, the world faces a large copper supply gap: the pace of development around the globe is generating demand that has far surpassed the available amount of copper. The supply crunch is estimated to come into full effect around 2020 and is comprised of approximately 5 million tons' worth of copper, an amount equivalent to eight new mines the size of Oyu Tolgoi (Ergo Strategy Group 2018). Besides construction, electrical networks, consumer products, transportation, and industrial machinery, copper has a large role to play in the application of renewable energy production. Renewables are a rapidly growing industry and use four times as much

copper on average as traditional silos such as industrial machinery (Ergo Strategy Group 2018). Additionally, copper grade decline, the depletion of existing mines, and growing lead times from discovery to production have constrained supply. If such trends continue, it is probable that commodities prices will rise unbearably in the future – making it even more necessary to understand the second-order consequences of the Oyu Tolgoi project and whether or not the project is truly doing more good than harm when we consider outcomes other than just revenue.

2. Background on the Mongolian Economy

Mongolia is an immense country, having a surface area of 155.4 million hectares – making it the 19th largest country in the world (Central Intelligence Agency 2019). Less than 1% of this land, however, is considered arable; the country ranges from grassy steppes to semi-desert and desert plains. Furthermore, Mongolia experiences extreme weather conditions, characterized by brief, hot summers and bitterly long and cold winters.

The country has roughly three million permanent residents. Nearly half this population live in the capital city, Ulaanbaatar (UB). The government manages this municipality separately from the 21 aimags (provinces), which are divided into 329 districts. There are high poverty levels – as high as 29.6% in 2016 – intensified by an urban-rural divide: poverty incidence in rural areas is approximately twice that of urban areas (Fisher et al. 2011). This is primarily because rural populations tend to be composed of nomadic herders, who are extremely vulnerable to poverty and face limited employment opportunities given their educational and cultural background.

Approximately 40% of the country's eligible workforce live a nomadic lifestyle and are livestock herders by trade (Fisher et al. 2011).

Following the collapse of the Soviet Union, Mongolia experienced a painful recession brought on by the transition from a centrally planned economy to a market-based economy. Growth was slow until the early 2000s, when China experienced a huge boom in infrastructure development. This relationship has only become more important to the Mongolian economy; China is responsible for nearly 75% of Mongolian exports. Furthermore, mined commodities represent roughly 80% of total exports distributed from 2006-2008 (Fisher et al. 2011). This is potentially indicative of a larger trend of "Dutch disease" – the gradual crowding out of a country's other industries due to the predominance of one industry. GDP contributions from manufacturing and agriculture have declined 19% and 10% respectively between 1995 and 2009, while mining and transport/communications have increased their contributions to GDP by 9% (Fisher et al. 2011). Such a dynamic makes the country extremely vulnerable to commodity prices, exchange rates, and the status of the Chinese economy. In light of this, Mongolia's management of its natural resources will play a key role in the country's economic future.

3. Background on Oyu Tolgoi

Figure 1: Map of Mongolia with aimags indicated. The Oyu Tolgoi mine site is indicated by the red star. Source: (Wikimedia Commons 2006)

Oyu Tolgoi, located in the South Gobi Desert, is approximately 80 kilometers north of Mongolia's border with China. The mine produces over 450,000 tons of copper annually, an amount equivalent to three percent of global production (see Figure 1) (Engineering and Mining Journal 2011).

The investment agreement (IA) was signed on October 6, 2009 and stipulates a 30-year term with the possibility of a 20-year extension.[1] This permitted a workforce of thousands of employees to begin constructing the site's open pit mine, concentrator facility, and infrastructure. Oyu Tolgoi is the largest investment in Mongolia's history and is already the country's largest mine and single largest taxpaying entity. Under the IA, Erdenes Oyu Tolgoi LLC on behalf of the government of Mongolia owns 34% of the mine, while Canadian-based Turquoise Hill Resources Ltd. (Turquoise Hill Resources)

[1] When this paper refers to "post-mine years," it is referring to the time period after the signing of the IA (2010, 2011, 2012, 2014, and 2016).

owns 66%. Rio Tinto Ltd. (Rio Tinto) owns 51% of Turquoise Hill Resources. During the IA's term, the mine must pay royalties to the government equal to 5% of the total value of all exported minerals, maintain a 90% Mongolian national workforce, commit to an extensive training and scholarship program, construct an airport, roads, and infrastructure, source energy domestically (once feasible), and mitigate against adverse environmental impacts at its own expense. This is a more stringent standard than other adjacent mines (shown in Figure 2) have historically faced.

The mine's layout is composed of two parts: the open pit mine and the underground section which is still in development. The open pit section contributed over 500 million tons of material in the first six years of operation. The project's underground section is still undergoing development and Oyu Tolgoi predicts that the project will achieve first production from this section by 2020.

Figure 2: Map of Mongolia with major mines indicated. Source: Cane et al., (2014).

The mine's location represents a significant infrastructural challenge, especially when considering the project's huge energy demands – equivalent to a quarter of Mongolia's production capacity (Ergo Strategy Group 2018). During the initial construction phase of the open pit mine, Oyu Tolgoi imported power from China as a temporary measure. The project, however, is committed to sourcing power domestically as per its IA. In order to maintain operations, Oyu Tolgoi requires water, transportation infrastructure, and personnel accommodation facilities amongst other needs. To satisfy this demand, the company has already constructed a water treatment plant close to the site, funded the investment of a sealed road to the Chinese border, built a permanent domestic airport, and created a company work camp.

Oyu Tolgoi and Rio Tinto have also committed to protecting the environment around the mine. Having already been involved in a few controversial incidents involving acid rock drainage and a worryingly fast rate of water supply depletion from the region, the company has pledged to closely monitor the social and environmental impacts of the mine and mitigate against any hazardous externalities (Goodland 2012; Schneider 2013). To this end, the company has established the Gobi Oyu Development Fund (the Fund) to help communities in the region and contribute to the growth of the South Gobi region.

3a) The Mining Process

Oyu Tolgoi's extraction process is highly automated and involves very few human inputs in the labor process. However, it employs over 16,000 people, making its human impact very significant. At the open pit section (Figure 3), workers operate large excavation machines that carve ore from the earth. Drivers utilize enormous haul trucks to transport the loads of raw ore to the concentrator facility. Open pit excavation, haul

truck activity along dirt roads, and underground blasting have all come under fire for being responsible for higher rates of air and groundwater pollution (discussed in Section 4). Upon interviewing health specialists at a local hospital in Umnogovi, I learned that public outcry over the excessive amounts of dust raised by Oyu Tolgoi vehicles have generated enough momentum to spur the construction of several new concrete roads over oft-traveled routes in addition to other pollution countermeasures such as strictly-enforced speed limits on all company vehicles.

Figure 3: View of the open pit section of the Oyu Tolgoi mine in Umnogovi. © Andy Zhou.

Once arrived at the concentrator, the ore moves through the primary crusher, the pebble crusher, semi autogenous grinding (SAG) mills, and ball mills. These machines utilize steel balls and magnets to reduce the size of the ore and remove any metal that might damage the pebble crusher (Figure 4).

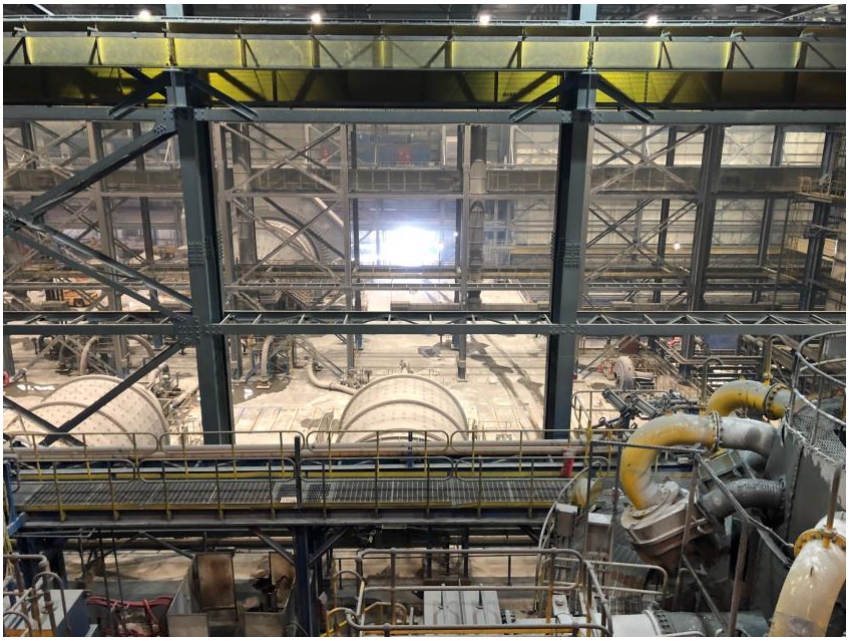


Figure 4: Ball mills in the concentrator facility. © Andy Zhou.

After passing through the crushing process, a process called flotation takes place in column cells that separates the copper and gold from the rest of the ore (Figure 5). This process creates material that is either ready to move on to the next phase or is sent back for regrinding in vertical mills and hydro-cyclones. After passing through flotation in the column cells, a series of presses and filters removes water from the concentrate and renders the final product, a powder consisting of 25 – 30% copper and smaller amounts of gold and other metals. This entire process is heavily automated, usually only requiring a few employees to monitor machines and make minor programming adjustments depending upon haul composition (Figure 6). These processes consume enormous amounts of water. Locals have already begun to feel the effects of groundwater depletion, citing the rapid disappearance of deep-water aquifers that have remained intact for generations prior to the commencement of mine activity. There is also concern that

underground excavation has loosened debris and harmful minerals such as arsenic into consumption aquifers, potentially leading to more frequent rates of digestive issues.

Finally, the concentrate arrives at the bagging plant, which employs a semi-automated process in packing the two-ton bags, sampling them for laboratory testing to ensure the proper proportion of copper, and tagging (Figure 7). The plant fills about one bag every six minutes. These bags are loaded onto trucks, each carrying 18 bags (36 tons of concentrate) and shipped to Oyu Tolgoi's customers.

Figure 5: Column cells perform the task of separating copper and gold from the processed ore. © Andy Zhou.

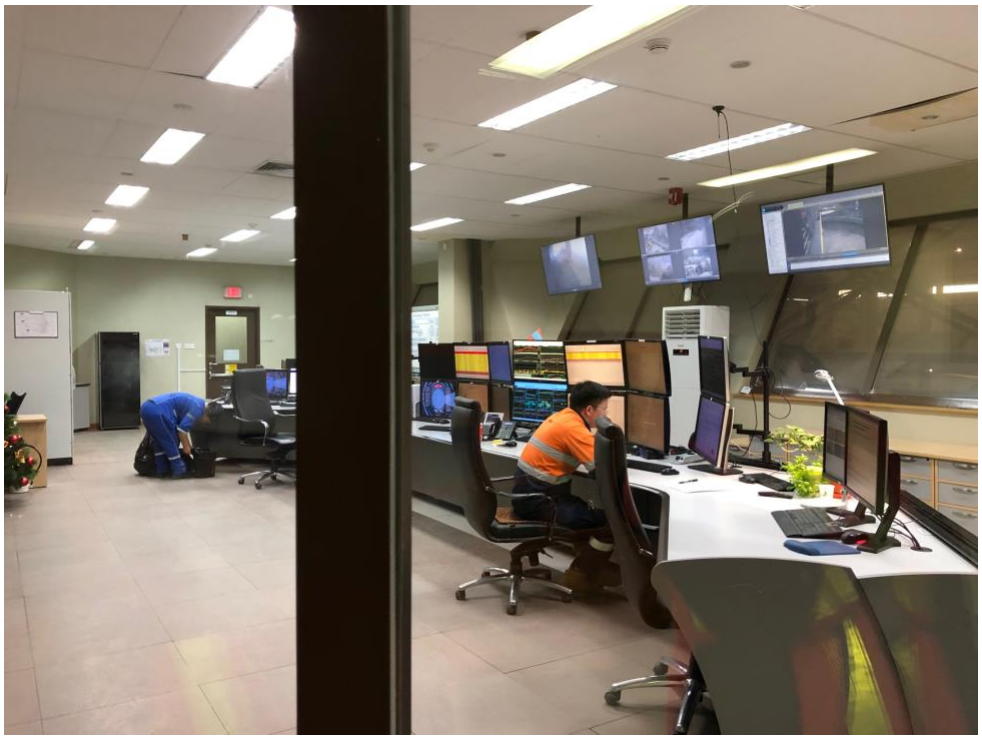


Figure 6: An employee monitors operations in the mine's concentrator facility. © Andy Zhou.

