CryptoMining:

Pollution, Government Incentives, and Energy Crowding-Out*

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Abstract

Cryptomining gives rise to negative externalities through consumption of scarce electricity. Thus why do local governments pursue cryptominers and what are the broader effects of cryptomining on the local economy? Our testimonial evidence supports cryptomining as a source of tax revenues and purported local economy spillovers. Using a novel panel dataset for counties in China and NY State we confirm that cryptomining increases electricity consumption and pollution (in coal regions). Yet governements respond to financial incentives: cities engaging in cryptomining experience higher tax revenues. However, cryptomining in coal-heavy cities is associated with lower levels of fixed investments and GDP per capita. Welfare analysis of cryptomining must balance global pollution externalities and local crowding out against oligopolistic cryptomining profits and local government revenue gains.

PRELIMINARY AND INCOMPLETE
COMMENTS WELCOME

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The functioning of decentralized blockchain-based payment systems, known as cryptocurrencies, requires enormous amounts of world energy. Alex De Vries of PWC estimates that, to clear a paltry 81 million transactions in 2018, Bitcoin consumed more energy than Ireland, even despite the crash in the bitcoin price. The energy consumption results from the fully democratized feature, proof-of-work transaction clearing, wherein no central agent is designated to validate and secure transactions. Rather, any person or firm can become a cryptominer, choosing to particate in the solving of increasingly complex computational puzzles in order to verify the validity of the transactions. Because the payoff from mining remains yet uncompetititve because of the organizational structure (Cong, He, and Li, 2018), an arms race has occurred in mining, resulting in massive building and use of cryptomining processing power in the race to validate transactions.

Advocates for the future of proof-or-work protocols stress that "the majority [of mines]... use some share of renewable energy ... in their energy mix," (Cambridge, 2018). Yet, such a claim stuggles with its own proof since much of cryptomining happens in coal or natural-gas producing areas such as Inner Mongolia, Xinjiang, Georgia, Alberta, and western Australia. If cryptomining is using fossil fuels, then it must be that these fuels have been diverted from other uses or are being extracted at a higher rate than would have occurred. Thus, increased fossil fuel use in cryptomining necessarily gives rise to negative local and global externalities, an insight that has been largely ignored in the economics literature.[1] In addition, anecdotes suggests that energy crowding out is occurring, whereby other firms and households face shortages or heightened costs resulting from local crytomining industries. A Missoula, Montana (a crytomining city) commissioner states "One-third of the county's residential energy used in one factory that employs 19 people to do something that, as of right now, is of dubious social good..." (*CrowdfundInsider*, 3/19/2019).

Our goal is to shed light on the interaction of cryptomining with local economies. In particular we study the economic spillover and tax incentives of governments in promoting cryptomining in their communities and the consequenes to the economy in terms of (i) the

[1] An important exception is Cong, He, and Li (2018), who show how concentration via the mining pools innovation has encouraged a greater arms race in mining. Their study shows that the global increase in mining pools is correlated in time with the increase in energy consumption.

realization of positive economic spillovers, (ii) energy consumption and pollution externalities, and (iii) energy crowding-out. We start by adapting the standard model of cryptomining from Ma, Gans, and Tourky (2018) to allow for pollution externalities. The modeling framework clarifies our concern that governments are not likely to be able to correct the potential negative externality by imposing taxes. The reason is that, since anyone with computing power can engage in cryptomining and the production reward is set externally, this is a global industry and therefore a tax will be ineffective unless it is levied world-wide. Local taxes are likely to only move the problem elsewhere, akin to the issue of corporate profit shifting to tax-friendly geographies.

We then introduce our main question that, given the negative exernality, why would local government allow cryptominers to be approved to divert public utility-based electricity generation? Our empirical investigations start with testimonial evidence that governments say that crytomining will generate more tax revenues and local economy spillovers (investment and jobs) than other uses of the electricity or increased production of electricity. Because testimonies of government intention come from fossil-fuel regions, as well as hydropower regions, it must be that the governments are factoring in the pollution and energy divertion aspects of cryptomining in a cost-benefit frame.

We take these insights to data using a novel dataset constructed from the local economies in China and New York State. We focus on China, because China has accounted for from 70% to 83% of cryptomining during the last decade. Furthermore, China provides us with the opportunity to study hyrdopower-based cryptomining in Sichuan as distinct from coal power-base cryptomining in the northern and western provinces. Our goal is to study three outcomes emerging from the testimonial evidence concerning government incentives. (1) Is there more pollution, suggesting either a greater use of fossil fuels in local production or a greater extraction overall? (2) Is there evidence supporting the benefits that governments purport to internalize – namely, tax revenue and more GDP-generating use of electiricty? (3) Do we find any evidence of other investment increasing locally (positive spillovers) or decreasing locally (energy crowding-out)?

First, we find that cryptomining correlates with higher levels of pollution at a local level.

Importantly, this happens only in provinces in provinces which relying heavily on coal for energy. In New York State, we find evidence for an extreme correlation of energy consumption and the bitcoin price at local township levels.

Second, we find strong evidence in local China data that cities engaging in cryptomining generate more tax revenues. Testimonial evidence, not only from China, but also from the U.S. states of Washington and Oregon, the Canadian province of Alberta, the country of Georgia, and regions of western Australia all suggest that this elasticity should be large. Local authorities in regions with cheap energy and declining industrial use of that energy seem to be seeking out and welcoming opportunities to home cryptominers. A selection story naturally arises concerning the crytominers choice of locations, but such a selection makes our difference-in-difference results conservative.

