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Natural resource prices and welfare: Evidence from Indonesia's coal and palm oil boom

Donny Harrison Pasaribu

Abstract

This study measures the impact of coal and palm oil prices during the 2000s commodity boom in Indonesia on regional poverty, household consumption, employment and wages. The strategy is to exploit the within-country variation in exposure to each commodity, interacted with exogenous changes in global commodity prices. I focus on two of Indonesia's main export commodities, coal and palm oil. I find that an increase in the price of coal and palm oil both decrease the poverty rate in districts that produce them relative to districts that do not. However, the mechanisms through which they affect poverty are different.

JEL Classification: O13, Q33, Q32, O53

Key words: Natural resource booms, welfare, poverty, subnational impacts

Natural resource prices and welfare: Evidence from Indonesia's coal and palm oil boom[1]

Donny Harrison Pasaribu[2]

1. Introduction

For about a decade, between 2003 and 2014, natural resource-producing countries enjoyed one of the largest and longest commodity booms in history. While the boom brought rapid economic growth and increased government revenue in commodity-exporting countries, how the benefits were distributed within these countries is still unclear. This question is important everywhere, but even more so in developing countries such as Indonesia where millions of people are still living under the poverty line, where institutionalized redistributive social transfers are very small, and where the natural resource extraction sector is historically an enclave sector, with little connection with the rest of the economy. In this setting, did the commodity boom contribute to poverty alleviation and welfare improvement?

In theory, the extractive industry should be able to contribute to development through positive fiscal impacts, gains in employment, local economic development, and easier access to energy (Weber-Fahr et al., 2001). Yet empirical evidence on the impact of natural resources on poverty is mixed, as summarised by Gamu, Le Billon, and Spiegel (2015). Some resource abundant countries such as Norway, Australia, Botswana and most of the gulf countries manage to achieve relative prosperity, while others, such as Nigeria, Angola, Brazil and Venezuela, fail to do so. This paradox of plenty, where countries with an abundance of natural resources fail to achieve relative prosperity, sparks debate among economists about the role that natural resources play in economic development.

The diversity of experience between countries, where some successfully harness natural resource wealth for economic development while others fail, highlights the need for country-specific case studies. To this end, this study attempts to test the welfare impact of a commodity boom using Indonesia during the 2000s commodity boom as a case study. The boom, driven by China's rapid economic growth, increased global commodity prices, which was then followed by production responses from commodity producers. While the boom can be measured in either prices or quantity, I focus on the impact of international prices. International prices are central in understanding the impact of the boom because they are an important channel through which a global boom can affect Indonesia's commodity sector, and therefore also affecting welfare at the local level.

Specifically, I look at the impact of international prices for palm oil and coal on the poverty rate, real per capita household expenditure, employment and real wages at the district level. Palm oil and coal are two of Indonesia's main export commodities and have contributed to most of the country's export growth after the Asian Financial Crisis (AFC, 1997-1998). I will discuss the characteristics of the palm

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oil and coal boom in the third section of the paper. These commodities have distinct characteristics which might lead to different effects on poverty and welfare. Since not all districts can produce palm oil and coal, and each district has different exposure to these commodities, the same level of global commodity prices will have a different effect on each district.

Commodity prices can affect poverty and welfare at the subnational level through two channels: directly through employment and wages, and indirectly through fiscal and institutional effects. This paper focuses on the direct channel but will also briefly discuss the role of the indirect channel. The direct channel works through suppliers' response to the increase in prices. Higher commodity prices will increase suppliers' income and induce them to increase their production (Blake, McKay, & Morrissey, 2002). This then leads to an increase in labour demand, wages and consumer prices. These effects can either positively or negatively affect district poverty and welfare. Positively, higher labour demand and wages from the increased commodity demand will increase workers' welfare and reduce poverty (Winters, McCulloch, & McKay, 2004). Negatively, higher consumer prices caused by higher spending and wages may lower welfare and increase poverty. This is especially the case if the benefits from higher commodity prices are concentrated among a small section of the population. Migration between districts is another important factor because it can lessen both the positive and negative effects. Since there is no restriction on labour mobility in Indonesia, an increase in labour demand can be met through migration, thus limiting the wage effect. With these multiple possible outcomes, there is no certainty as to which would occur. These channels, time frame and possible outcomes will be discussed in more detail in the following section.

In this study, I use a panel fixed effect model to estimate the welfare impact of the international price of crude palm oil (CPO) and coal at the district level in Indonesia between 2007 and 2013. Examining the impact of commodity price on poverty is a complicated process because each region has a different exposure to commodities, depending on various factors such as soil fertility and sub-soil resource reserve. My identification strategy to address this issue is to use the cross-sectional variation in exposure to each commodity, interacted with global commodity prices. I assign an exposure level to each district based on the size of oil palm plantation in the district and the size of coal reserve using the earliest available data at the district level (2007 for palm oil and 2013 for coal). Although Indonesia's coal and palm oil production soared during the period, this exposure level is held constant (not time-varying). This allows the focus to be on the impact of commodity prices. A supply response, such as plantation expansion, is considered as a mechanism through which these prices can affect the district outcomes, given an exposure level.