Figure 7: Workers process the two-ton bags of concentrate for shipping. © Andy Zhou.

3b) Labor Force

As of year-end 2018, Oyu Tolgoi employs a total number of 16,604 employees, including contractors. Of these employees, there are 15,381 Mongolian nationals and 1,223 expatriates. This proportion fulfills the obligatory 90% minimum Mongolian national employment stipulated by the IA. Table 1 depicts a detailed breakout of employee categories, separated by sex.

Table 1: Oyu Tolgoi employee categories. Source: Oyu Tolgoi LLC, 2018.

Employee group	# Female	Percentage	# Male	Percentage
Contractor	2115	15.24%	11759	84.76%
Employee	664	24.32%	2066	75.68%
Total	**2779**	**16.74%**	**13825**	**83.26%**

Many employees of the mine work on a fly-in, fly-out (FIFO) basis, traveling on company-sponsored airlines to the newly established Khanbogd airport (also paid for and constructed by Oyu Tolgoi). Employees stay at the mine for an allotted amount of time and then return home; most follow a 2-week on-site, 1-week off-site cycle. Of the Mongolian nationals employed there are 3,202 residents of Umnogovi, representing approximately 21% of the entire workforce. The largest employment impact to Umnogovi has been in the form of contractors rather than direct employment – these 3,202 employees are made up of 2,812 contractors and 390 directly-employed personnel.

Since Umnogovi has a population of approximately 60 thousand, a labor force of 16 thousand represents a proportion of more than 25% of the province. While these people would naturally be directly affected by the mine due to their proximity, I argue that there are also larger ripple effects that must be considered upon taking microeconomies, vendors, and other externalities that the mine has generated into account. Upon considering the range of these effects, the number of people this project

directly affects, and its value to the Mongolian economy, it becomes even more critical to study how the mine's operations have affected local wellbeing.

4. Literature Review

An endowment of natural resources and a subsequent growth in a country's mining sector can have both positive and negative impacts on growth. Growth in mining and its associated industries can result in positive returns to GDP and GNP as labor and capital rise, all else held equal. History, however, has told us a different story. Poor macroeconomic policies and unproductive investments are generally the cause of a failure to translate resource wealth into economic prosperity. According to some researchers, "in the great majority of cases, weak institutions are the 'transmission channel' via which these decisions are taken. On the other hand, effective management of the fiscal flows from the exploitation of natural resources can mean that an abundance of natural resources is a blessing rather than a curse " (Fisher, Batdelger, et al. 2011 p.85).

Growth in the mining sector has proven to be a major problem for many developing countries that are not able to properly manage their resources, creating the story of the "curse of natural resources." This concept refers to the phenomenon that many countries with large natural endowments in many cases tend to perform economically worse than counterparts with fewer resources (Humphreys, Sachs, and Stiglitz 2007). In another study, East Asian "tiger" countries with fewer natural endowments exhibited much higher growth rates from the 1960s to 90s, while Latin American economies with ample endowments stagnated and fell short of growth targets (Jones-Luong and Weinthal 2010). Sachs and Warner (2001) concluded that the crowding

out of other production sectors due to mining's predominance and associated drops in real currency strength lead to lower growth (i.e., Dutch disease). The appreciation in the real exchange rate and the associated labor migration towards a blossoming natural resources sector reduce the competitiveness of other export sectors such as agriculture or manufacturing, creating a simultaneous contraction effect on overall GDP. Dutch disease would then lead to accelerating domestic inflation as strong demand for capital and labor in the construction and mining sectors crowd out other sectors.

The mining sector has also produced socially harmful effects at a more micro level. The growth of mining communities in Mongolia has been associated with an increase in gender-based violence and transient population migration within these communities and the areas affected by them (Cane, Terbish, and Bymbasuren 2014). Some have argued that mining has led to negative educational outcomes – school enrollment at all levels and public expenditure on education relative to national income appear to be inversely related to abundance of natural resources (Birdsall, Pinckney, and Sabot 2001). Furthermore, it has been argued that education and training – i.e., the accumulation of human capital – are crowded out by a profusion of resources in that these nations tend to underinvest in education, so focused as they are on extractive industry (Gylfason 2001). A lack of human capital would lead to long-run economic consequences in the form of lower physical capital accumulation and reduced total factor productivity – worsening the situation by making the country even less capable of economic diversity and even more dependent on the mining sector. This represents a negative feedback loop: as the country becomes more dependent on the resources sector,

the demand for skilled labor decreases and reduces human capital accumulation once again. These studies provide evidence that further the "curse of natural resources."

There are, however, counterexamples to this trend. Haney and Shkaratan (2003) studied the impact of mine closures in the former Soviet bloc and found that stopping mine activity was associated with negative municipal expenditures, reduced social services such as education and health spending, limited community cohesiveness, and large environmental remediation cost. Mining has been shown to have a directly positive impact on employment and generates microenterprises as well. Weber-Fahr (2002) show that large-scale mining provided direct employment for approximately 2.5 million workers worldwide; the author estimated that each large-scale mining job accounted for up to 25 jobs in related microenterprise (microeconomy) activities. The paradox of abundance merits further investigation. Brunnschweiler and Bulte (2008) argue that this paradox is in fact a red herring because resource abundance is often confused for resource dependence, which is endogenous to underlying structural factors. The authors find that resource dependence does not affect growth of its own accord and that resource abundance positively affects growth and institutional quality.

Many proponents of the "blessing of natural resources" argue that resources themselves are not in fact the issue, but rather the management of such resources that has been the main impediment for developing countries. An oft-cited example to support the "blessing" theory is Botswana and its booming diamond industry. Botlhale (2017) argues that the discovery of diamonds, coupled with a prudent mineral management strategy, financed the creation of a developmental state (as opposed to the extractive-style states set up during the age of imperialism in Africa) and was largely responsible for

Botswana's high growth in the latter stages of the 20th century. Botswana's inclusive institutions have been characterized by their protection of private property and the preponderance of the rule of law; in Botswana's case, diamonds generated enough rent for all so that no social group had enough incentive to break the status quo – resulting in the highest rate of per capita GDP growth of any country in the last few decades (Acemoglu, Johnson, and Robinson 2002). Furthermore, Botswana's income inequality levels, mitigated by government policies to restrain wage and salary pressures, did not rise as a result of newfound prosperity (Valentine 1993). Valentine finds that formal employment sector growth in this case allowed the government to apply mineral revenues to public services and development programs, increasing social goods. Other examples include Peru, where researchers find a positive effect of a large mine's demand for local inputs on real income, suggesting "the potential of backward linkages from extractive industries to create positive spillovers in less developed economies" (Aragon and Rud 2013 p.1).

This study contributes to the existing literature by exploring mining dynamics in the Mongolian context. Previous studies such as Fisher, Batdelger, et al. (2011) and Chuluundorj and Khyargas (2018) have explored changes in first-order variables such as GDP and direct expenditure or have attempted to use models to predict impact to national GDP. Moreover, these previous studies have focused on impact at either the immediate proximity of the mine (district or surrounding township) and/or the impact to aggregate national data. It is also worth noting that Rio Tinto sponsored both the previous studies on the mine.

This paper is unique to previous studies concerning Oyu Tolgoi because it concentrates on second-order outcomes, focuses on impact at the regional level, uses household survey data, and contains multiple years of data before the IA. Furthermore, I implement a difference-in-differences methodology supplemented by a synthetic control comparison to assess mine impact, a model never before used to analyze Oyu Tolgoi. By investigating the selected second-order outcomes at the provincial level, this paper gives a more candid view of actual changes in living standards and contributes to how we think about the effects of natural resources.

5. Data

This paper utilizes repeated cross-sectional individual-level and household-level census data spanning 2007-2016 from the Mongolian National Statistics Office's (NSO) Census and Survey Catalogue. The NSO's responsibility is to survey the population of Mongolia and provide nationally representative data that describes the social and economic situation of the country. The Census and Survey Catalogue is an archive of various data categories, including information on labor force outcomes, population and housing, health and other economic variables. These data are nationally representative and contain information at both the household and the individual level. The NSO collects these data at various periods of time (depending on which data category) using questionnaires. I use the Household Socioeconomic Survey (HSES) to measure the economic outcomes affected by Oyu Tolgoi. The survey covers households and individuals in all 21 aimags (provinces) of Mongolia and also the municipality of Ulaanbaatar, which is administered separately from provinces.

This dataset contains household and individual information on economic variables such as salary, employment, health treatment payments, and also on social variables such as education, sex, age, and household size. I use HSES data from 2007, 2008, 2009, 2010, 2011, 2012, 2014, and 2016. Table 2 details the 16 outcome variables I analyze and describes their structure. The summary statistics in Table 3 present aggregated values for all studied outcome variables for the treatment province (Umnogovi), the capital of Ulaanbaatar, and all other provinces. I display monetary variables in Mongolian togrog, which hovered at an exchange rate of approximately two thousand togrog to one United States dollar during the years 2009 – 2016 (Trading Economics 2019b). Statistics are grouped by province and include all years' data.

By using provincial-level data, my strategy risks capturing competing effects from other factors in Umnogovi. I am primarily concerned with the other major active mining operation within the province, Tavan Tolgoi (see Section 9: Risks and Considerations). Tavan Tolgoi is a large coal mine split into several different ownership sections; the oldest-operating section has been active since 1967.

Table 2: Description of Outcome Variables

Infrastructure Variables)	
Ger	Dummy variable equal to one if an individual's main residence is a ger (yurt)
Centralized Water	Dummy variable equal to one if an individual's main residence has access to centralized water
Internet Users	Number of household members who use the internet
Health variables	
Health Problem	Dummy variable equal to one if an individual reported a health problem within the last month
Respiratory Problem	Dummy variable equal to one if an individual's health problem is respiratory in nature
Digestive Problem	Dummy variable equal to one if an individual's health problem is digestive in nature
Treatment fee	Amount paid by individual for the medical treatment received to address their health issue, in Mongolian togrog
Medicine fee	Amount paid by individual for any purchases of medicine in the last month, in Mongolian togrog
Sought Treatment	Dummy variable equal to one if an individual with a health problem sought medical treatment
Education variables	
Secondary Education	Dummy variable equal to one if an individual has obtained a secondary education or higher degree, restricted to population eighteen years or older
Vocational Education	Dummy variable equal to one if an individual has obtained a vocational/technical degree, restricted to population eighteen years or older
Youth Secondary Education	Dummy variable equal to one if an individual is between eighteen and twenty years of age and has obtained a secondary education
No Education	Dummy variable equal to one if an individual less than twelve years of age has had no formal education
Income variables	
Annual salary	Salary earned in last twelve months, in Mongolian togrog
Annual remittance	Amount of remittance payment received in the last twelve months, in Mongolian togrog
Job Hours Worked Weekly	Number of hours worked by an individual in a week

Note: Data on all variables come from the Mongolian NSO's HSES data. Selected years include 2007, 2008, 2009, 2010, 2011, 2012, 2014, and 2016.

Table 3: Aggregated Summary Statistics

	(1) All Provinces	(2) Umnogovi	(3) Ulaanbaatar
Prevalence of Ger Residence	0.354	0.777	0.254
	(0.478)	(0.416)	(0.435)
Prevalence of Centralized Water	0.293	0.053	0.349
	(0.455)	(0.223)	(0.477)
Number of Household Internet Users	2.315	1.864	2.375
	(1.142)	(0.906)	(1.149)
Health Problem in Last Month	0.069	0.098	0.069
	(0.253)	(0.298)	(0.253)
Proportion of Respiratory Health Problems	0.387	0.387	0.392
	(0.487)	(0.487)	(0.488)
Proportion of Digestive Health Problems	0.101	0.096	0.100
	(0.301)	(0.295)	(0.300)
Medical Treatment Payment	53.118	62.620	50.245
	(317.099)	(262.370)	(321.587)
Medicinal Payments	25.181	21.535	25.508
	(80.316)	(70.987)	(84.864)
Share of Treatment Seekers in Last Month	0.675	0.747	0.660
	(0.469)	(0.435)	(0.474)
Prevalence of Secondary Education amongst adults	0.688	0.535	0.728
	(0.463)	(0.499)	(0.445)
Prevalence of Vocational Education amongst adults	0.135	0.103	0.146
	(0.342)	(0.305)	(0.353)
Prevalence of Secondary Education amongst 18, 19, and 20-year-olds	0.837	0.837	0.854
	(0.369)	(0.369)	(0.353)
Proportion of children under 12 with no formal education	0.079	0.094	0.074
	(0.269)	(0.292)	(0.262)
Annual Salary	4233.133	3752.343	4298.332
	(3711.897)	(4098.183)	(3731.999)
Remittance Received in Last Year	411.487	579.915	419.456
	(1611.510)	(2041.398)	(1622.343)
Hours Worked Per Week	51.889	51.288	52.577
	(14.535)	(17.234)	(14.120)
Observations	109783	9406	89839

Note: Table reports means for each outcome variable with standard deviation in parentheses.
Data is sorted by province and aggregates all survey years: 2007, 2008, 2009, 2010, 2012, 2014, and 2016. Annual salary and remittance are shown in thousands of Mongolian togrog.