To unpack the strong tax revenue result, we look at GDP per kilowatt of energy use across cities. The results show that coal-based cities with cryptomining are increasingly using energy more efficiently to produce GDP. In other words, local governments are correct in their assessment that cryptomining offers their economies a way to make more GDP from their coal. Local governments trade this benefit against the environmental costs.

Third, we study the potential for positive or negative externalities in terms of local investment and energy crowding-oout. Anecdotes by local media suggest that cryptominers in Oregon are driving up electricity prices, such that cities may be importing electricity from outside suppliers. In a more extreme instance, Venezuelan homes and businesses have been experiencing blackouts while electricity consumption by miners has increased. We find that cryptomining in coal-heavy cities is associated with lower levels of fixed asset investments and GDP per capita. This is consistent with both a story of selection (cryptomining emerging in accelerated declining cities) and treatment (cryptomining inducing an energy crowding-out effect on other uses of electricity). In a future draft, we will try to distinguish the incidence of these possibilities.

Our paper contributes to a growing literature on the functioning of the proof-of-work model of the Nakamoto-blockchain innovation, most closely tied to the bitcoin cyptocurrency (see Nakamoto, 2009). However, the economics literature has focused most proof-of-work atten-

tion to the features and stability of the proof-of-work protocol itself (Budish (2018), Weinberg (2014)). We instead focus on the implications of proof-of-work for local economies. We build off the literature that models how the mining equilibrium evolves with the bitcoin-blockchain supply structure (Ma, Gans, and Tourky (2018)). Others have studied other aspects of the bitcoin-blockchain supply model including the role of transaction fees (Easley, O'Hara and Basu (2018)). The important model of Alsabah and Capponi (2018) of firm decision-making allows for heterogeneity across miners to study how much investment in R&D emerges for cost reduction. Important for an overlay to our work, these authors then relate how efficiencies gained from R&D investment may increase the total computational power devoted to mining by lowering mining costs. The model also captures the trend towards more concentration in the mining industry that has been observed recently, which is the focus of Cong, He, and Li (2018). Cong et al (2018) show that the rise in mining pools tends to exacerbate the arms race between miners, thus resulting in even higher energy consumption relative to the case of solo mining.

Our work also complements the work by energy engineers and scientists on the energy consumption more directly (Li, Li, Peng, Cui, and Wu (2019), Truby (2018), and de Vries (2018). Finally, the Cambridge report (Cambridge, 2018) referred to a number of times in this paper has excellent statistics on the energy measurement as well as on all aspects of the supply of cyptomining and is generally an excellent read.

1 Model

We model the Bitcoin mining market based on the framework of Ma, Gans, and Tourky (2018) (MGT, henceforth). However, relative to this paper, we allow for externalities from mining. We refer to the existing literature for details on the Bitcoin protocol (e.g. MGT, Budish (2018), Alsabah and Capponi (2018), Cong, He, and Li (2018)). Here, we just describe the basic elements of the system. Bitcoin is a decentralized payment system in which transactions are verified by anonymous agents, called miners, as opposed to a third-party entity such as a bank or credit card company. Miners compete to be the first to

solve complex computational puzzles. The winner of each competition adds a new block of transactions to the system and in return obtains a reward consisting of newly minted bitcoins as well as a fee. The network sets the complexity of the computational puzzle in order to keep the expected completion time approximately constant.

We consider a network with N identical miners competing to win a reward P. The network sets the number of computations, K, required to solve the puzzle with the goal of keeping the expected completion time at a target level δ^*. Each miner i chooses a computing technology $x_i \in \mathbb{R}_+$. The choice of x_i affects i's expected computing speed and thus the time i expects to take to complete the K computations. In order to acquire x_i, miner i incurs a private cost $c(x_i)$, where the function c is strictly increasing and convex. In addition, the computing technology leads to a social cost $\phi(x_i) \geq 0$ (with ϕ an increasing function) which is not taken into account by miners. This externality represents, for instance, the consequences in terms of pollution and greenhouse emissions of the energy used to power the machines performing the computations.

In this setting, miner i's payoff function takes the form

$$U_i(x_i, x_{-i}, K) = P\pi_i(x_i, x_{-i}, K) - c(x_i) \tag{1}$$

where $\pi_i(x_i, x_{-i}, K)$ denotes the probability that i is the first to solve the puzzle, and the subscript $-i$ denotes all miners other than i. Then, miner i's first-order condition is

$$P\frac{\partial \pi_i(x_i, x_{-i}, K)}{\partial x_i} = \frac{\partial c(x_i)}{\partial x_i} \tag{2}$$

Now, we make assumptions on the winning probability $\pi_i(x_i, x_{-i}, K)$ which will be helpful to establish existence and uniqueness of an equilibrium in this game.

Assumption 1. For each miner i, the winning probability $\pi_i(x_i, x_{-i}, K)$ is strictly increasing and strictly concave in x_i.

Assumption 1 imposes the intuitive restriction that the more each miner invests in the mining technology the more she is likely to win, and that the returns to the technology are decreasing.

Next, we make a mild assumption on the relationship between the expected time to solve the puzzle and the number of computations K.

Assumption 2. All else equal, the expected time that it takes for at least one miner to solve the puzzle increases strictly with the number of required computations K.

Under these assumptions, MGT show existence and uniqueness of a symmetric equilibrium, which we now formalize.