I measure the impact on several outcomes, including the poverty rate, the number of employment, average real household expenditure, and average real wage in the district. To check the mechanisms, I test for its impact on the district employment and average real wages in eight job types and nine sectors as defined by Indonesia's Bureau of Statistics. This test will also show if there is any employment and wages spill-over effect on the non-booming sectors in the district. Furthermore, I test the impact on wages at the 25th and 75th percentiles in the district to explore how the benefit from the commodity boom has been distributed. To check the role of the price mechanism, I also test for its impact on the CPI inflation rate at the closest district in which price data is collected.

This study has multiple contributions. Firstly, it contributes to the already extensive resource curse literature, especially in the within-country evidence for the impact of natural resources. Secondly, the study contributes to the literature about the difference between mining and agricultural commodities in how they affect welfare. Thirdly, the study enriches the poverty literature with evidence on how external commodity prices can affect poverty. Lastly, the study contributes to the measurement of labour market outcomes, particularly wage distribution, in the case of a commodity boom in a developing economy.

This study also has important policy implications in how a country or subnational administrative unit (district) can respond to exogenous changes in commodity prices. The distributional impact of the commodity prices needs to be recognised and responded appropriately both at the national level and at the district level. These responses can include a fiscal policy which can amplify the positive distributional effect of some commodities while reducing the negative distributional impact of other commodities. Another policy implication is on the labour market policy. In the case of palm oil, the average real wage and real household expenditure impacts of prices are not significant. This might be because a large portion of the workers is informal workers. A labour market policy that can increase the proportion of formal workers in the sector might help to strengthen the wage impact of commodity demand and improve the welfare effect. Lastly, while the impact of an increase in commodity price from a boom appears to be desirable, the possible price fall that follows during a bust can be problematic. Policies that prepare for the bad times during the good times are important at both the national and subnational level.

2. Mechanisms

Although the research question is straightforward, the answer depends on various factors. Factors such as sectoral labour intensity, policies, and institutional settings can influence the distributional effect of commodity prices, and thus affect its poverty and welfare impact. I divide these factors into two mechanisms, the direct mechanism and the indirect mechanism. This dichotomy is based on whether the effect on poverty and welfare is caused by the intrinsic characteristics and production process of the sector (and therefore direct) or because how it affects external factors such as spillover to other sectors, the fiscal balance and institutional quality (therefore indirect). This dichotomy is not perfect, as there are cases where the two mechanisms are intertwined, but it can help to simplify and understand the mechanism. Furthermore, it is helpful to clarify the time frame and to observe the spending effect and the resource movement effect. This study measures the impact of price on the same year, so it focuses on the short-term effects.[3] In the short term, I assume that labour is the only mobile factor because it takes time to expand plantation or mines.

The direct mechanism operates through the production process. It is best understood using a modified version of the Dutch disease model, applied to a within-country setting. There have been several attempts to develop a within-country Dutch disease model with various objectives, such as to show the local poverty and employment effect (Weber, 2012), and to show agglomeration versus learning by doing effect in the local economy (Allcott & Keniston, 2014). However, it is important to remember that the research question is not about the Dutch disease effects. This section only uses familiar Dutch

[3] Nevertheless, I also test the impact of lagged prices as a robustness check to see if there are any lagged effects of prices.

disease terminologies to help explain the mechanisms of how international commodity prices can affect welfare in a within-country setting.

Firstly, consider the resource movement effect. The booming sector will demand more factors of production, in this case, labour. This will create employment, but the effects on wages depend on the local labour market. If the labour market is tight, or if the booming sector needs workers with specific qualifications (and it is expensive to train new workers), wages may increase to attract workers from other sectors or from other districts. However, if there are enough people looking for employment and the booming sector does not require workers with specific skills (or if it is affordable to train new workers), wages need not increase. Another possibility is if commuting residents switch jobs to the local booming sector for a wage similar to the level they previously earned in another district. If this is the case, wages and income will not increase, although utility might increase due to less time spent commuting. The local resource movement effect can also have different effects on the traded and non-traded sector, depending on the labour market. If the local labour market is tight, both sectors may need to pay higher wages, which can, in turn, affect their performance.

Secondly, consider the spending effect. As district income rises due to the resource boom induced employment creation and potentially higher wages, spending on traded and non-traded will also increase. Like the original model, non-traded prices are expected to increase while traded prices are not. As the non-traded sector expands, it will demand more labour. Once again, the impact on wages depends on the local labour market. However, in contrast to the original model, the effects on the traded sector are not certain since they also depend on the condition of the local labour market.

The size of both the resource movement effect and the spending effect depend on the propensity of labour migration between districts. Higher internal migration can diminish the size of both effects. If the local labour market is tight, but migration between districts is likely, an increase in labour demand can be fulfilled by migrating workers from other districts. In that case, the impact on wages may be marginal, although the impact on employment will still be positive.