The survey's design allocates sampling units randomly and each location's sample size is determined proportionally. Since each survey year selects a different sample group, these data do not represent a panel dataset but rather a cross-sectional snapshot of the population. The explicit organization of the survey's strata undergoes some change throughout the years but generally follows a consistent structure. I visited the National Statistics Office of Mongolia in order to procure the full dataset I utilize in this study.

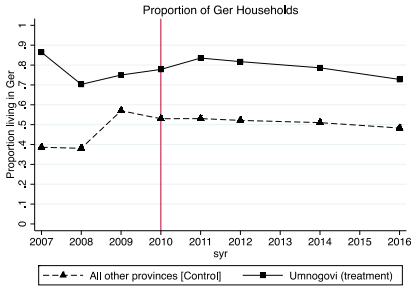
6. Empirical Methodology

I use a difference-in-differences (DID) comparison to estimate the causal effect of Oyu Tolgoi upon the outcome variables outlined in Table 2 over the course of the available years: 2007, 2008, 2009, 2010, 2011, 2012, 2014, and 2016. I define the timing of the exogenous event to be the date that the Oyu Tolgoi IA was signed, since this marks the Mongolian government's official recognition of the mine's holding companies to develop the project. In my analysis, post-treatment years include 2010, 2011, 2012, 2014, and 2016. I use all other provinces as the DID control group.

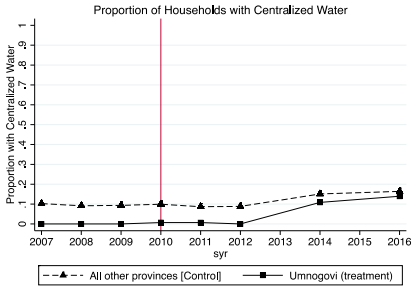
The basic idea behind this DID strategy is to satisfy the pre-mine parallel trends assumption between the treatment group and the control group. This means that prior to the IA, Umnogovi and the rest of the country exhibited similar directional trends in their development and progressed at similar rates. Satisfying this assumption allows us to then claim any deviation from these patterns in Umnogovi after the IA to be causally related to the mine being established.

As shown in Graphs 1-16, I demonstrate pre-mine parallel trends for the selected outcome variables and then attempt to discern any change between the treatment province and the rest of the country post-mine.[2] I do this using an all-province regression with province and year fixed effects added, an approach similar to the one utilized in a study on the effect of a diamond mine in Zimbabwe (Muradzikwa 2018). Furthermore, I control for education and population changes in all provinces. I assume that potential predictor variables I do not control for satisfy the parallel trends assumption and as such do not influence the DID measurement.

Graphs 1-16: Collapsed-mean data used to demonstrate satisfaction of the parallel trends assumption necessary for DID.

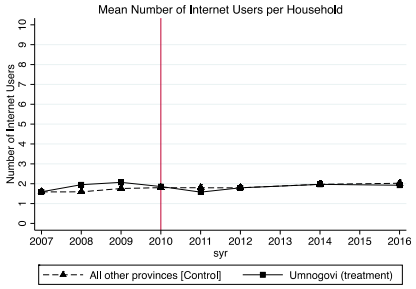


Graph 1

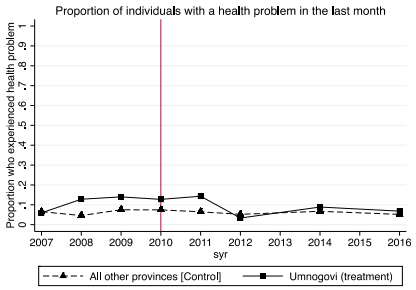


Graph 2

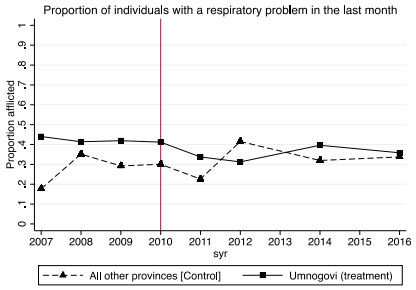
[2] While the actual signing date of the IA was in October of 2009, it is reasonable to assume that any activity at the mine site would be subject to executive lag. As such, I perform my analysis using 2010, 2011, 2012, 2014, and 2016 as post-mine years.



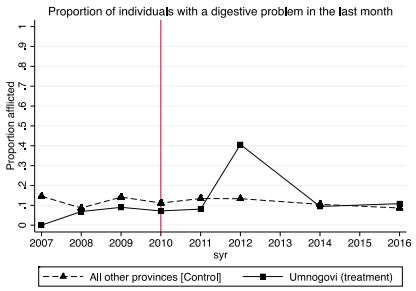
Graph 3



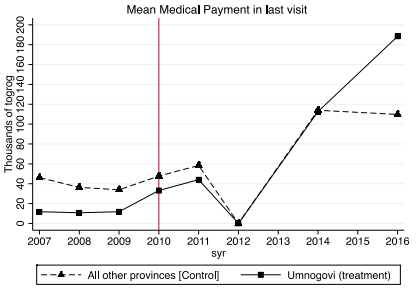
Graph 4



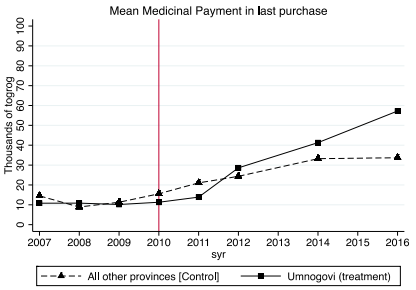
Graph 5



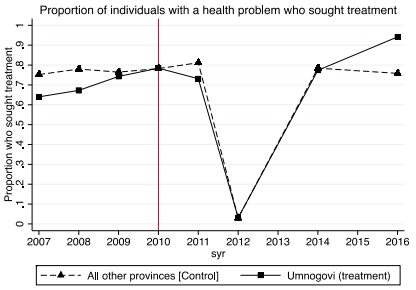
Graph 6



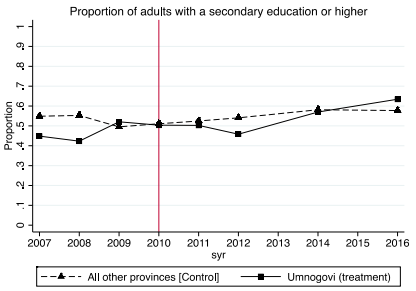
Graph 7



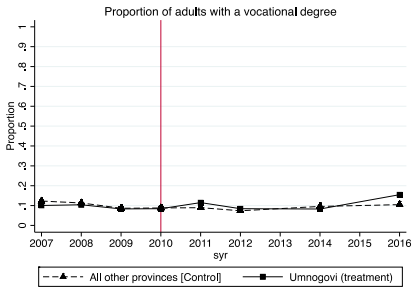
Graph 8



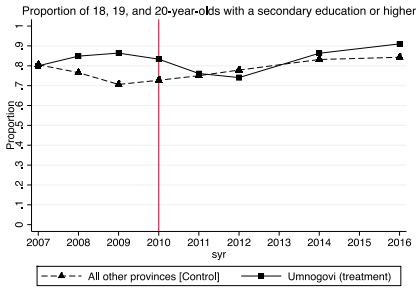
Graph 9



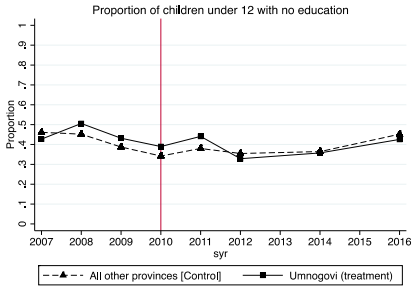
Graph 10



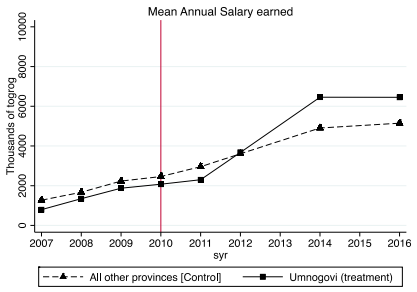
Graph 11



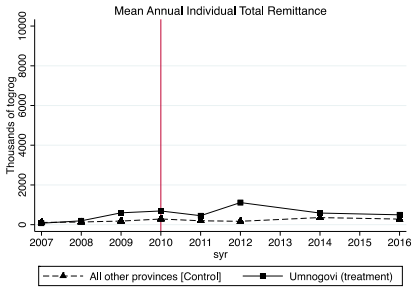
Graph 12



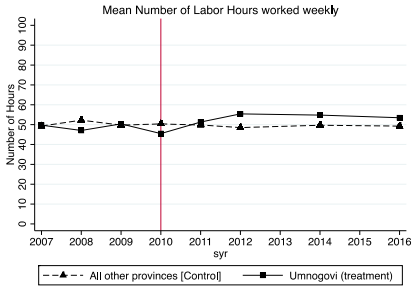
Graph 13



Graph 14



Graph 15



Graph 16

Equation 1 outlines the model: a country-wide regression with province and year fixed effects included. Using data from all provinces improves clarity by virtue of large sample size and also gives insight into how other provinces fare along different outcome variables in comparison to the treatment province. I weigh the data for each analysis using the dataset's survey weights, rendering each sample representative of the population. I cluster standard errors at the province level.

$$Y_{ihpt} = ß_0 + ß_1(Umnogovi_{ihp}) + ß_2(Post_t) + ß_3(Umnogovi_{ihp}\ x\ Post_t) + \pi_{iht} + \rho_{pt} + \tau_p + \tau_t + \mu_{ihpt} \quad (1)$$

This equation describes the treatment effect for an individual *i* in household *h* in province *p* during year *t*, where Post is an indicator equal to 1 if the year is after 2009 (the commencement of mine production) and Umnogovi is an indicator equal to 1 if household *h* in year *t* is within this treatment province. In this model, the DID is represented by the coefficient on the interaction variable. The variable π_{iht} represents a vector of individual and household controls such as sex, age, education, and household size; ρ_{pt} represents population control for each province in each year; τ_p represents province fixed effects and τ_t represents year fixed effects.

To verify the results obtained from the DID, I utilize the synthetic control method (SCM) as a robustness check. The SCM weighs the effect of the intervention by comparing the Umnogovi to an artificial counterfactual province. This method generates a hypothetical counterfactual province by selecting other provinces and taking a weighted average of these donors' outcomes. This process artificially creates a counterfactual for how Umnogovi would have performed in each outcome if the mine had never been established. Existing literature has demonstrated this method to be appropriate for comparative studies such as this one (Abadie, Diamond, and Hainmueller 2010; Olper, Curzi, and Swinnen 2018) The SCM is also useful because time trends in differing provinces vary continuously before and after the treatment event and may still remain after using DID analysis, making interpretation difficult. By creating the synthetic control province and comparing its projected trend against Umnogovi's actual trend we can

observe the timing of changes, enabling more interpretive power than just viewing the DID coefficients.

7. Results

This section discusses results obtained from the datasets. For each outcome I present the results from the primary method in which I utilize the DID analysis. I then supplement the analysis using the secondary SCM. Figure 8 is a summary of the direction of change in the treatment province for each outcome variable given by the DID coefficients.

	Significant Increase	Significant Decrease	Insignificant
Infrastructure			
Ger	✓		
Centralized Water	✓		
Internet		✓	
Health			
Health Problem		✓	
Respiratory		✓	
Digestive	✓		
Amount Paid for Treatment	✓		
Amount Paid for Medicine			✓
Share of Treatment Sought	✓		
Education			
Secondary Education			✓
Vocational Education	✓		
Youth Secondary Education		✓	
No Education	✓		
Income			
Annual Salary	✓		
Remittance Received	✓		
Labor Hours	✓		

Figure 8: Umnogovi's directional change relative to all-province directional change. Note that these directions do not indicate actual level change, but rather the directional sign of DID coefficients. Insignificant coefficients are located in the right-hand column.

7a) Infrastructure

Table 4 presents the effects of the mine establishment on a group of selected infrastructure variables. Compared to all other provinces, I find an increase in the proportion of Umnogovi residents who resided in gers, an increase in the prevalence of centralized water, and a relatively slower growth rate in the number of internet users per household. It is worth mentioning that a decrease in internet users would be logical in the context of an increase in rates of ger residence since most gers do not possess internet capabilities.