Lemma 1. *Let Assumptions 1 and 2 hold. Then, for any fixed number of miners N and reward P, there exist a unique $x^* \in \mathbb{R}_+$ and a unique $K^* \geq 1$ such that:*

1. $U_i\left(\underbrace{x^*, ..., x^*}_{N \text{ times}}, K^*\right) \geq U_i\left(x_i, \underbrace{x^*, ..., x^*}_{N\text{-}1 \text{ times}}, K^*\right)$ *for all $x_i \in \mathbb{R}$ and all i;*
2. *The expected time for at least one miner to solve the K^* required computations is equal to the target level δ^*.*

Proof. See Proposition 4.4 in MGT. □

The result in Lemma 1 treats the number of miners N as exogenous. In order to endogenize N, MGT assume that entry into the mining market is free and show that this leads to the following equation

$$Nc\left(x^*\right) = P \tag{3}$$

In words, the sum of the private costs of mining equals the reward in equilibrium, so that there are zero aggregate private profits.

So far we have assumed that miners maximize their private payoff functions. If, instead, they maximized payoffs inclusive of social costs, then their payoff function would be

$$U_{i,social}\left(x_i, x_{-i}, K\right) = P\pi_i\left(x_i, x_{-i}, K\right) - c\left(x_i\right) - \phi\left(x_i\right) \tag{4}$$

leading to the first-order condition

$$P\frac{\partial \pi_i\left(x_i, x_{-i}, K\right)}{\partial x_i} = \frac{\partial c\left(x_i\right)}{\partial x_i} + \frac{\partial \phi\left(x_i\right)}{\partial x_i} \tag{5}$$

In addition, by the same argument above, in a free-entry equilibrium we would have

$$N\left[c\left(x^{*}\right)+\phi\left(x^{*}\right)\right]=P \tag{6}$$

Comparing (2) to (5) and (3) to (6) yields the following comparative statics:

1. All else equal, the level of x_i chosen by i decreases if i internalizes the social cost;
2. In the free-entry equilibrium with internalization of social cost, either N is lower or x^* is lower (or both) relative to the case of no internalization.

In order to correct this market failure, the regulator could decide to impose a tax on consumption of x devoted to crypto-mining. However, note that, since anyone in the world is able to participate in Bitcoin mining, this is a global market and thus the tax would need to be imposed simultaneously world-wide. A local tax would not achieve the goal of remedying the negative externality, since miners from non-taxing countries would make up for the reduced activity from the miners subject to the tax. This is a similar pattern to that of multinational companies shifting their profits to low-tax countries (see, e.g., the recent paper by Tørsløv, Wier, and Zucman (2018)).

Finally, it should be noted that the current model does not account for the fact that most of Bitcoin mining is performed by mining pools, as opposed to individual miners (see Cong, He, and Li (2018)). By pooling together, miners share the risk inherent in the mining activity. As shown in Cong, He, and Li (2018), this exacerbates the arms race between miners, i.e. it induces each miner to invest more in her computing technology, which makes the computational problem harder for all other miners and, in turn, prompts them to also invest more. Therefore, accounting for the presence of mining pools would yield even starker model predictions in terms of consumption of input x.

2 Empirical Analysis

In this section we describe qualitatively different channels through which mining can effect the local economy and provide some reduced-form evidence on them.

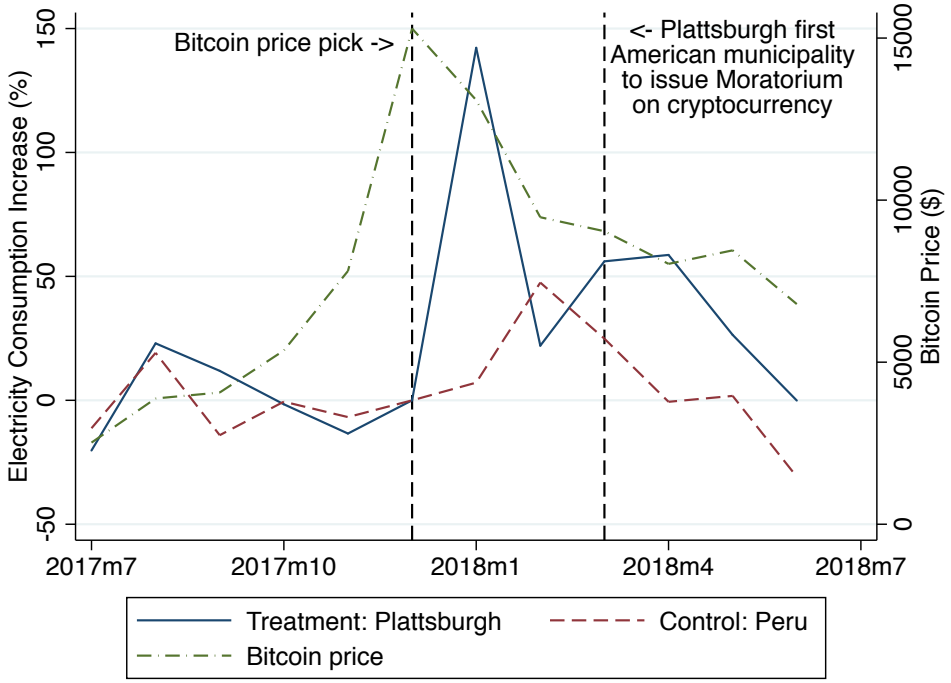
2.1 Preliminary Evidence from New York State