Commodity characteristics are also an important factor. Commodities are not equal in how they can affect employment and wages. Consider the difference between coal and palm oil sector in Indonesia. The coal sector, for example, is a relatively capital-intensive sector that requires a small amount of high-skilled labour with high wages. The palm oil sector, on the other hand, often requires a large amount of low skilled labour, especially if the estate is not owned by a big company. As an illustration, Indonesia’s 2010 Input-Output table indicates that the coal sector spent only ten per cent of its total expenditure on wages, while the palm oil sector spent twenty seven per cent. A boom in the palm oil sector, which requires minimal specific skills, would be more likely to increase employment of local residents and therefore, wages.

The effects of the resource boom on income and poverty are the consequence of its effects on employment, wages, and prices. In any case, the employment effect should be positive and should have poverty eradicating effects. Even if the employment effect is moderated by migration from other districts, the effect on poverty should still be positive. The effect on the average wage is expected to be non-negative. If it is positive, it may have poverty eradicating effects, and if it is not positive, it should not affect the poverty rate. Finally, the impact on poverty also depends on how the boom affects the price level since the poverty line is defined in local prices. An influx of workers, for example, may push non-traded goods prices, such as rental rates, upward. If the cost of living increases more than nominal income, the cost-of-living adjusted poverty rate may increase.

So far, I have not discussed the rents to landowners or capital owners. While these rents are not the focus of this study, it is important to note that they play a key role in how a commodity boom affects the local economy. If land ownership is concentrated in the hands of a few, the gain from rents would also be concentrated. Land ownership is also important because land is an immobile factor. This has two implications: (i) land for plantation or coal mining can only expand (or shrink) in the long term, but not in the short term; and (ii) the return from land ownership (rents) should fluctuate with the price of the relevant commodities. The rents might have a spillover effect on other sectors, and they can also be spent locally, such as on the property sector, thus increasing housing prices. Tax revenues on these rents, on the other hand, would likely have broader effects through public services and investment. These effects are part of the indirect mechanism.

The indirect mechanism involves everything that is not directly related to the production process in the commodity sector. As I have shown, the line might be blurred in the case of employment and wages spillover effect into other sectors. The fiscal effect, which comes through taxes on the collected resource rents, is as important as, if not more important than, the direct mechanism. Studies have shown how fiscal management can determine whether a country can avoid the Dutch disease or the resource curse. For example, Indonesia's success in avoiding the Dutch disease during the 1970s and 80s oil boom is partly attributed to its government's ability to manage and spend oil revenues on developing infrastructure, agriculture and education throughout the country (Booth, 1992; Gelb, 1988; Hill, 1992; Pinto, 1987; Scherr, 1989). By spending their resource windfalls on public services and investments, the Indonesian government has indirectly used the commodity boom to improve welfare and reduce poverty. This is evident in Indonesia's rapidly declining poverty incidence during the period. Whereas 40.4 per cent of the rural population were below the poverty line in 1976, in 1987, this percentage has fallen to 16.4.[4] The decline in urban areas is less dramatic; the urban poverty rate declined from 38.8 per cent in 1976 to 20.1 per cent in 1987.

Unfortunately, not many countries shared this experience with Indonesia. Countries have diverging experiences in managing resource booms. While some countries such as Venezuela and Nigeria have been unable to escape this resource curse, other countries such as Norway and Botswana have performed relatively well. These diverging experiences are often attributed to institutional quality differences. The argument is if there is a natural resources windfall in a country with poor institutions, it will encourage people to engage in rent-seeking and taking as much as possible of the windfall. But a windfall in a country with strong institutions will lead to more complementary demand and encourage more productive entrepreneurship (Mehlum, Moene, & Torvik, 2006a). The cross-country evidence suggests that with a good institution, a resource curse can be turned into a blessing with good enough institutional quality (Boschini, Pettersson, & Roine, 2007).

In the local context, empirical evidence suggests the indirect mechanism through fiscal effect also depends on institutions and how the resource rents are taxed. Many countries allow the tax revenues from resource rents to be collected and spent by a local government entity, such as a state or municipality. This means local government have an important role in managing the resource windfall and using it for the benefit of the local resident. Nevertheless, the diversity of experience still exists.

[4] Official figures based on BPS poverty line.

In the US, an exogenous increase in a state's resource revenue leads to a lower level of state taxes, and increased spending and saving (James, 2015). In Brazil, however, oil windfall in municipalities only translates into little improvement in the provision of public goods or the local population's living standard (Caselli & Michaels, 2013). This evidence of diversity in experience appears to confirm the findings of cross-country studies. To my knowledge, the fiscal effect of natural resources in Indonesia has not been empirically tested. While this issue is not within the scope of this study, it is important to note that in the last twenty years Indonesia has experienced substantial changes in its central-local fiscal arrangement and how it collects taxes on natural resources. Some of these changes will be discussed in the next section.