Ger

While the entire country appears to have experienced an increase in the proportion of ger residence during the post-mine years, this increase is even more pronounced in Umnogovi. As shown in Column 1 of Table 4, the primary method yields a DID coefficient indicating a three-percentage point higher proportion of ger residence in Umnogovi than the national baseline and also point towards a much higher pre-treatment proportion of ger residence in Umnogovi than elsewhere (twelve percentage points). These coefficients imply a fifteen-percentage point higher fraction of ger residence in post-mine Umnogovi than the post-mine countrywide average.

Centralized Water

Results are consistent with an increase in the proportion of centralized water in Umnogovi during the post-mine years. As presented in Column 2 of Table 4, regressions show a DID coefficient of 0.04, indicating a relative increase in the incidence of water

infrastructure in Umnogovi after the mine relative to the control group. I find no significant change in the control group's incidence of centralized water after the IA.

Internet Users

I find evidence that despite pre-mine Umnogovi's greater number of internet users per household, the national average increased at a much faster rate post-mine than Umnogovi did during the same time period. Even after the mine and these fluctuations, Umnogovi still exhibits 0.50 more users per household than the national average, but this gap appears to be narrowing.

7b) Health

Table 5 displays results obtained from the analysis of selected health outcomes. I find a marginal decrease in the prevalence of health problems throughout Umnogovi, accompanied by a relatively smaller increase in the proportion of respiratory problems compared to that of the national average. While Umnogovi exhibited no change in its proportion of digestive problems, nationwide the incidence of digestive issues decreased. The DID also suggests that post-mine years are associated with comparatively larger growth in the average amount paid for medical treatment in Umnogovi than the national average. I find no statistically significant deviation in the amount paid for medicine in Umnogovi relative to the national average. Finally, I observe no significant change in the proportion of people who sought medical treatment in other provinces but do find a significant growth in proportion of treatment seekers in Umnogovi.

Health Problems

According to this analysis, Umnogovi's reported rate of health problems decreased even more than that of the national average's in the years after the mine. Column 1 of Table 5 shows that the magnitude of the DID coefficient to be a drop of one percentage point. Pre-mine, Umnogovi reported a seven-percentage point higher incidence of health problems than the national average. After the Oyu Tolgoi IA, the proportion of health problems reported in Umnogovi decreased six percentage points; nationwide the average decreased five percentage points.

Respiratory Problems

Umnogovi residents experienced an increase of one percentage point in the proportion of individuals with respiratory problems, while the countrywide average observed an increase of eight percentage points in the incidence of respiratory problems, indicating an overall worsening of respiratory health that was weaker in Umnogovi. Pre-Oyu Tolgoi, Umnogovi reported an eight-percentage point higher proportion of respiratory problems than the national average. In the context of a rapid nationwide increase in respiratory problems, residents of Umnogovi appear to have only marginally experienced this increase.

Digestive Problems

The analysis indicates that Umnogovi experienced no significant change in the proportion of digestive problems reported – but the nationwide average exhibited a decrease of four percentage points in the incidence of digestive problems. While pre-

mine Umnogovi exhibited a three-percentage point lower proportion of digestive problems than the countrywide average, post-mine Umnogovi observed no change in the incidence of digestive problems while digestive health appears to have improved elsewhere.

Payments for Medical Treatment

In the years following the IA, the whole country exhibited an increase in the average sum paid for medical treatment, but the effect was especially pronounced in Umnogovi. Prior to the mine, Umnogovi residents paid approximately 15 thousand fewer togrog for their medical treatment than the national average; in the years following the IA, residents elsewhere were paying more for their medical treatment but residents in Umnogovi paid significantly more (increase of approximately 114 thousand togrog in post-mine Umnogovi compared to pre-mine).[3]

Payments for Medicine

I find no statistically significant DID coefficient for the average amount spent on medicine in Umnogovi. The data indicate that prior to the mine, individuals paid approximately eight thousand more togrog for medicine, and that after the IA citizens elsewhere in Mongolia paid approximately 20 thousand more togrog in medicinal

[3] Health insurance is not widespread in Mongolia. Officially, the health care system compels individuals to cover the costs of their own health care procedures, after which the government reimburses a portion of treatment costs incurred to each individual at the end of each fiscal year. Costs range from purchasing medicine to receiving life-saving surgery. Anecdotally, however, these reimbursements are often too insufficient to make treatment inexpensive for the vast majority of Mongolians.

purchases. According to the DID Umnogovi did not deviate significantly from this pattern.

Share of Ill Individuals who Sought Medical Treatment

The DID suggests that the mine's presence in Umnogovi is associated with a trend of higher incidence of treatment sought. I find no significant change in the rate of treatment sought elsewhere in Mongolia after the mine, implying that while no change occurred in the control group, proportion of ill individuals who sought medical treatment in Umnogovi increased.

7c) Education

Table 6 presents the results of the primary method of analysis on differences in educational outcomes.[4] For the analysis of the proportion of individuals with a secondary education and the proportion of vocational education, I limit the sample to only respondents 18 years or older. I limit the sample to only 18, 19, and 20-year-olds when analyzing the completion rates of youth secondary education (high school). I limit the sample to children under 12 years of age when analyzing the share of individuals with no formal education.

During post-mine years, I find that the proportion of vocationally-educated adults increased above that of the national baseline. The proportion of young adults between 18

[4] Education in Mongolia is based on a promotional system, where exams validate students to advance to the next stage of schooling. Students are required to take exams at the end of primary, lower secondary, and upper secondary education. Historically, more than 20% of primary school children drop out of school due to travel or meal costs, lack of commitment to study, poor living standards at home or health problems that preclude them from attending school ("WENR, July/August 2003: Education in Mongolia" 2003). Despite this history, recent trends point towards a more positive future. Mongolia's Human Development Index (HDI), a summary measure for assessing long-term progress in the development of a country, has increased its "access to knowledge" metric sixteen percentage points from 1990 – 2017 (United Nations Development Program 2018). My findings in Umnogovi contradict this literature.

and 20 years of age with high school diplomas decreased dramatically in Umnogovi, even when compared to the decrease exhibited nationwide. The analysis points towards an increase in the proportion of children under 12 years of age with no formal education in Umnogovi relative to all other provinces. I find no statistically significant change in Umnogovi for the proportion of adults with at least a secondary education.

Proportion of Adults with at least a Secondary Education

Since the DID coefficient lacks statistical significance, I am unable to conclusively determine any change for this outcome. Noting that prior to the mine Umnogovi exhibited a seven-percentage point higher proportion of individuals with at least a secondary education, these coefficients would suggest that Umnogovi and the national average proportion of educated individuals grew at approximately the same rate.

Adult Vocational Education

The DID points towards a significant increase in the proportion of vocationally-educated adults in Umnogovi relative to the nationwide average during the post-mine years. I find no statistically significant difference in the incidence of vocational education between Umnogovi and all other provinces prior to the mine. Additionally, the data suggest that no significant change occurred in this proportion in the other provinces after the IA. Umnogovi, however, exhibited an increase of four percentage points in the proportion of vocationally-educated adults relative to the control group.

Proportion of 18, 19, and 20-year-olds with a Secondary Education

I find that while the entire country experienced a decrease in the proportion of high school graduates during the post-mine years, this effect was even more severe in Umnogovi. This change is in stark contrast to the rate of graduation in Umnogovi prior to the mine, which was 17 percentage points higher than the national average. During post-mine years, all other provinces' rate of diplomas amongst this age group fell eight percentage points. In Umnogovi, however, the Oyu Tolgoi IA is associated with a 15-percentage point fall in the proportion of young adults with a high school diploma.

Proportion of children under 12 with No Education

The DID coefficient points towards a large increase in the proportion of young children without any formal education in Umnogovi compared to the national average. I find no statistically significant difference between Umnogovi and the control group pre-mine. Additionally, I find no significant difference in the rate of children with no formal education in the control group after the IA.

7d) Income

Table 7 presents the results obtained for the selected income-related outcomes. Annual salary serves as a baseline measure for the economic prosperity of survey respondents. By implementing fixed effects across years, salary is measured in real terms relative to the base year of 2007. I find that annual salary earned in Umnogovi grew at a faster rate in Umnogovi than it did in the rest of the country during the post-mine years. Furthermore, I find that remittance levels in Umnogovi have increased more rapidly than

the comparative increase in the rest of the country.[5] I also observe a significant increase in the number of job hours worked per week in Umnogovi after the mine's establishment relative to the national baseline.

Annual Salary

I find that in the years following the IA, annual wages increased throughout Mongolia – but this effect was exhibited even more keenly in Umnogovi. After the IA, wages rose over three million togrog in Umnogovi while the comparative increase in the national average wage was about 2.3 million.

Annual Remittance Received

The data indicate that while Mongolia as a whole experienced an increase in annual remittance received, Umnogovi residents received even more remittance than citizens elsewhere during post-mine years. Pre-mine, Umnogovi residents received nearly 370 thousand togrog more in annual remittances on average than the national baseline. I find evidence of an increase of approximately 190 thousand togrog in post-mine Umnogovi, while the national average increased approximately 122 thousand togrog.

[5] Remittance, or inflows of migrants' income transfers, is a significant contributor to living standards in Mongolia – especially for rural families who fully or partially depend on the income of friends and relatives living abroad for their livelihoods. During the survey years included in my analysis, remittance in Mongolia fluctuated wildly, reaching an all-time high of 18.6 million U.S. dollars in August of 2010 and a record low of nine million U.S. dollars in September of 2012. Remittance fluctuated between 4.35% and 2.32% of total GDP during these survey years (Trading Economics 2019).

Weekly Labor Hours

The analysis presents evidence for a marked increase in job hours worked in Umnogovi after the mine's establishment relative to the national average. Prior to the mine, Umnogovi residents already worked almost six hours per week more than their average countrymen. I find no statistical evidence indicating any change in weekly work hours in other provinces but do find an increase of approximately three weekly labor hours worked between pre and post-mine Umnogovi.

7e) Synthetic Control Observations

Utilizing the SCM adds value to my analysis as both a robustness check and a method of visualizing outcome progression over time. In this analysis, I interpret Oyu Tolgoi's impact as the difference between the projected synthetic Umnogovi curve and the actual Umnogovi curve.

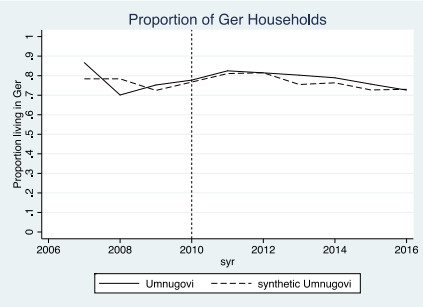
Table 8 in the appendix includes the weights utilized for each outcome and their corresponding donor provinces. It is worth noting that all of these graphs are consistent with the comparisons of Umnogovi and the national average (Graphs 1-16) and support the results obtained using the primary DID analysis, further strengthening the validity of these trends. Whereas viewing just the DID coefficient is a static snapshot of an overall effect, using the synthetic control figures allows us to capture a sense of "momentum." Graphs 17-32 depict the SCM-produced figures and corroborate the parallel trends shown earlier in the Section 6.

Where the DID analysis renders insignificant results, the SCM graphs give us more insight. Certain elements of my DID analysis for the following outcomes lacked statistical significance: amount spent on medicine, proportion of adults with at least a

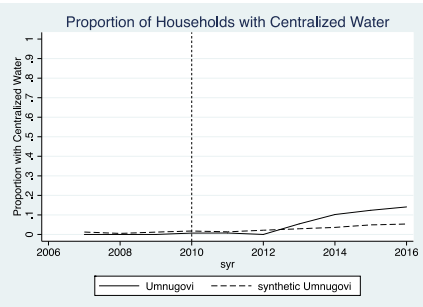
secondary education, proportion of vocationally-educated adults, and proportion of children under 12 with no formal education.

Graph 24 depicts rising levels of payments on medicine significantly above the control curve, despite no significant trend in the control group being shown in DID analysis. This is also consistent with anecdotal evidence gained from my field research. Additionally, despite insignificant DID results, Graph 26 suggests that the share of adults with at least a secondary education in Umnogovi has fluctuated compared to the control but has largely remained equivalent. As such, I argue that the proportion of adults with at least a secondary education in Umnogovi's population has not changed significantly relative to the national average in post-mine years. Graph 27 corroborates the direction of the DID coefficient for vocational education, depicting a higher proportion of vocationally-educated adults in Umnogovi after the mine than in the synthetic control, which remains relatively stable – confirming the DID's insignificant finding for any change in the other provinces. Furthermore, Graph 29 indicates that the proportion of children without any formal education experienced a comparative increase relative to the national average but in later years matches the pattern exhibited by the national average very closely. This implies that the initial spike in the incidence of this outcome after the IA may be driving the DID result, and that in later years Umnogovi exhibited no notable difference from the control group.