Before discussing our data and empirical strategy we present some anecdotal evidence on the effect of cryptomining at the local level.[2] Most notably, we focus on the city of Plattsburgh in New York state, which has been the first municipality in the US to issue a moratorium on cryptocurrency. Plattsburgh attracted a lot of mining activities due to its cold climate and cheap electricity. Residents pay about 4.5 cents per kilowatt-hour, compared to 10 cents which is what the rest of the country pays on average, and the price of electricity for industrial activity is even lower at 2 cents per kilowatt-hour. Figure 1 shows the pattern of electricity consumption in Plattsburgh and Peru, a neighboring town, in the period around the pick of Bitcoin price. We normalize to zero December 2017, which is the month is which Bitcoin prices reach their maximum at around $15.000. Before the end of 2017 both Plattsburgh and Peru experience a similar change in electricity consumption. However, in January 2018 just after the pick of the BItcoing price we observe an increase in electricity consumption of almost 150% relative to December in Plattsburgh, while almost no change in Peru. Interestingly, after Plattsburgh issues the moratorium on cryptocurrencies the energy consumption returns to a pattern which resembles the one of the neighboring town Peru.

Our results are consistent with cryptomining inducing an large increase in electricity consumption at the local level. We are in the process of collecting additional information on local electricity prices, but preliminary evidence from articles suggests that residents in Plattsburgh experienced increases in electricty bills by $100-200 during January and February 2018. To reinforce our story of a causal effect of cryptomining on local electricity consumption we show a placebo test in Figure 2. We look at the pattern of electricity consumption in Plattsburgh and Peru in year before the Bitcoin price picked. We do not find large differences in consumption between Plattsburgh and Peru as the price of Bitcoin fluctuates mildly around an average of $1.000.

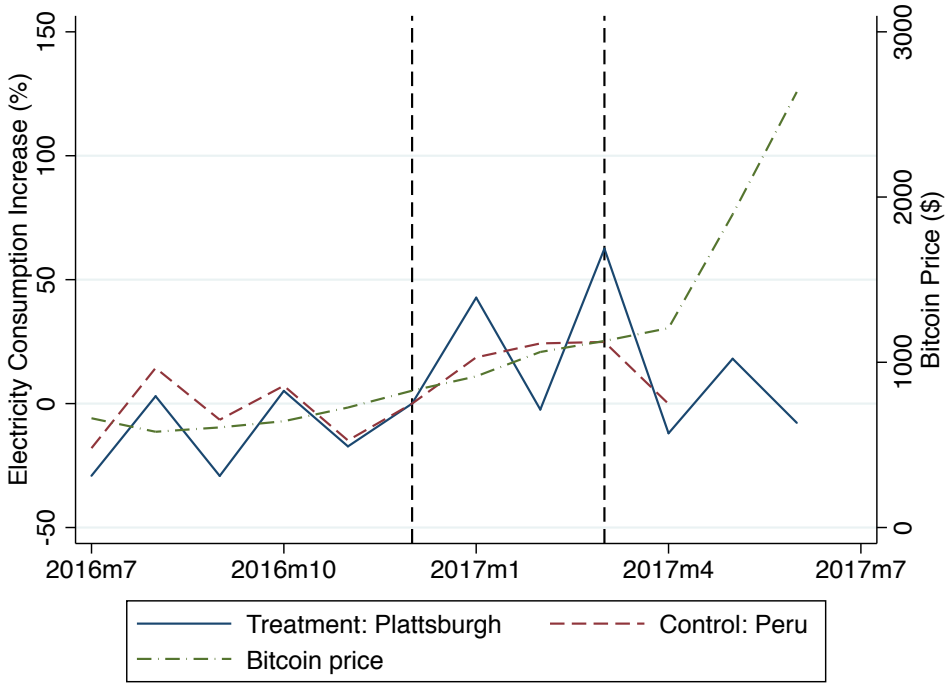
[2] In the Appendix we summarize the anecdotal evidence we collected.

Figure 1: Bitcoin Prices and Electricity Consumption



Note: Energy consumption data from NYSERDA. Bitcoin price data from Coinmarketcap.

Figure 2: Bitcoin Prices and Electricity Consumption: A Placebo



Note: Energy consumption data from NYSERDA. Bitcoin price data from Coinmarketcap.

2.2 Data for China

In order to quantitatively investigate the importance of the different channels suggested by the anecdotal evidence, we focus on China, where the vast majority of mining has taken place (70-83% in the last decade).[3] To provide a more compelling identification with respect to previous studies, we shift the focus from the global level to the local level. Most notably, we design an empirical strategy that exploits cross-sectional variation in mining activity across cities in China together with time-series variation. In contrast, previous work has mostly leveraged only the latter. Our main source is the China Yearbook from 2005 to 2017 from which we extract the main variables of interest at the province and city level. To measure government incentives we look at corporate tax revenues, while as main outcome variable we look at sulphure dioxide level, as a measure of pollution, and fixed assets investment and gdp per capita, as proxies for spillover effects and crowding out.

Additionally, we use hand collected information from reports and online sources to create a measure of mining activity, our main explanatory variable of interest. In the current version of the paper, this measure varies at the province level. We are currently working on collecting additional evidence on mining factories and data on local coal consumption and distance from rivers to generate additional variation in mining activity across cities within a province. Figure 3 shows mining activity across provinces in China. We identify four provinces in the treated group: Xinjiang, Neimonggu (Inner Mongolia), Heilongjian and Sichuan. Using additional information on local conditions and from our stylized facts, we also classify the province of Sichuan has a hydro-mining province given the large availability of rivers and hydroelectric energy.