While institutions are often viewed as an exogenous variable, evidence suggests that commodity type affects the institutional capacity to respond to shock (Isham, Woolcock, Pritchett, & Busby, 2005). "Point source" resources, which are extracted from a narrow geographic or economic bases, such as mineral and oil, are found to weaken institutional capacity. In contrast, "diffuse source" resources, which tend to be dispersed and rely on livestock and agricultural produce from small farms, do not have any institutional effects. Other studies also suggest that some resources, such as mining and oil, are more "lootable" than others because they are concentrated and easily taxable, and if combined with a bad institution can lead to slower income growth (Mehlum, Moene, & Torvik, 2006b). If the kind of commodity can affect institutional capacity, it can then affect the government's capacity to manage resource windfall and consequently, its capacity to eradicate poverty and improve welfare.

Both the direct and indirect mechanisms are important in explaining the impacts of commodity prices on poverty, welfare, and wages. This study measures the total impact of both mechanism on those variables and tries to explain the results using the two mechanisms. By including coal and palm oil, the results will test if there are any poverty and welfare outcome differences between the prices of these commodities. The spillover effect on other sector and surrounding areas will also be tested in the model. However, variables such as institutional quality and public services, which are part of the indirect mechanism, will not be part of the empirical model but will be discussed as part of the explanations for the results.

3. Indonesia: the second boom

Both agricultural and natural resource commodities, have always played a crucial role in the Indonesian economy. While the mix of commodities may change, they always make up a sizeable bulk of the country's exports (Figure 1). This continuous reliance on commodities means Indonesia's economy is highly influenced by commodity price booms and busts. Over the last fifty years, two major commodity booms have shaped the structure of Indonesia's economy: the 1970s oil boom and the 2000s commodity boom.

The oil boom delivered an unprecedented windfall for Indonesia. Since the oil sector is a highly capital-intensive sector, it had minimal direct employment impact or wage impact. However, it had a substantial impact on the government's revenue, which reached 71 per cent of total revenue during the peak of the oil boom in 1981-1982. Although development progress was unequal between regions, overall poverty incident declined rapidly, particularly in rural Java (Booth, 1992; Hill, 1992). The rapid decline in rural poverty can be mainly attributed to the government's agricultural development program, especially in rice production, through programmes of lavish input subsidies (Booth, 1992;

Gelb, 1988). Others attribute it to the importance of recycling mechanism of resource windfall into productivity-enhancing investment in the traded sector, notably agriculture and manufacturing (Coxhead, 2007; Coxhead & Li, 2008; Pinto, 1987).

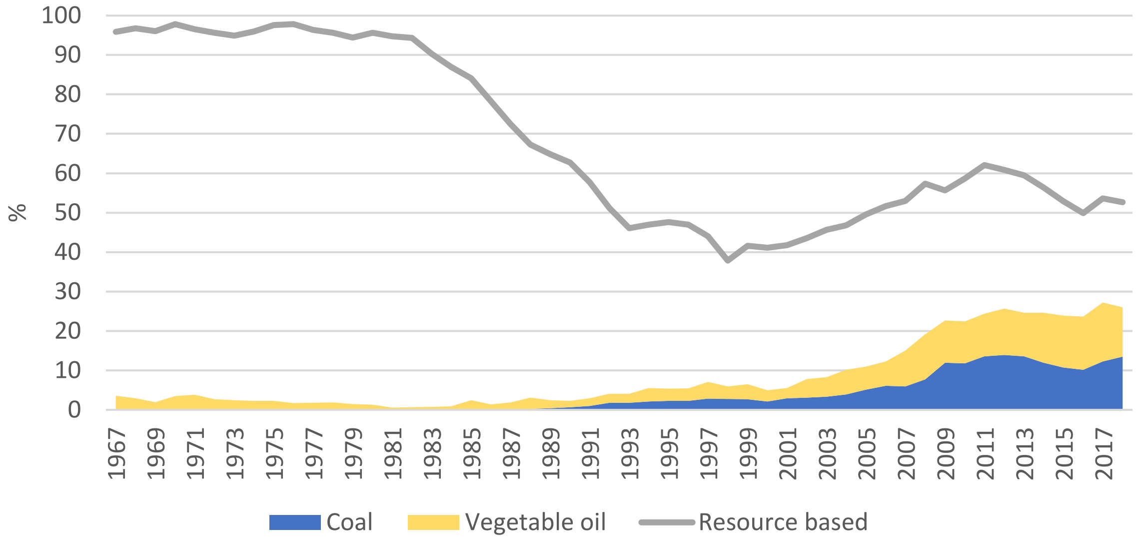

Figure 1. The percentage share of coal, vegetable oil and total resource-based goods in Indonesia's merchandise exports

Source: Author's calculation based on UNCOMTRADE data. Notes: resource-based sector includes agriculture, forestry, mining, and oil and gas.

There are at least two important points from Indonesia's oil boom experience that need to be noted. Firstly, the oil boom affected welfare and poverty mainly through how the government spent the oil windfall, and less through employment in the petroleum sector. Secondly, it is fair to say that Indonesia managed to escape the curse of natural resources wealth during the oil boom. The government did better in managing the windfall than other resource-rich countries such as Nigeria (Gelb, 1988; Pinto, 1987; Scherr, 1989) or Mexico (Scherr, 1989; Usui, 1997). The result of this good management is not only apparent in macroeconomic performance, but also in the reduction of the incidence of poverty.