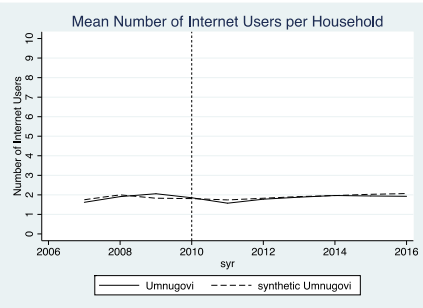
Graphs 17-32: SCM-produced figures of each outcome variable. The difference between the synthetic counterfactual curve (dashed line) and the actual curve (solid line) is interpreted to be the causal impact of the mine.



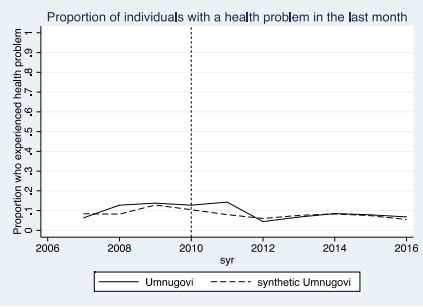
Graph 17



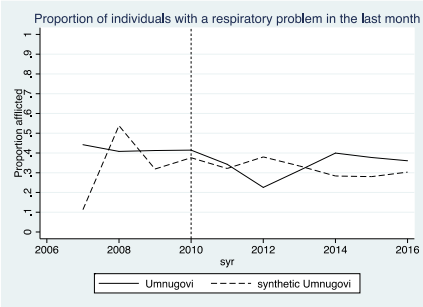
Graph 18



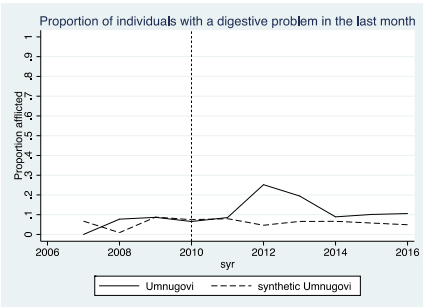
Graph 19



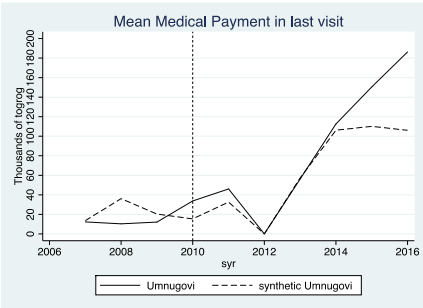
Graph 20



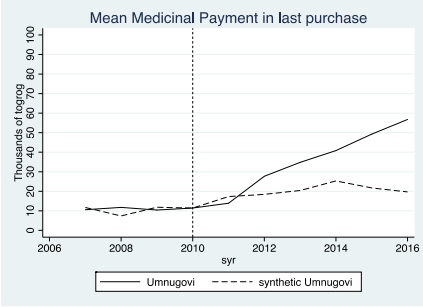
Graph 21



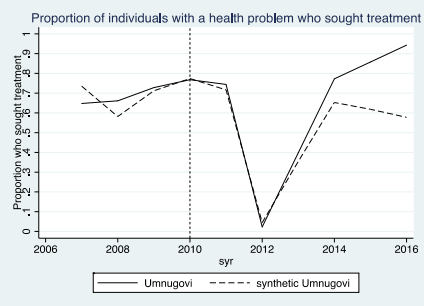
Graph 22



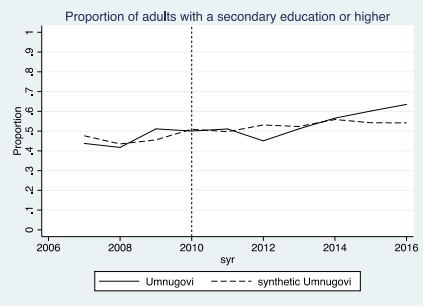
Graph 23



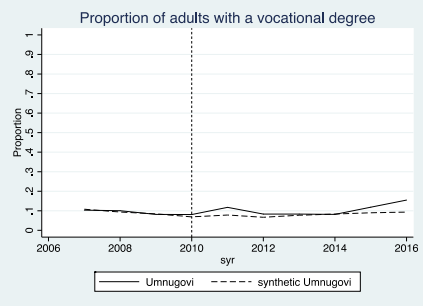
Graph 24



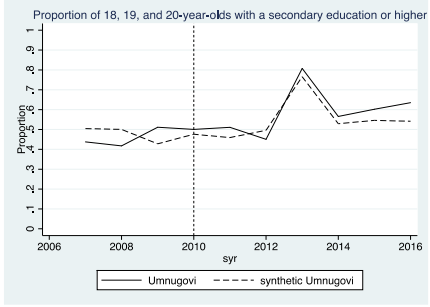
Graph 25



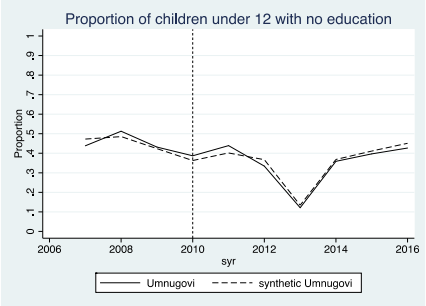
Graph 26



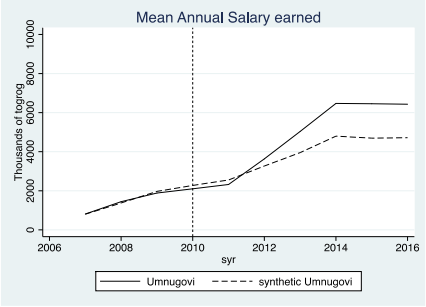
Graph 27



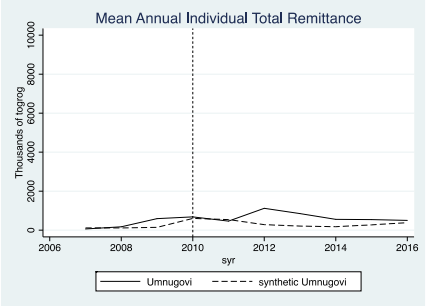
Graph 28



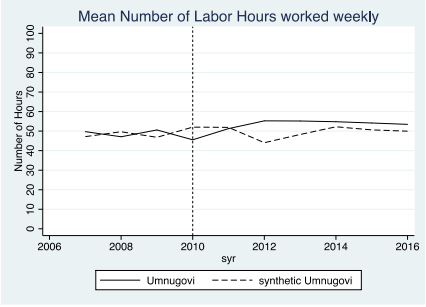
Graph 29



Graph 30



Graph 31



Graph 32

7f) Regression Tables

Table 4: All-province regressions of selected infrastructure variables. Population includes all sexes and ages.

VARIABLES	(1) Ger	(2) Water	(3) InternetUsers
Umnogovi	0.12***	-0.03***	0.63***
	(0.01)	(0.01)	(0.02)
PostMine	0.05	-0.01	0.57***
	(0.04)	(0.02)	(0.06)
UmnogoviPostMine	0.03**	0.04***	-0.13***
	(0.01)	(0.01)	(0.03)
Household Size	0.00	-0.02***	0.26***
	(0.00)	(0.01)	(0.02)
Female	0.02***	-0.01***	-0.03***
	(0.00)	(0.00)	(0.00)
Age	0.01***	-0.00*	-0.01***
	(0.00)	(0.00)	(0.00)
AgeSquared	-0.00***	0.00*	0.00***
	(0.00)	(0.00)	(0.00)
Urban	-0.20***	0.07***	0.27***
	(0.03)	(0.02)	(0.03)
Employed	0.04**	0.00	0.06***
	(0.02)	(0.00)	(0.01)
Observations	217,770	217,770	55,868
Province FE	YES	YES	YES
Year FE	YES	YES	YES
Clustered SE	YES	YES	YES
Education Controls	YES	YES	YES
Population Controls	YES	YES	YES

NOTE: Table reports regression coefficients using standard errors clustered by province. Ger and Water are binary dependent variables equal to one when an individual's main residence is a ger or when an individual's main residence has access to centralized water. InternetUsers refers to the number of internet users within an individual's household. Urban and Employed are binary variables equal to one when an individual lives in an urban environment or has been employed within the last six months of survey response, respectively. *** p<0.01, ** p<0.05, * p<0.1

Table 5: All-province regressions of selected health variables. Population includes all sexes and ages.

VARIABLES	(1) HealthProblem	(2) RespiratoryProblem	(3) DigestiveProblem	(4) TreatmentPay	(5) MedicinePay	(6) ShareTreated
Umnogovi	0.07***	0.08***	-0.03***	-14.80*	8.20***	0.03**
	(0.00)	(0.01)	(0.00)	(7.26)	(1.81)	(0.01)
PostMine	-0.05***	0.08**	-0.04*	71.53***	21.21***	0.05
	(0.01)	(0.04)	(0.02)	(21.25)	(4.13)	(0.06)
UmnogoviPostMine	-0.01*	-0.07***	0.04***	42.85***	2.74	0.06***
	(0.01)	(0.02)	(0.01)	(10.08)	(2.12)	(0.02)
Household Size	-0.00***	0.00*	0.00	-2.31	-0.09	0.00
	(0.00)	(0.00)	(0.00)	(2.28)	(0.48)	(0.00)
Female	0.02***	0.01	-0.01	-1.05	-2.14**	0.00
	(0.00)	(0.01)	(0.00)	(3.95)	(0.95)	(0.01)
Age	0.00***	-0.02***	0.00***	0.88	0.50***	0.00***
	(0.00)	(0.00)	(0.00)	(0.87)	(0.09)	(0.00)
AgeSquared	0.00***	0.00***	-0.00*	-0.01	-0.00**	-0.00***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Urban	0.01**	0.01	-0.00	-7.17	0.58	0.01
	(0.01)	(0.01)	(0.01)	(6.94)	(2.67)	(0.02)
Employed	-0.03***	0.04***	0.01*	-12.49**	-3.65***	-0.05***
	(0.00)	(0.01)	(0.01)	(4.61)	(0.61)	(0.01)
Observations	217,768	14,752	14,752	11,401	20,533	14,746
Province FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES	YES	YES
Education Controls	YES	YES	YES	YES	YES	YES
Population Controls	YES	YES	YES	YES	YES	YES

NOTE: Table reports regression coefficients using standard errors clustered by province. HealthProblem, RespiratoryProblem, and DigestiveProblem are binary dependent variables equal to one when an individual reports a general health problem, a respiratory problem, or a digestive problem within the last month. TreatmentPay and MedicinePay are numerical variables that refer to the amount of cost incurred for medical treatment measured in thousands of Mongolian togrog. ShareTreated refers to the proportion of individuals who had a health problem and sought treatment. Urban and Employed are binary variables equal to one when an individual lives in an urban environment or has been employed within the last six months of survey response, respectively. *** p<0.01, ** p<0.05, * p<0.1

Table 6: All-province regressions of selected education variables. For Columns 1 and 2, population includes all 18-year-olds and older. Column 3 reports analysis for 18, 19, and 20-year-olds only, and Column 4 restricts the sample to those younger than 12.

VARIABLES	(1) SecondaryEducation	(2) VocationalEducation	(3) YouthSecondaryEducation	(4) NoEducation
Umnogovi	0.07***	0.00	0.17***	0.01
	(0.01)	(0.00)	(0.02)	(0.02)
PostMine	0.06*	-0.00	-0.08**	-0.08
	(0.03)	(0.02)	(0.04)	(0.04)
UmnogoviPostMine	0.01	0.04***	-0.07***	0.18***
	(0.01)	(0.01)	(0.02)	(0.03)
Household size	-0.01***	-0.00***	-0.01***	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Female	0.05***	0.00	0.05***	-0.00
	(0.01)	(0.00)	(0.01)	(0.01)
Age	0.01***	0.02***	2.36***	0.33***
	(0.00)	(0.00)	(0.18)	(0.01)
AgeSquared	-0.00***	-0.00***	-0.06***	-0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
Urban	0.26***	0.06***	0.10***	-0.10***
	(0.01)	(0.01)	(0.02)	(0.02)
Employed	0.00	0.03***	-0.19***	-0.00
	(0.02)	(0.01)	(0.05)	(0.01)
Observations	177,083	177,083	15,929	12,480
Province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Clustered SE	YES	YES	YES	YES
Population Controls	YES	YES	YES	YES

NOTE: Table reports regression coefficients using standard errors clustered by province. SecondaryEducation and VocationalEducation are binary dependent variables equal to one when an individual has attained a secondary education degree or higher, or when an individual has attained a vocational degree. Urban and Employed are binary variables equal to one when an individual lives in an urban environment or has been employed within the last six months of survey response, respectively. *** p<0.01, ** p<0.05, * p<0.1

Table 7: All-province regressions of selected income variables. Population includes all sexes and ages.