To better understand the local incentives and effects of mining we focus on the four provinces that have been identified as main mining centers and implement a within-province across-cities identification strategy. We hand-collected data on the presence of mining for all cities in the four provinces where mining is likely to take place. Figure 4 shows the location of cities in the four provinces together with the location of power plants and the of energy they

[3] See the 2018 Cambridge report.

Figure 3: Mining Activity in China: Province Level



Note: Figure from the University of Cambridge Report.

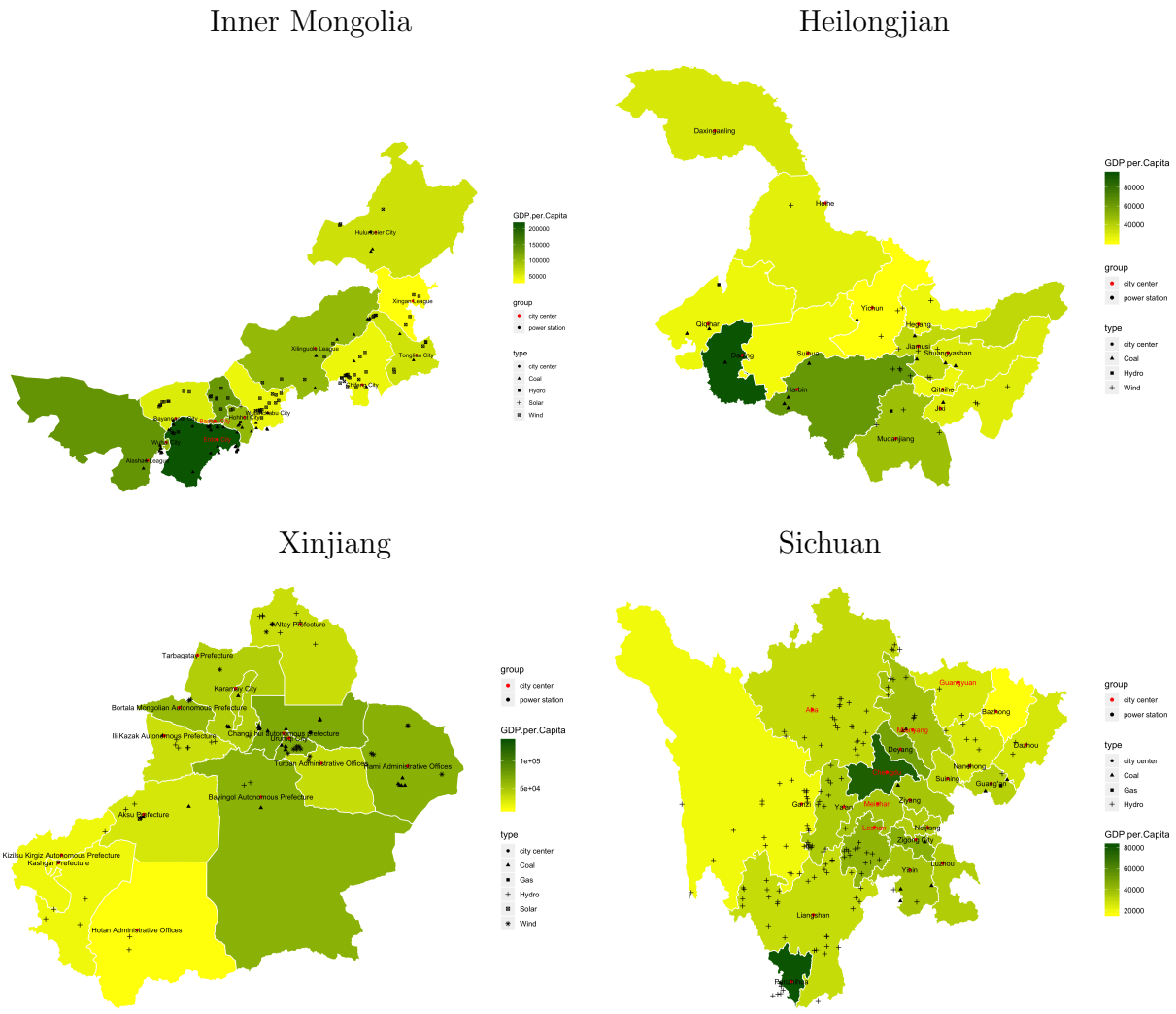
provide (coal, hydro, etc). Interestingly the two cities where cryptomining is taking place in Inner Mongolia: Erdos and Baotou are located in areas surrounded by a large supply of coal plants. Consistent with the stylized facts in Sichuan a lot of the plants are based on hydroelectric power, but close to the city of Mianyang where cryptomining is taking place we can identify two coal plants.

2.3 Channels and Empirical Strategy

The stylized evidence from suggests that mining increases pollution without overall positive effects on the local economy, but that at the same time governments often actively intervene to promote mining. In this section, we describe in more detail the different channels through which mining can affect the local economy and discuss our empirical strategy to identify them in the data.