The 2000s commodity boom was driven by strong global economic growth, mainly in China, and to some extent, India. In 2004, the year when commodity prices rose substantially, economic growth in the OECD area was at a historical high of 3.2%, while growth in developing Asia was 8.5%. This rapid growth in developing Asia had enormous impacts on the commodity market because these countries, particularly China (Figure 2), were passing through a development stage which is much more commodity-intensive than the dematerialising OECD economies (Radetzki, 2006). Demand acceleration in the early 2000s took commodity suppliers by surprise, leading to supply shortage which drove the increase in prices. The boom was briefly interrupted by the Global Financial Crisis in 2008, which dropped commodity demand in developed countries but not in China and India (Figure 2). Supported by the consistently growing commodity demand in China and India, commodity prices recovered quickly, and by 2010 they have climbed back to the pre-crisis level. The price hike continued until 2011 when it reached its peak.

The 2000s commodity boom brought another episode of natural resources windfall to Indonesia, but this time instead of oil, it was driven by coal and palm oil (Figure 1). These commodities were not a significant part of the country's export mix prior to the boom. Each of them contributed to less than one per cent of Indonesia's merchandise exports in 1990. By 2011, coal already made up 13.5 per cent of Indonesia merchandise export and palm oil made up 10 per cent, while the total merchandise export value has increased nearly eightfold (in nominal US dollar).

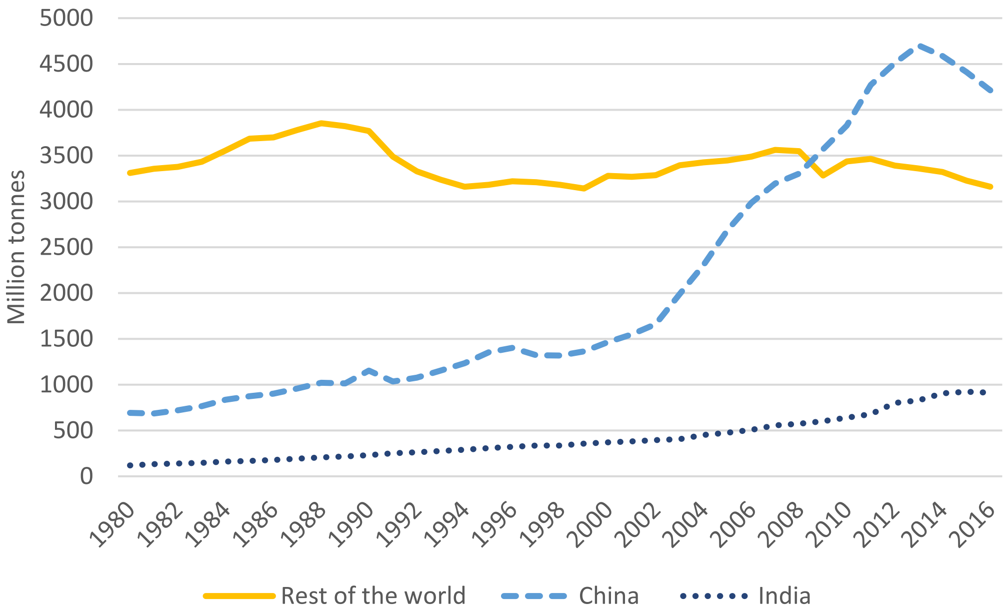

Figure 2. Coal consumption of China, India, and the rest of the world (in million tonnes)
Source: International Energy Statistics data, U.S. Energy Information Administration data (2019).

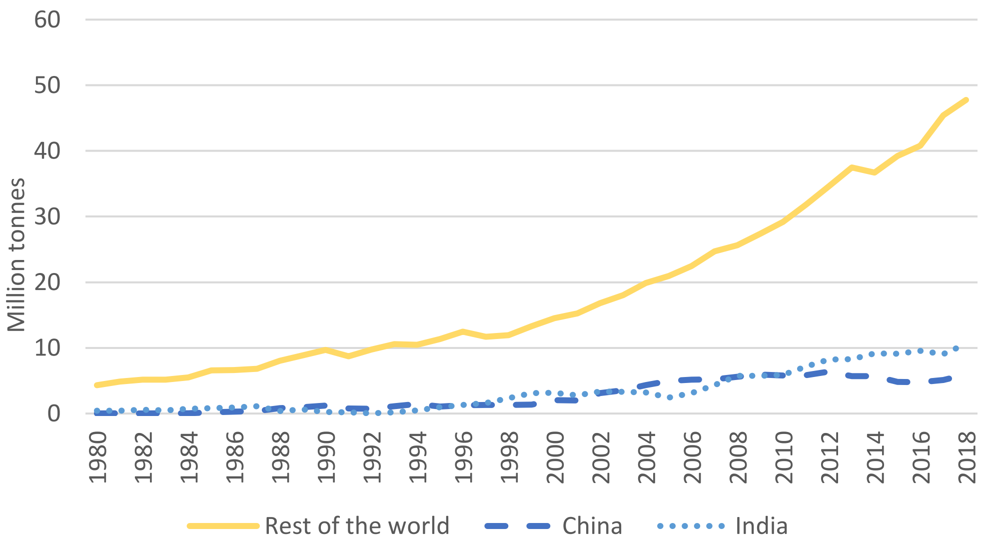

Figure 3. Palm oil consumption of China, India, and the rest of the world (in million tonnes)
Source: Global Agriculture Information Network data, U.S. Department of Agriculture (2019).