VARIABLES	(1) AnnualSalary	(2) RemittanceReceived	(3) WeeklyJobHours
Umnogovi	219.94**	368.90***	5.63***
	(84.86)	(20.10)	(0.60)
PostMine	2,352.33***	121.97*	0.92
	(201.55)	(67.14)	(1.92)
UmnogoviPostMine	708.50***	68.14*	2.38**
	(120.85)	(35.64)	(1.01)
Household size	-59.81***	-19.76**	-0.14
	(7.91)	(7.82)	(0.16)
Female	-896.08***	25.88**	-3.89***
	(126.25)	(10.68)	(0.87)
Age	110.47***	-2.63	0.38***
	(27.37)	(2.33)	(0.09)
AgeSquared	-1.12***	0.02	-0.01***
	(0.36)	(0.02)	(0.00)
Urban	140.45**	71.77***	1.16
	(51.47)	(24.19)	(1.08)
Employed	1,190.72***	-166.18***	-0.34
	(106.60)	(39.92)	(0.29)
Observations	65,354	217,770	116,392
Province FE	YES	YES	YES
Year FE	YES	YES	YES
Clustered SE	YES	YES	YES
Education Controls	YES	YES	YES
Population Controls	YES	YES	YES

NOTE: Table reports regression coefficients using standard errors clustered by province. AnnualSalary and RemittanceReceived are numerical variables represented in thousands of togrog. Urban and Employed are binary variables equal to one when an individual lives in an urban environment or has been employed within the last six months of survey response, respectively. *** p<0.01, ** p<0.05, * p<0.1

8. Discussion

In the following section I discuss and interpret the findings presented in Section 7. For each category of outcomes, I utilize anecdotal evidence, field research, and other evidence to support my explanations of how Oyu Tolgoi has affected living conditions in Umnogovi. I find that a combination of mine policies, allocation of funds, and economic effects has contributed to these findings (Figure 9).

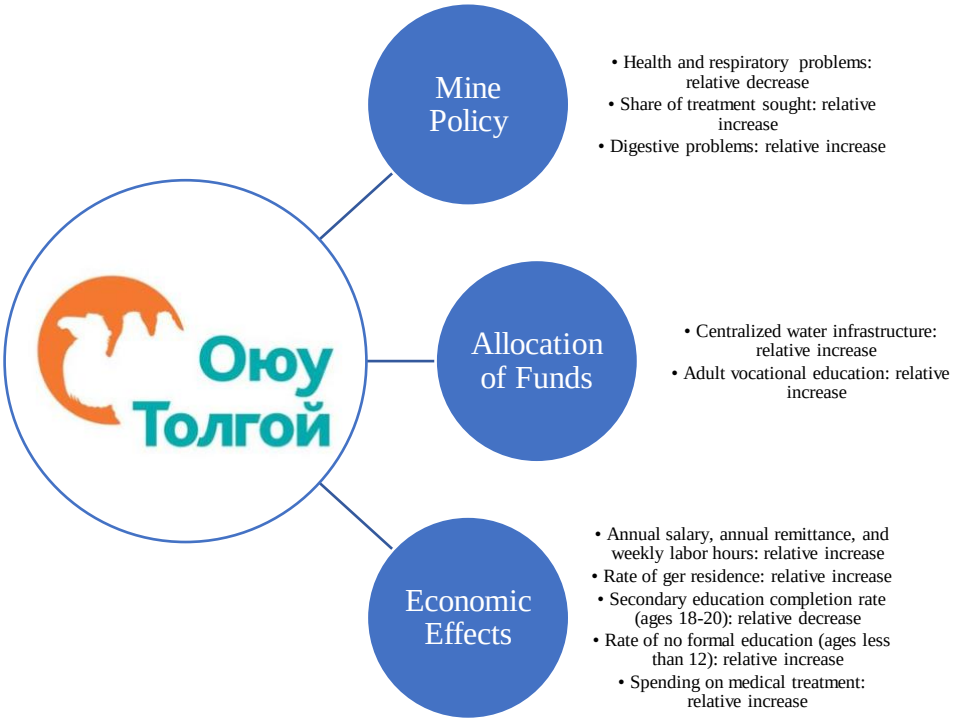


Figure 9: Summary of main causes contributing to major findings from the analysis.

Infrastructure

To capture a sense of the infrastructural changes in Umnogovi province by the Oyu Tolgoi mine, I analyze the proportion of residents living in gers, the proportion of residents with access to centralized water, and the average number of internet users in residents' households. I find that relative to controls, in Umnogovi ger residence

increased, centralized water prevalence increased, and internet usage grew but at a slower rate than in other provinces.

The change in ger residence rates is unusual for Mongolia's rapidly urbanizing population. Referencing Graphs 1 and 17 I observe that the average proportion of ger residence is higher in Umnogovi than the national baseline but both groups' ger residence rates are declining over time. Just after the IA, however, there is an initial increase in ger residence in Umnogovi in 2011. I hypothesize that this spike in ger residence is due to migration into Umnogovi immediately following the beginning of mine operations and the microeconomy opportunities generated by the project. The rural population in Umnogovi increased in the time period between 2009 and 2013 (Figure 10), consistent with the spike in ger residence shown in Graphs 1 and 17 (National Statistics Office of Mongolia 2019). As migrants are typically of lower economic class and would be unlikely to move into urban housing, gers represent the most economical choice.

It is also important to note that ger residence may be correlated with higher rates of respiratory and digestive problems. Causally, gers lack air filters and are typically heated from within the dwelling using a traditional stove – exposing inhabitants to a constant level of pollution. Furthermore, inhabitants of gers lack access to centralized water systems and the filtering and purification advantages these systems possess. Instead, ger residents boil and purify their water themselves, which is less effective and less safe. I postulate that the lack of "proper" housing could be causing rates of respiratory and digestive issues to be higher than they would be otherwise.

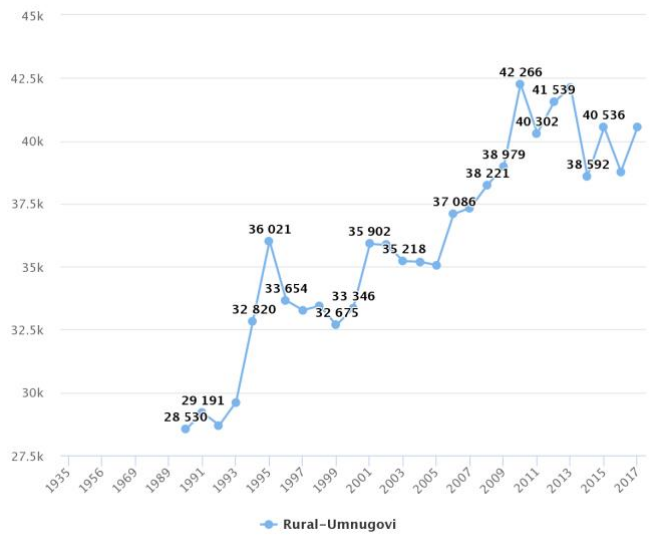


Figure 10: Rural population of Umnogovi aimag. Source: National Statistics Office of Mongolia, 2018.

The data point towards an increase in the proportion of households in Umnogovi with access to centralized water systems. The establishment of the mine in the vicinity of Khanbogd has resulted in large infrastructure creation efforts in the community's vicinity and beyond, including the paving of a new road, construction of a large veterinary clinic, and development of waste management systems. The Fund, an entity created by the IA and jointly managed by Oyu Tolgoi personnel and Mongolian representatives, has spearheaded many of the development efforts not immediately critical to mining operations. My field research in Khanbogd involved interviews with local inhabitants, who confirmed that many rural communities historically have had very little existing water purification or distribution systems. The presence of the Oyu Tolgoi project has resulted in the construction of public goods (such as the veterinary clinic) that require centralized water systems, which are then utilized by individuals adjacent to the site.

Both my methods of analysis indicate that while internet access increased in post-mine Umnogovi, it did not increase as much as the increase experienced in other provinces. I hypothesize that the higher proportion of ger residence contributes to this

slower rate of growth, as living in a ger in Mongolia is typically associated with lack of access to internet infrastructure. I argue that without the presence of the mine, internet infrastructure would actually be even more scarce in Umnogovi: the presence of the mine has brought a demand for telecommunications networks to a region historically without much need for internet. Moreover, economic activity associated with the mine has brought about an increase in wages (discussed later in this section), giving people more purchasing power and leading to an increase in internet usage.

Health

I analyze a selection of health outcomes that form a picture of health standards in Umnogovi relative to other provinces. Data indicate a decrease in health problems during post-mine years in Umnogovi. In the context of a national increase in the incidence of respiratory problems, Umnogovi residents' incidence of respiratory problems magnitude of increase was much smaller. While digestive health improved in other provinces, it did not change in Umnogovi. Concurrently, I find a significant comparative increase in the amount Umnogovi residents paid for medical treatment and medicine relative to a national increase. Furthermore, evidence indicates a marked increase in the rate of medical treatment sought to address health issues.

To better understand these patterns, I visited the district-center hospital in Khanbogd, a small village of about two thousand inhabitants located approximately 40 kilometers away from the Oyu Tolgoi site (Figure 11).

Figure 11: District-center hospital in Khanbogd, Umnogovi province. © Andy Zhou.

I discussed the channels through which the Oyu Tolgoi project may be mitigating the prevalence of health problems with various hospital personnel, including the hospital's director. Firstly, Oyu Tolgoi has provided financial and technological support to local health operations by not only contributing to this hospital, but also installing state-of-the-art equipment never before seen in Umnogovi in the mine's own on-site clinic. Thanks to this aid, Khanbogd's hospital has facilities that other hospitals in the Gobi-desert provinces do not, such as a donor's room, maternity bathroom, scanning equipment, etc. Additionally, Oyu Tolgoi's company policy has been to mandate routine health checkups for its 16 thousand employees. Due to this policy, employees and family members of employees have routine access to preventative visits instead of going to see health specialists when a serious health issue compels them to do so. This is especially relevant given the historically poor background of most Umnogovi families, who would avoid visiting a health specialist to avoid financial burden. This pattern is consistent with the

information provided by hospital personnel, who stated that frequency of visits has gone up and the proportion of preventative care visits versus reactive care visits has increased.

The analysis indicates a countrywide increase in the proportion of respiratory problems during post-mine years and a comparatively smaller increase (which may be correlated with the increase in ger residence discussed earlier) in this proportion in Umnogovi. So how is Oyu Tolgoi mitigating against the pattern of more frequent respiratory problems in other parts of Mongolia? I propose that much of the credit is due to the health policies put forth by the Oyu Tolgoi corporation. Besides instituting a platform through which employees and families of employees can receive more frequent medical attention, the company has sought to avoid practices specific to mining that tend to generate respiratory issues.

According to my interviews with residents of Umnogovi, other mining corporations in Umnogovi caused havoc for the air quality of citizens because of the large amounts of loose dust released into the air by excavation and transportation processes. The lack of paved roads has been central to this problem, cited as the source of airborne dust and dust-born disease vectors that are affecting humans and responsible for declining livestock populations that many of the nomadic herders in the region (still a significant portion of the population) depend upon for their livelihood (Jackson 2015). Oyu Tolgoi has been quite forward with its infrastructure developments, including the paving of a new concrete road between the mine and Khanbogd. During my visit, I also observed the strict vehicle speed limit enforced by company regulations and monitored by tracking devices in every company vehicle – both for safety purposes and also to limit the amount of airborne dust raised by transportation activities. Furthermore, a 2017 study suggests

that mining at Oyu Tolgoi is not significantly affecting the rates of human exposure to dust (Sternberg and Edwards 2017). Rather, dust concentration is dispersed throughout the community rather than being more intense at the mine site and declining in concentration as one moves away from the site, suggesting that natural factors are more responsible for dust patterns than mine site activity. This finding in part reflects the practice of high safety and regulatory standards at Oyu Tolgoi. These policies stand in sharp contrast to the regional mining executed elsewhere in Umnogovi, claimed by Sternberg and Edwards (2017) to be sub-standard and actually aggravate the process of dust degradation in the region. Data and previous studies indicate the possibility of Oyu Tolgoi's safety practices mitigating against the rise in respiratory problems seen elsewhere in the country; further research is necessary to understand the extent to which mining has affected dust patterns in this environment.