First, we consider the "pollution externality channel," i.e. the fact that cryptomining requires huge amounts of energy, which can have a negative effect on the environment. Note that even in an economy where all households benefits equally from mining, for example thorough

Figure 4: Mining Activity in China: City Level



Note: GDP data from China Yearbook. Mining data hand collected from internet searches. Location of plants come from global power plant database.

a tax that redistributes profits, the pollution externality persists as long as it is not taken into account in cryptocurrencies prices. This effect has been acknowledge very prominently in recent debates and reports about the crypto industry (see Rauchs, Blandin, Klein, Pieters, Recanatini, and Zhang (2018) and Bevand (2017) among others). In 2017, bitcoin mining generated 69 million tonnes of CO2 and bitcoin emissions alone could push global warming above 2 degrees Celsius (Mora, Rollins, Taladay, Kantar, Chock, Shimada, and Franklin (2018)).

Given the negative externality from pollution, we might expect governments to be averse to mining. However, our anecdotal evidence suggests that this is not the case. Therefore, we consider the government incentives to promote mining: "the tax revenue channel." New firms engaging in cryptomining have a direct positive effect on the local economy by increasing investment and labor. Despite the lack of comprehensive data on mining firms, mining does not appear to be a labor-intensive activity. One of worlds largest Bitcoin mines, located in Inner Mongolia, operates 25 thousands mining machines with 50 employees earning about $17 per day.[4] Another Bitcoin farm in a secret location in Russia hosts more than 3 thousands mining machines maintained by four engineers.[5] The private gains from cryptomining are likely to be profits concentrated in the hands of few individuals controlling the mining machines, rather than wages for employees. However, cryptomining could benefit the local economy also indirectly, through spillover effects. Revenues generated by mining as profits and wages may be spent locally, thus promoting other local economic activities. Even if concentrated private gains are unlikely to be used locally, we acknowledge the possibility that one extra Bitcoin mined can generate more than one Bitcoin in local GPD. How much more (if at all) is an empirical question. Governments have then an incentive to allow mining and collect the taxes generated by the direct and indirect effects of mining on the local economy.

However, this argument leaves the possibility that cryptomining consumes energy which would otherwise be used for other activities: "the crowding-out channel." In an environment

[4]See https://digiconomist.net/deep-dive-real-world-bitcoin-mine.

[5]See https://steemit.com/bitcoin/@raven5478/largest-bitcoin-farm-in-russia-earns-millions-of-dollars

with limited resources and capacity constraints, cryptomining crowds out energy that can be used by firms in other industries or by households for consumption. While it is true that miners tend to operate in areas with excess capacity (Rauchs, Blandin, Klein, Pieters, Recanatini, and Zhang (2018)), there are several instances of mining negatively impacting local businesses and households, through increase electricity prices and even blackouts. For example news from Georgia reports that cryptocurrency mining could adversely impact the entire power grid of Abkhazia, increasing the risks of blackouts.

To empirically understand the effect of mining on local pollution, the incentives for governments and the crowing-out of other activities, we exploit our newly assembled data on Chinese cities and estimate the following fixed-effect model:

$$y_{ct} = \alpha \; mining_c \times Post_t + \gamma_c + \gamma_t + X_{ct} + \epsilon_{ct}, \tag{7}$$

where $mining_c$ is a dummy equal to one if city c is in a cryptomining province and $Post_t$ is a dummy equal to one if t is after 2012; γ_c and γ_t are city and time fixed effects; $X_{c,t}$ are time-varying city level controls. The dependent variables y_{ct} are: surphur dioxide ("the pollution channel"); gdp per kilowatt and corporate tax revenues ("the tax revenue channel"); fixed assets investment and gdp per capita ("the crowding-out channel"). We further refine model (7) distinguishing between coal and hydro mining of crypto currencies.

2.4 Results

We now present our results on the three channels that we described in the previous section: pollution externality, tax revenue and crowding-out.

Table 1 shows our first set of results on the effect of cryptomining on pollution. To measure pollution we look at sulphur dioxide emissions. The main dependent variable is the logarithm of sulphur dioxide emission in 10 thousands of tons. As expected, column (1) shows a positive effect of mining on the amount of sulphur dioxide emissions, but the estimates are noisy and we cannot reject a zero effect. In column (2), we allow the effect of mining to vary depending on the energy used. We find no significant effect for hydro mining,

Table 1: Pollution externality channel

	Log Sulphure Dioxide	
	(1)	(2)
Crypto Mining	0.071	
	(0.047)	
Coal Crypto Mining		0.115*
		(0.061)
Hydro Crypto Mining		-0.024
		(0.066)
Controls (energy)	YES	YES
Year FE	YES	YES
City FE	YES	YES
Number of Cities	16	16
Observations	99	99
Adjusted R^2	0.69	0.69

Note: The table shows the result from equation (7). The dependent variable is the logarithm of sulphure dioxide in 10 thousands tons. All regressions include year and city fixed effects and the logarithm of energy consumed measures in tons of Standard Coal Equivalent (SCE) as control.

but a marginally significant effect for coal mining. The effect is also large in magnitude: cities located in provinces engaging in coal cryptomining are associated with an 11 percent increase in sulphur dioxide emissions.

The evidence from Table 1 shows to a positive correlation between mining and pollution, consistent with anecdotal evidence and previous studies using aggregate data. In Table 2 we study why the government may be willing to allow mining, despite the negative externality it imposes on local citizens. In column (1) of Table 2, we show that cities located in provinces where mining takes place experience an increase in GDP per Kilowatt. In column (2) of Table 2, we find that mining is associated with higher corporate tax revenues. Cities in mining regions experience a 150 percent increase in corporate tax revenues.