Although both palm oil plantation and coal mines have existed in Indonesia since the Dutch colonial era, their rapid expansion is relatively recent. This is the result of a combination of the recent increase in global demand for these and the changes in Indonesia's economic and political system. During the 1970s oil boom, coal and palm oil were simply not as profitable as oil. In real (USD) terms, oil price increased by more than tenfold between 1970 and 1982. By comparison, the coal price barely doubled, and palm oil price dropped by nearly half of its original price in real terms during the same period (Figure 4). In contrast, during the 2000s commodity boom, all three commodities experienced a similar level of price increase. The increase in coal price was even higher than in oil price (Figure 5). This means coal and palm oil production are comparatively more attractive in the 2000s commodity boom than in the 1970s oil boom.

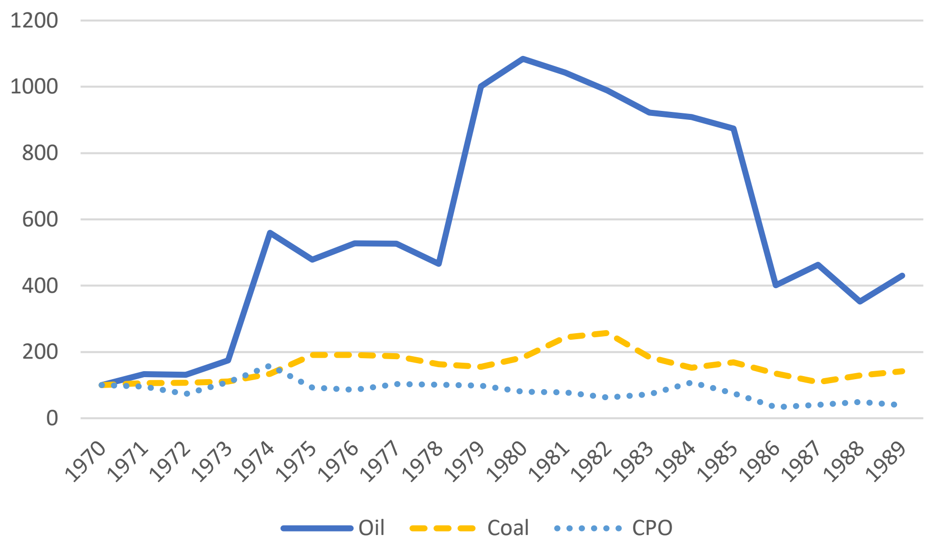

Figure 4. Indices of Oil, Coal, and CPO prices in real 2010 USD (1970=100) during the 1970s oil boom

Source: Author's calculation based on World Bank (2019) commodity price data. Notes: 2010 USD value is based on manufacturing unit value index constructed by the World Bank

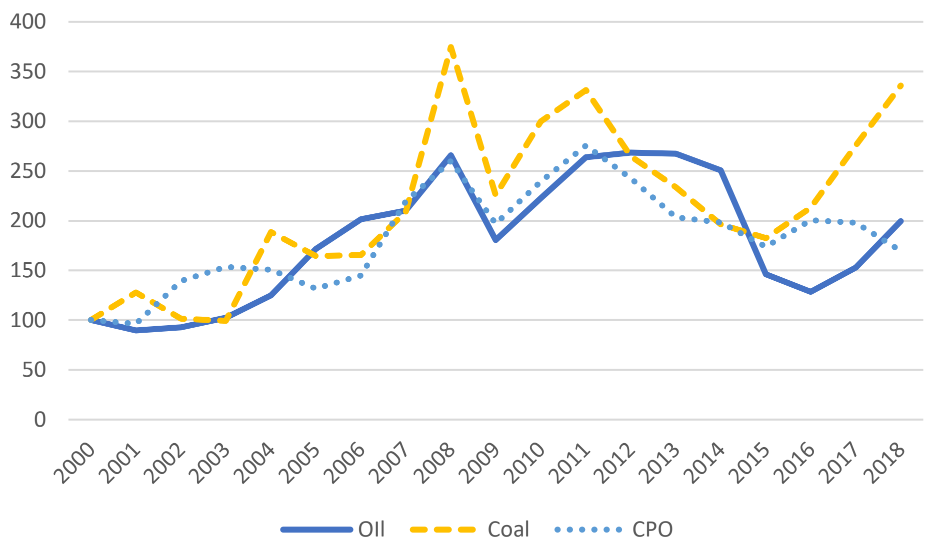

Figure 5. Indices of Oil, Coal, and CPO prices in real 2010 USD (2000=100) during the 2000s commodity boom