While digestive health appears to have improved in the rest of the country, Umnogovi exhibited no notable change. Umnogovi's failure to display the same fall in the proportion of digestive issues as the rest of the country may be due to many different factors. I propose that (in addition to the increase in ger residence discussed earlier) this pattern is due to changes in water quality and in diet driven by Oyu Tolgoi mining activity. Previous studies on mining in Mongolia point to mines' operational demand for water, indicating a pattern of enormous outtake of groundwater, depleting deep aquifers in the South Gobi (Nemer and Tuinhof 2010). Many locals fear for the supply of water, already scarce in the desert region without a major project consuming hundreds of kilotons of water per day. The practice of diverting shallow aquifers and surface water in order to meet project needs has greatly affected the resident population (McGrath et al.

2011). Not only has this reduced the consumption availability of well water, it has also drastically altered the quality of surface water and shallow aquifers through the drainage of silt and acid leachate from operationally-excavated waste rock. In the case of Oyu Tolgoi, these effects may be exacerbated even more by the underground development, which would affect deep-water aquifers.

Another channel through which mining may be affecting the digestive health of residents in Umnogovi is through the quality of consumption livestock and exposure to foods new to the region. Many locals complain of finding their livestock with entrails blackened from dust and air pollution, unfit to be consumed safely.[6] Until the recent establishment of an Oyu Tolgoi-funded veterinary clinic, the herders of the region had no place to care for their animals' health, meaning that the animals upon which residents depended for their food were likely to be affected by such pollution issues. In my interviews with doctors from Khanbogd's hospital, they largely attributed the high prevalence of digestive problems to unhealthy consumption habits and low quality of food. This is an area in which Oyu Tolgoi has made an effort to improve the living standards of employees, importing foods and fruits not traditionally consumed in the desert region. The presence of the company and its pledge to source locally has created a demand for local catering companies to supply the employees' consumption needs. Several Oyu Tolgoi employees commented on the novelty of the foods supplied by these local catering companies which are compelled to adhere to corporate (and Western)

[6] This seemingly conflicts the reduced prevalence of air pollution discussed earlier. To clarify: animals may be experiencing pollution humans are not because pollution-preventative policies have been focused on areas populated by humans. Mongolian animal shepherding practices do not utilize animal corrals. Livestock is allowed to roam freely, and anecdotal evidence suggests that these animals are ranging into areas that are in fact exposed to more dust and pollution.

nutrition guidelines, pointing towards the companies' ineptitude and unfamiliarity with foods such as baked goods and nonnative fruits or vegetables. It is possible that the introduction of and unfamiliarity with these new foods, while in the long run beneficial to the digestive health of Umnogovi residents, has contributed to the relatively higher rate of digestive issues in the region compared to other provinces as people (Figure 12) accustom themselves to new diets.

Figure 12: Oyu Tolgoi employees eat in the Oyut Camp mess hall. © Andy Zhou.

Umnogovi inhabitants reported a significant increase in spending on medical treatments. According to interviews with doctors in Khanbogd's hospital, this higher level of spending on health care is explained by higher income generating greater demand for treatment as well as more expensive supply options spurred by the movement of private health practices into the province. Oyu Tolgoi presents an economic opportunity attractive to many private practitioners, especially in the context of the Mongolian health system. State-sponsored hospitals charge the lowest fees for services rendered, but

frugality is counterbalanced by lower quality of treatment, administrative inefficiency, and extremely long queues for even simple operations.[7] Individuals with higher incomes thus tend to utilize private practitioners, who in exchange for higher fees deliver a wider variety of higher-quality services with much less wait time. Those employed by the mine have access to more comprehensive health care benefits and tend to choose these private practices over state hospitals.

Additionally, I propose that increases in income and a wider range of treatment options are responsible for higher spending on health care. Since individuals have experienced a rise in their disposable income, they have more capacity to spend on managing their health. This hypothesis is consistent with the evidence indicating more frequent rates of treatment sought, as more visits mean more incidences of spending. Concurrently, the introduction of Oyu Tolgoi-sponsored technologies and funds gives people a wider range of services to spend on, potentially leading to spending on more expensive treatments previously unavailable in the region.

I find no statistically significant increase in spending on medicine relative to other provinces during post-mine years. My rationale is that while spending on treatment may be increasing, the demand for and cost of medicine has remained uniform across the country. The country relies heavily on the importation of pharmaceutical drugs; these imports account for 80% of the domestic market.[8] I argue that since prices are set abroad, the price of medicine has not changed much within the country. Curiously, we observe no

[7] Khanbogd's state-sponsored hospital (albeit supported financially by Oyu Tolgoi as well) employs 42 personnel, 13 of which have medical practice licenses. These 13 doctors must oversee the care of not only Khanbogd (a village of over two thousand), but also the greater district area – which includes five other towns of a similar size.
[8] In 2016, the government imported nearly $106 million in drugs with more than half of these imports originating in Russia, Slovenia, Germany, Hungary, India, and China (Export.gov 2018)

increase in demand for medicine. It seems that the same effect I propose is causing spending on medical treatment to rise has not occurred for medicine. It is possible this is due to the monetary threshold between medicine and specialist-administered procedures (actual medical treatment). Citizens will forgo treatment in favor of buying medicine up until a certain "illness threshold", after which the gravity of their ailment compels them to seek treatment. I argue that, assuming that the proportion of sick individuals is constant for any given time period, the demand for and price of medicine below this illness threshold has remained constant in Umnogovi. Those who are sicker instead seek treatment – combined with the factors mentioned previously, this explains why spending on treatment has risen whereas spending on medicine has not changed.

The rise in the share of people with health problems who sought treatment is consistent with rising accessibility of health clinics in Umnogovi. I have already discussed how higher purchasing power due to Oyu Tolgoi and company policy may be increasing demand for treatment. I suggest that Oyu Tolgoi has also improved people's ability to access health care due to infrastructure and transportation improvements. While doing field research I observed several new concrete roads constructed by Oyu Tolgoi connecting different population centers. The mine's presence has also brought in a supply of shuttles and other vehicles that can be commissioned as ambulances. Additionally, I propose that a positive feedback loop is occurring in Umnogovi: the company-mandated increase in preventative cases may have led to a population more health-aware and more susceptible to seeking follow-up treatment or treatment for new ailments – as patients visit health specialists more often, they receive "education" about their own health status

and become aware of previously unknown or ignored health risks, prompting them to return.

Education

Relative to all other provinces, in Umnogovi I find no significant change in the proportion of adults with at least a secondary education, an increase in the proportion of vocationally-educated adults, a decrease in the proportion of completed secondary education amongst 18 to 20-year-olds, and an increase in the proportion of children under 12 with no formal education.

I postulate that no significant change in the composition of adult education in Umnogovi means that we can rule out any notable "brain draw" (migration of individuals with high human capital into the region) lured by the mine. This evidence suggests that no marked change occurred in the composition of Umnogovi's population due to migration.

Field research points towards the Oyu Tolgoi project as a major reason for the pattern of rising levels of vocational education amongst adults in Umnogovi. Oyu Tolgoi has established several funds, scholarships, and programs devoted to training technically-educated individuals in the province. Since the establishment of the mine, Oyu Tolgoi has sponsored many students to study for a variety of different degrees.[9] Moreover, Oyu Tolgoi has established a training school within the mine complex in order to educate engineers and workers. Students at the school have gone on to win international competitions in various technical fields; while some join other industries, most return to

[9] The largest proportion of sponsored students consists of those training to become mining engineers or machinists.

work at the mine. The resources for local students provided by the Fund have created an opportunity and demand for vocational education.

In the context of a nationwide decrease in secondary educational attainment amongst 18 to 20-year-olds, data indicate a significant relative decrease in Umnogovi. I attribute this decrease to the economic opportunity presented by the mine. While Oyu Tolgoi is unlikely to hire many of these youths, the microeconomies generated by the mine have provided employment for many local families and their children, raising the opportunity cost of schooling. For many of these rural families, livelihood is a job that employs all members of the household. To illustrate this point, interviews with mine employees revealed that many catering and dining service companies that supply the mine source their labor locally and in some cases were even created by local entrepreneurs. I posit that the opportunities for direct income present a more lucrative option for these young teenagers than the prospect of finishing high school and going on to obtain a higher degree, leading to a decrease in the proportion of young students obtaining their diplomas.

Analysis indicates no significant change in the proportion of children under 12 with no formal education in all other provinces, but a large increase in this proportion in Umnogovi during post-mine years. Previously Umnogovi children displayed no notable difference to the rest of the country in its share of children without education – so why has Oyu Tolgoi's appearance caused such change to occur? I propose that increased employment opportunities for adults have come at the cost of education for children. Field research indicates that in many rural areas of the country education has historically relied upon adult involvement: homeschooling, transportation, procuring educational

inputs, food services, etc. With the introduction of economic opportunities tied to the mine, adults who previously were engaged with supporting educational standards in this region now find it more attractive to spend their time elsewhere. This idea is consistent with the spike in rates of children without education in the first few years after the IA. Oyu Tolgoi, however, has contributed significantly to furthering formal education within the province, perhaps resulting in Umnogovi's rate of "non-education" amongst children matching that of the control's more closely in recent years (Graph 29).

It is worth mentioning that while some of these educational results appear bleak, the future is not without hope. During my field research, I attended the opening of a new primary and secondary school in Khanbogd funded almost entirely by the Fund (Figure 13). Secondary and tertiary educational enrollment in Mongolia have increased more than 10% in the last ten years, while gross enrollment ratios for primary education have remained near 100% since 2008 (UNESCO Institute of Statistics 2016). Along with the Fund's continued sponsorship of scholarships for Umnogovi students and technical training schools, the foundation for education in this isolated region appears to be growing steadily.

Figure 13: New K-12 school established by the Gobi Oyu Development Support Fund in Khanbogd, Umnogovi. © Andy Zhou.

Income

After the IA, Umnogovi residents reported a significant increase in annual wages, remittance received, and weekly job hours worked relative to the rest of the country.

I propose that the mine has contributed significantly to rising income within Umnogovi, giving local residents new employment status and generating microeconomies. The scale of the endeavor has brought a whirlwind of economic activity and demand for local employment. Whereas the vicinity of Khanbogd and other areas in Umnogovi were previously devoid of economic activity save for animal shepherding, there is now massive demand for construction, infrastructure, labor, power, and food to operate a multi-billion-dollar project.

The amount of remittance received by individuals in Umnogovi increased significantly relative to control entities during post-mine years. After speaking with Umnogovi residents, I conclude that this pattern is not directly caused by Oyu Tolgoi: a combination of rising wages and a buoyant global economy has contributed to increasing remittance across Mongolia. I argue that Umnogovi's relative greater increase is a function of income and spending opportunities new to the region. According to a 2009 paper, the most important determinant of higher remittance is income level in migrants' host countries, and that migrants remit back to their dependents even if their dependents' income increased in the home country because the quality of services these remittances can buy increases (Miotti, Mouhoud, and Oudinet 2009). This is consistent with evidence of rising wages and increased consumption of services such as medical treatment or internet usage. More spending outlets mean that more remittance can bring greater economic value.

Weekly job hours worked in Umnogovi display a significant comparative increase relative to other provinces. I posit that the establishment of the mine led to longer work weeks on average due to increased employment and altering the industry of the region. Previously industry in Umnogovi mainly consisted of rural shepherding, agriculture, or basic services; Oyu Tolgoi has introduced regulated operations with consistent timetables and demanding work schedules. Moreover, the mine is in operation constantly, creating a more strenuous work schedule for its employees and suppliers, raising labor hours worked.

9. Risks and Considerations

Hazards to this study's integrity include the possibility of competing effects in Umnogovi and the failure to satisfy the DID assumption that factors not controlled for are changing in the same way between the treatment and control groups.