According to our estimates, governments allowing cryptomining in their constituencies seem to face the following trade-off: higher pollution externalities coming from coal cryptomining (see Table 1), but higher tax revenues coming from energy-efficient coal cryptomining (see 2). In addition, cryptomining may have an indirect impact on local economies through crowding-out and spillover effects. We look at them in Table 3.

The first three columns focus on local fixed assets investment. Column (1) focuses on overall

Table 2: Tax revenue channel

	Log GDP/Kilowatt (1)	Log Corporate Tax Revenues (2)
Crypto Mining		1.528**
		(0.069)
Coal Crypto Mining	0.106**	
	0.048	
Hydro Crypto Mining	-0.008	
	(0.066)	
Controls (energy)	YES	YES
Controls (GDP)	NO	YES
Year FE	YES	YES
City FE	YES	YES
Number of Cities	60	60
Observations	636	307
Adjusted R^2	0.86	0.87

Note: The table shows the result from equation (7). The dependent variables are the logarithm of GDP per kilowatt and corporate tax revenues in 10 thousands Yuan. All regressions include year and city fixed effects and the logarithm of energy consumed measures in tons of Standard Coal Equivalent (SCE) as control. In Column (2) we also include the logarithm of GDP in 100 million Yuan as a control.

mining activity. We find a significant negative correlation between mining and fixed assets investment. Cities located in mining regions have a 20 percent lower level of fixed assets investment after the increase in mining activity relative to cities without mining. This effects is driven by coal mining (column (2) of Table 3), while we find a positive effect for hydro mining (column (3) of Table 3).

Finally, we focus on coal cryptomining which is the main case of interest given the trade-off between pollution, government revenues and crowding-out effects. In column (4) of Table 3 we look at GDP per capita as a summary measure of the effect of mining on the local economy. We find that GDP is negatively associated with mining activity. Cities with mining have a 15 percent lower level of GDP per capita after the increase in mining activity relative to cities without mining.

This negative correlation can be due to at least two effects. First, mining can have a causal effect on GDP per capita by crowding out other activities and shifting profits away from the local economy. Second, miners can choose to operate in location with declining GDP per capita, because they find cheaper energy sources and more accommodating governments. In this second case, the negative correlation between mining and GDP per capita comes

Table 3: The crowding-out channel

	Log Fixed Assets Investment			Log GDP/Capita
	(1)	(2)	(3)	(4)
Crypto Mining	-0.208***			
	(0.043)			
Coal Crypto Mining		-0.179*		-0.151***
		(0.090)		(0.041)
Hydro Crypto Mining			0.159*	
			(0.092)	
Controls (energy)	NO	NO	NO	YES
Controls (GDP,Population)	YES	YES	YES	NO
Year FE	YES	YES	YES	YES
City FE	YES	YES	YES	YES
Number of Cities	44	44	44	54
Observations	515	515	515	564
Adjusted R^2	0.901	0.904	0.903	0.965

Note: The table shows the result from equation (7). The dependent variable is the logarithm of fixed assets investment measured in 100 millions Yuan and the logarithm of GDP per capita. All regressions include year and city fixed effects. Column (4) controls also for the logarithm of energy consumed measures in tons of Standard Coal Equivalent (SCE) as control. Columns (1) to (3) control for GDP in 100 million Yuan and population in 10 thousands people.

from a selection effect, rather than from a causal effect of mining on GDP per capita. Even if our current empirical model cannot disentangle the importance of these two competing hypotheses, our anecdotal evidence suggests that mining may harm the local economy. We are concurrently working on a more compelling identification strategy to tease out these different mechanism using changes in mining incentives over time and across cities. Most notably, we are studying how the outcomes of interest are affected by: 1) two warnings by the People Bank of China after meeting with major domestic exchanges around operational and regulatory policies in January and February 2017; and 2) floods in Sichuan, where according to local news 20,000 mining machines were destroyed or damaged and power cuts may have impacted the operations of Bitcoin miners.[6]

3 Conclusion

In this paper, we have presented anecdotal and empirical evidence of three main channels through which cryptomining may affect local economies. First, we show that cryptomining

[6]See https://www.crowdfundinsider.com/2018/07/136661-disaster-capitalism-floods-in-sichuan-knock-out

is associated with higher pollution levels in Chinese provinces that rely heavily on coal for energy production. Second, we find that crypto-mining also correlates with higher tax revenues, which may explain why local governments are willing to allow it in spite of the pollution externality. Third, we show that cryptomining in coal-heavy cities is associated with lower levels of fixed asset investments and GDP per capita. This is consistent with two stories: cryptomining may crowd out other electricity uses or cryptomining may tend to be located in previously declining cities. Disentangling the latter selection effect from the former causal interpretation is an interesting direction that we are currently pursuing.

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Appendix Table 1: Testimonial Evidence on Local Government Motives for CryptoMining

	Country	Province	Government Motive	Source	Author	Date
1	China	Inner Mongolia	Tax Revenue	*Tech In Asia*	Eva Xiao	11/22/2016

"China's bitcoin mining scene is catching the eye of the government": In Inner Mongolia, for instance, Bitmain is partnering with the local government to access electricity from the State Grid for about four cents per kilowatt hour. In exchange, the profit from Bitmain's Ordos mine is taxed.