Source: Author's calculation based on World Bank commodity price data. Notes: 2010 USD value is based on manufacturing unit value index constructed by the World Bank

Domestically, this period marked a transformation in Indonesia's economic and political system. Sharp currency depreciation, as well as commodities and market liberalisation after the 1997-98 Asian Financial Crisis (AFC), provided incentives for Indonesia's commodity producer to assert their comparative advantage in natural resources and cash crops (Rada, Buccola, & Fuglie, 2011; Rada & Regmi, 2010). The incentives are even stronger when combined with the already increasing global commodity prices. In agriculture, the trade liberalising process further steered the growth away from domestic-oriented food crops toward export-oriented crops, such as palm oil (Rada et al., 2011).

Politically, the period marked a sudden transformation from a highly centralised country towards a much more decentralised system of government. This has facilitated rapid growth in oil palm plantations, but not necessarily in coal mines. Firstly, decentralisation brought a new revenue-sharing agreement between the central and regional government. This change means revenues from natural resources were to be shared between levels of government. Revenue sharing laws covered forestry, mining, fisheries, and oil and gas, but not palm oil or other estate crops. This omission supported the palm oil industry as they can get easier access to permit from district heads who were not required to share revenues with the central government (Barr, Resosudarmo, Dermawan, & Setiono, 2006; Naylor, Higgins, Edwards, & Falcon, 2019).

Furthermore, decentralisation also brought a proliferation in the number of districts (district splitting) and ambiguous authority over land titling (Barr et al., 2006). This led to weak institutional capacity in new districts and weaker enforcement of land and environmental law. These factors facilitated deforestation and conversion of forest into oil palm plantations. As a result, oil palm plantations spread across the country, not only in traditional areas such as Sumatra and Kalimantan but also in other areas (Figure 6). While both plantation companies and smallholder plantation were involved in the conversion process, smallholder plantations grew more rapidly during the period (Figure 6). This is partly because it is harder to enforce land and environmental law to the numerous and scattered smallholder plantations than to big plantation companies (Naylor et al., 2019).

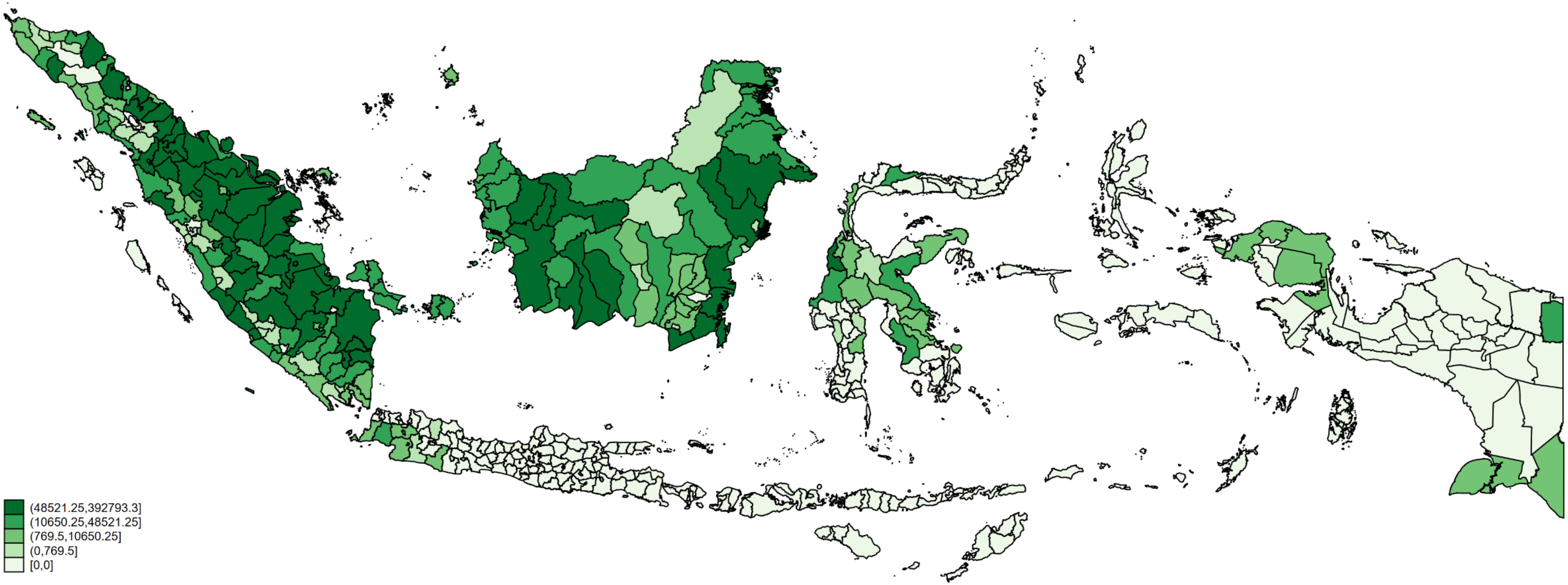

Figure 6. District palm oil size averaged for the whole period between 2007 and 2013 (in hectares)