Utilization of the HSES data means that my investigation includes individuals from all over the province. While this allows me to study the regional effect of the mine, it also exposes the data to dilutive forces – in particular, the Tavan Tolgoi operation. Tavan Tolgoi is one of the world's largest untapped coking and thermal coal deposits and is located approximately 150 kilometers northwest of Oyu Tolgoi. A Soviet exploration team discovered the deposit first in 1945, with feasibility studies and drilling continuing until 1985 ("Mongolia Energy Sector Review" 1995). The mine is currently largely state-owned with a small section called Ukhaa Khudag owned by a private company, the Mongolian Mining Corporation (MMC). I argue that because Tavan Tolgoi has been an operational presence in Umnogovi for so long, its effects on second-order outcomes are not changing over time. I find no evidence indicating major activity at Tavan Tolgoi post-2010 that would cause any of the changes discussed previously. Furthermore, production at Tavan Tolgoi is heavily dependent upon international coal prices. A slump in coal demand and the following commodities bust of 2012-2016, during which coal prices fell from $139 to $49 per metric ton, causing Tavan Tolgoi's production and exports to drop dramatically. This is relevant because it signifies a period during which Tavan Tolgoi's impact to the province would have been minimal. In the same time period, construction, production, and exports at Oyu Tolgoi were in full swing, meaning that the patterns indicated by the HSES data most likely reflect Oyu Tolgoi's impacts more heavily.

There is also the inherent risk assumed by my empirical approach. In utilizing a DID methodology, this study risks misinterpretation of results by exposure to differing trends between Umnogovi and other provinces. I mitigate this risk by using the SCM as a robustness check for my control group. An SCM figure that starkly contrasts with a DID coefficient could lend doubt to a particular finding. For these data, no SCM-produced figures clearly contradicted the change indicated by the DID. Additionally, my interviews with expert personnel and field research give me a base of anecdotal experience against which I verify my findings. Collectively, these factors lead me to conclude that these methods are optimized for this study.

10. Policy Recommendations

The data in this study have shown that while some elements of wellbeing have improved in the mine's presence, others have not. The recommendations outlined below are a product of this analysis, conversations with numerous Umnogovi locals, interviews with various experts on these issues, and my own experience in Umnogovi. I address the following issues: rates of respiratory and digestive problems, increasing levels of ger residence, and drops in educational attainment among youth demographics.

Respiratory and Digestive Issues

Rates of respiratory and digestive problems are still higher in Umnogovi than they are in other parts of Mongolia. Oyu Tolgoi can contribute to mitigating this trend by constructing more paved roads, distributing pollution-mitigating equipment, and instituting more rigorous regulation of food inputs at the mine. Developing more paved

roads will reduce the amount of airborne pollution generated by mining activities. Furthermore, distributing air filters, pollution masks, and water purification tablets amongst locals represents a relatively simple solution that would go a long way to reduce the number of health problems experienced. Additionally, another possible cause of the higher rate of digestive issues is diet change. More strenuous regulation of food standards may improve quality, particularly when considering the novelty of many of these foods to the local contractors who are now supplying them to Oyu Tolgoi.

Ger Residence

It is important for Oyu Tolgoi to address the high proportion of ger residence in Umnogovi because poor housing conditions are potentially related to higher rates of respiratory and digestive issues. I believe Oyu Tolgoi should actively encourage Umnogovi's urbanization by subsidizing housing projects in the neighboring townships around the mine. Anecdotally, many of the mine's current employees who currently live outside of Umnogovi are considering relocating permanently to local communities around the mine site in order to stop working on a FIFO basis and because local amenities are improving. To Oyu Tolgoi, constructing urban housing would reduce the massive costs associated with maintaining the FIFO system. A rise in the stock of housing would give many ger residents a chance to move into proper housing structures, which would vastly improve overall living conditions in Umnogovi and potentially reduce the prevalence of pollution-related health issues.

Youth Educational Attainment

Since the IA, Umnogovi has observed decreases in secondary education attainment amongst 18 to 20-year-olds and increases in the share of children under 12 who have had no formal education relative to other provinces. To address the lower rate of high school completion, Oyu Tolgoi should consider efforts to reduce the opportunity cost of education. Potential options include: offering internships to local students with the mine, increasing the number of potential scholarships, and creating employment channels that include educational prerequisites. By implementing these incentive programs, Oyu Tolgoi can combat the education-repelling effect that its own microeconomies have created.

In order to reduce the share of children under 12 who lack education, policymakers must reduce how much educational infrastructure relies on active adult participation. Oyu Tolgoi can contribute to young students' autonomy by funding school inputs (food, textbooks, learning materials) and improving physical infrastructure to make school more accessible: establishing more schools in different locations, funding school buses, and developing more roads. These actions would make attending school much easier and potentially more affordable. Additionally, the incentive programs discussed previously may also help to entice a higher educational capture rate amongst children.

11. Looking Further

Based on my experience in the field, there are more macro-level issues that are relevant to the development of Oyu Tolgoi, Umnogovi, and Mongolia that this study does

not address. In this section, I discuss more global policy options pertinent to the administration of the project: divestment, encouraging business, decentralization, and addressing public perceptions.

Divestment

Currently the Mongolian government owns 34% of the Oyu Tolgoi project. While this 34% entitles the state to an equivalent portion of the mine's riches, it also binds the state to investing its due portion into the project. This partnership made political sense in the early years of the project, but now its drain on state coffers, associated taxes, and the resulting institutional gridlock it has generated for the mine has become a thorn in the side of all parties involved. Numerous experts interviewed were of the opinion that the government should divest itself from the mine, solely reaping revenue from the land taxes and royalties it is already entitled to by the original IA and allow the private investors to operate the mine independently.

Encouraging Domestic Business

Government policy in the last few years has prioritized recouping the national deficit, resulting in universally-punishing tax rates. These taxes stifle many small enterprises and drive larger ones abroad, while regulatory incentives exist to encourage business development. By lowering tax rates or offering tax credits for small to mid-size enterprises, Mongolia would be able to grow its level of domestic investment, especially in rural areas like Umnogovi where few large corporations have a presence. Consider the thousands of contractors working for Oyu Tolgoi in Umnogovi. I argue that in a more

favorable regulatory environment, these individuals and their families would have more disposable income, more savings, and more willingness to invest in their local communities. I submit that offering government-sponsored long-term loans with minimal interest rates would be a suitable means of speeding up the growth of such small and mid-size enterprises and greatly benefit the development of Umnogovi.

Decentralization

Drawing upon my research in the field, I find that many of the more troublesome results discussed previously can be drawn to a lack of executive capacity at the local level. Almost every major decision concerning the development of the region must be channeled back to the parliament in Ulaanbaatar for approval. I argue that politicians and policymakers in Ulaanbaatar are removed from the situation on the ground and unable to perceive the situation in Umnogovi well. Lobbyists for Oyu Tolgoi and public officials in Ulaanbaatar discuss Umnogovi's fate in boardrooms while the local town hall in Khanbogd remains deserted. Lacking the capability to raise funds for itself or make final decisions on matters of local importance, local representation has no autonomy, something desperately needed by residents in order to raise money for schools, establish infrastructure, and bargain with the massive corporation that has taken up residence on their doorstep. Either Ulaanbaatar must put more weight on local representation's input, or hand negotiating power completely over to the government of Umnogovi. Meanwhile, Oyu Tolgoi can advance local autonomy by appropriating funds to local budgets rather than using them to directly commission products designed by negotiations with Ulaanbaatar. This would give residents more autonomy over their own livelihoods,

represent an improvement in the relationship between Umnogovi and the mine, and may even be a more effective use of funds.

Addressing Public Perception

Since the country's democratic revolution, the media system in Mongolia has undergone large reforms that have turned it into one of the freest systems in Asia. Under the 1998 Media Freedom Law, censorship of media outlets is forbidden. The issue with media in Mongolia is that there are too many outlets. Despite having a population of only three million people, there are 555 media outlets (Press Institute of Mongolia 2014). By contrast, Uruguay, a country with a population of about 3.4 million people to Mongolia's 3.1 million, has only 17 press outlets (BBC News 2016).

These outlets are controlled by a variety of different lobbyist groups and political factions. Without technically censoring, these outlets are able to manipulate the course of public opinion to great political effect. In recent years, public perception has largely been centered on the issue of mining. These outlets broadcast a panoply of different opinions driven by interest groups that create chaos in the public arena. Mongolia is especially vulnerable to this kind of media manipulation because the Oyu Tolgoi project is the first of its kind in the country. Many factions have demanded to know why dividends from the project have not yet arrived in their coffers. This sentiment of public impatience, bolstered by media outcry, has become a major obstacle for Oyu Tolgoi's efforts. As more and more have joined in the complaints, I argue that politicians have begun to take advantage of this surge in public opinion to score political points at the cost of genuinely beneficial policies. Many of these points have been scored at Oyu Tolgoi's expense,

causing the mine to become a source of conflict. This has made the job that Oyu Tolgoi needs to perform very difficult. Without addressing the trend of public opinion, it will be increasingly difficult to have the political maneuverability necessary to continue operating. The government and Oyu Tolgoi should cooperate to sponsor a countrywide educational campaign to inform the public on the nature of the project and its projected timeline for returns to investment. Such a marketing campaign can increase public awareness and decrease and reduce the viability of "fake news." This would reduce political pressure to criticize the mine, minimizing turmoil and making further development easier to facilitate.

12. Conclusion

To the best of my knowledge, this study represents the first assessment of Oyu Tolgoi's impacts at the individual level along the outcomes measured. Key results are mixed: I find that relative to all other provinces, wages increased, rates of general health and respiratory problems decreased, treatment rates rose, water infrastructure became more prevalent, vocational education rose and medical spending increased. On the other hand, rates of ger residence increased, digestive health failed to improve, high school completion rates decreased, and enrollment rates amongst young children decreased. This research represents an important progress check on the mine but also has significant implications for our understanding of mining in the Mongolian context. Umnogovi appears to exhibit a trade-off between certain first-order benefits (increasing wages, more accessible health care) and second-order detriments (reductions in human capital, increases in rates of ger residence).

Has Oyu Tolgoi been a "blessing" or a "curse" to Umnogovi? From these findings alone, it is difficult to determine – it seems that progress in some elements has come at the cost of others. The results, particularly in educational outcomes seem to support existing literature that espouse mining's harmful effects (Birdsall, Pinckney, and Sabot 2001; Gylfason 2001).

Reflecting upon my experience in the field, however, I am compelled to argue that it is still too soon to render a verdict. The mine has brought enormous economic stimulus to a region that was previously economically desolate. Some of the data's negative findings have shown improvement in more recent years, such as rates of digestive problems, secondary education completion rates amongst 18 to 20-year-olds, and the share of children under 12 without any formal education (Graphs 6, 12, and 13). Oyu Tolgoi has expended significant effort in developing human capital in more recent years and it is possible that this study's data fail to reflect these endeavors due to executive lag. The findings presented in this study should raise policymakers' awareness and further Oyu Tolgoi's mission of sustainable development.

Future research is necessary to determine to what degree these effects are related to Oyu Tolgoi and whether or not similar patterns are repeating elsewhere in Mongolia's mines. As a young, resource-rich country, Mongolia is at a critical juncture in its development. This study presents new evidence that sheds light on the range of mining impacts and can influence the management of Mongolia's resources to become more socially sustainable.

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14. Appendix

Table 8: List of synthetic control weights utilized on donor province data for each outcome variable. Sum of weights is not always equal to 100% due to rounding. Blank cells correspond to zero weight utilized.

	Ger	CentWater	InternetUsers	HealthProb	Respprob	Digesprob	MedicalCost	MedicineCost	%SeekingTreatment	SecEduc	VocationEduc	YouthSecEduc	NoEduc	YrSalary	Remittance	JobHrs
Arkhangai			0.00					0.31			0.03	0.04	0.03			0.09
Bayan-Ulgii			0.02		0.35						0.04		0.05			0.01
Bayankhongor	0.01	0.34	0.01		0.26		0.56				0.06		0.07			0.03
Bulgan			0.43	0.51		0.23		0.66	0.51		0.03		0.02			0.41
Darkhan-Uul			0.09	0.11					0.00		0.02	0.46	0.01			0.01
Dornod			0.01						0.00	0.69	0.02		0.04	0.47	1.00	0.14
Dornogovi			0.02				0.33				0.04		0.03			0.01
Dundgovi			0.02								0.02		0.04			0.01
Govi-Altai	0.90		0.01								0.07		0.02	0.13		0.01
Hentii			0.02								0.03		0.03			0.02
Khovd			0.01								0.11		0.05			0.02
Khuvsgul			0.01	0.38					0.08		0.03		0.08			0.02
Orkhon			0.02			0.06					0.34		0.02			0.01
Selenge			0.23		0.40	0.64					0.01		0.02			0.02
Sukhbaatar			0.02								0.02		0.02			0.01
Tov			0.02						0.00		0.02	0.50	0.02			0.02
Ulaanbaatar	0.10		0.03			0.07	0.11				0.02		0.01			0.01
Uvs		0.37	0.01					0.03	0.41		0.03		0.22	0.41		0.01
Uvurkhangai		0.30	0.01						0.00	0.31	0.04		0.18			0.11
Zavkhan			0.01								0.02		0.02			0.02