2	China	Inner Mongolia	Employment, Tax Revenues, GDP	*Quartz*		11/22/2016

"How bitcoin miners work": A decade ago, after a speculative coal boom fizzled, the once-thriving desert city of Ordos, in Inner Mongolia, became China's largest ghost town, littered with unfinished or empty buildings and desperate for another way to make money... The bitcoin mine and the industrial firms have one thing in common: They use a lot of electricity. The local government has attracted Bitmain...to the park by offering them a 30% discount on the electricity price, said Su Jiahai, who deals with local governments to build mining farms for Bitmain. The mining farm uses 40 megawatts of electricity per hour, about equivalent to the amount used by 12,000 homes during the same period. It pays roughly $39,000 a day for its electricity bill, even with the discount. The electricity in Ordos mostly comes from nearby coal-fired power plants, which provide a stable and constant source of electricity—although at a price to the environment.

3	China	Inner Mongolia	Jobs, Economic Spillovers	*New York Times*	Cao Li, Giulia Marchi	9/13/2017

In China's Hinterlands, Workers Mine Bitcoin for a Digital Fortune: … On the other hand, the digital currency may represent an opportunity for China to push into new technologies. Now the mine has about 50 employees," said Wang Wei, the manager of Bitmain China's Dalad Banner facility. "I feel in the future it might bring hundreds or even thousands of jobs, like the big factories."...The county of about 370,000 people on the edge of the vast Kubuqi Desert boasts coal reserves and coal-powered heavy industries like steel. But it lags behind much of the rest of the country in broadly developing its economy.

4	Canada	Alberta	Jobs, Investment, Diversification	*Medicine Hat News*	Collin Gallant	3/20/2018

It's a major economic win for the city, said Mayor Ted Clugston, who hailed it as a strong move toward diversification, and the city gaining a high-tech industry and another industrial-sized power user in need of a massive 42-megawatt power supply. "It's an exciting day," he told reporters following the meeting. "It's 42 jobs, an investment of $100 million, and it's just what we need right now.

5	U.S.	Washington	Taxes, Economic Spillovers	*CNBC*		1/11/2018

Interview with Ron Cridlebaugh, the Port of Douglas County economic development manager. "It's good for the economy. We're seeing [bitcoing mining] really diversifying our economy. There are millions of dollars being invested in the economy. It's going to help our tax base.... Our infrastructure is actually being put to the test. We're full"

6	Georgia / Abhazia		Economic Spillovers	*BitCoin News*		10/20/2018

"Cryptocurrency Mining Could Crash The Entire Power Grid Of Abkhazia": The tiny Republic of Abkhazia has high hopes that cryptocurrency mining and operations could be its solution to economic woes. But the rickety ex-Soviet electricity network is already at capacity, leaving risks of blackouts if a cold snap hits.

7	Australia		Economic Spillovers	*CoinTelegraph*	William Suberg	5/7/2018

"Australia: Disused Coal Plant To Become 'Blockchain Applications Complex'": Two blockchain companies have partnered to launch a $190 mln Bitcoin mining operation in a disused coal plant in Australia....Similar attempts in New York State and across the border in Canada drew criticism from authorities, who considered such projects did not generate sufficient value for the local economy.

Appendix Table 2: Testimonial Evidence on Local Outcomes from CryptoMining

	Country	Province	Local Outcome Expressed	Source	Author	Date
1	Georgia / Abhazia		Blackouts	*BitCoin News*		10/20/2018
	"Cryptocurrency Mining Could Crash The Entire Power Grid Of Abkhazia": ...But the rickety ex-Soviet electricity network is already at capacity, leaving risks of blackouts if a cold snap hits.					
2	Australia		More Fossil Fuels	*CoinTelegraph*	William Suberg	5/7/2018
	"Australia: Disused Coal Plant To Become 'Blockchain Applications Complex'": Two blockchain companies have partnered to launch a $190 mln Bitcoin mining operation in a disused coal plant in Australia.					
3	U.S.	Oregon	More Fossil Fuels	*Willamette Week*	Katie Shepherd	2/21/2018
	"Bitcoin Miners Are Flocking to Oregon for Cheap Electricity. Should We Give Them a Boost?": The Bitcoin boom poses a challenge to small towns like The Dalles. Electricity here may be cheap, but it isn't endless. Dams kill endangered salmon. And the more hydropower is used by Bitcoin miners, the more the rest of the state must rely on electricity generated by fossil fuels, including coal.					
4	U.S.	Oregon	Rising Energy Costs	*Politico*	Paul Roberts	3/9/2018
	"This Is What Happens When Bitcoin Miners Take Over Your Town": Many also fear that the new mines will suck up so much of the power surplus that is currently exported that local rates will have to rise. In fact, miners' appetite for power is growing so rapidly that the three counties have instituted surcharges for extra infrastructure, and there is talk of moratoriums on new mines. There is also talk of something that would have been inconceivable just a few years ago: buying power from outside suppliers.					
5	Venezuela		Blackouts	*Daily Mail*	Scot Campbell	1/19/2019
	"Bitcoin mining 'is causing electricity blackouts": In Venezuela, Bitcoin mining has caused blackouts while experts say the mass amounts of energy consumed could instead be used to power homes and businesses.					
6	U.S.	New York	Rising Energy Costs	*CoinTelegraph*	Aaron Wood	3/16/2018
	"US: Plattsburgh NY Introduces Temporary Ban On New Crypto Mining Operations": The city council unanimously approved an 18 month moratorium on crypto mining activities in Plattsburgh. The moratorium only affects new Bitcoin mining operations and does not affect ones already existing in the city. The idea of a moratorium was first introduced by mayor Colin Read in January after residents reported inflated electricity bills					