Source: Author’s calculation based on Directorate General of Estate Crops (2017) data

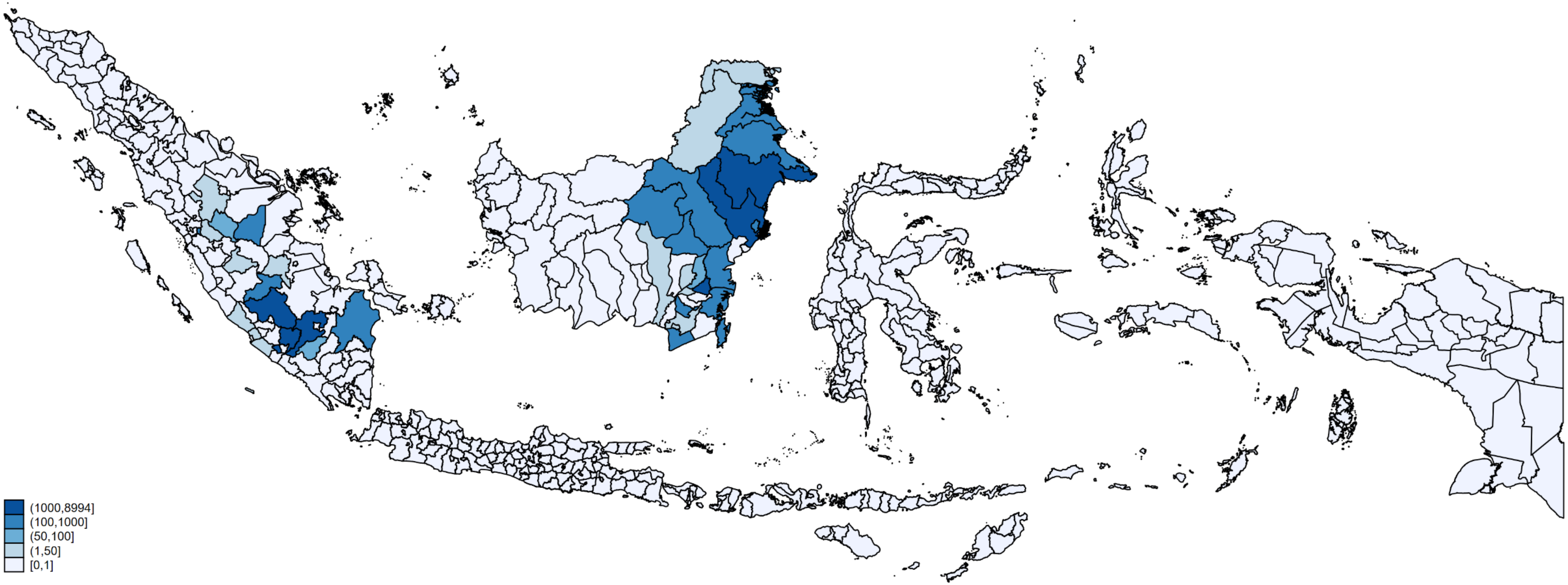

Figure 7. District coal reserve in 2013 (in million tonnes)

Source: Author's calculation based on GeoRIMA (2019a)data from the Ministry of Energy and Mineral Resources

In contrast, coal mining operations do not receive such special treatment and instead have to face uncertainties due to a lack of clear guidance regarding the distribution of revenue to the local government (Resosudarmo, 2009). Moreover, the industry was subjected to greater regulatory control by provincial and district government (Lucarelli, 2010). In several regions, the regional government also issued a variety of taxes and levies on mining companies (Resosudarmo, 2009). As a result, nearly all of the increase in coal production during the early part of the boom came from mining companies which were established during the late 1980s under Coal Contract of Work (CCOW). These contracts involved direct agreements between the government and locally registered foreign companies, which were given special law status ("lex specialis"). This status exempts their holder from changes in Indonesian general law, such as revisions to the tax code, investment laws, and land use laws which occur after the CCOW was signed (Lucarelli, 2010).[5] This condition lasted at least until 2009 when the New Mining Law came into effect.[6]

The new mining law clarifies some of the uncertainties in the mining licenses and grants equal status to foreign and domestic investors. The new law also gave district and municipal governments the authority to issue permits for mid-sized mines. Similar to the problem with oil palm plantation, empowered local districts lack the capacity to enforce environmental law. This, combined with a boom in global commodity prices, resulted in a subsequent explosion of mining permits across Indonesia, many of which have operated in violation of permit laws. According to the International Energy Agency (2014), an estimated 74 million tons of coal were extracted illegally from small mining operations in Indonesia in 2013. Against this background, coal mining operations managed to thrive during the period (Figure 7 & Figure 9). Indonesia became a major coal exporter since 2004, vying to be the biggest coal exporter in the world with Australia.

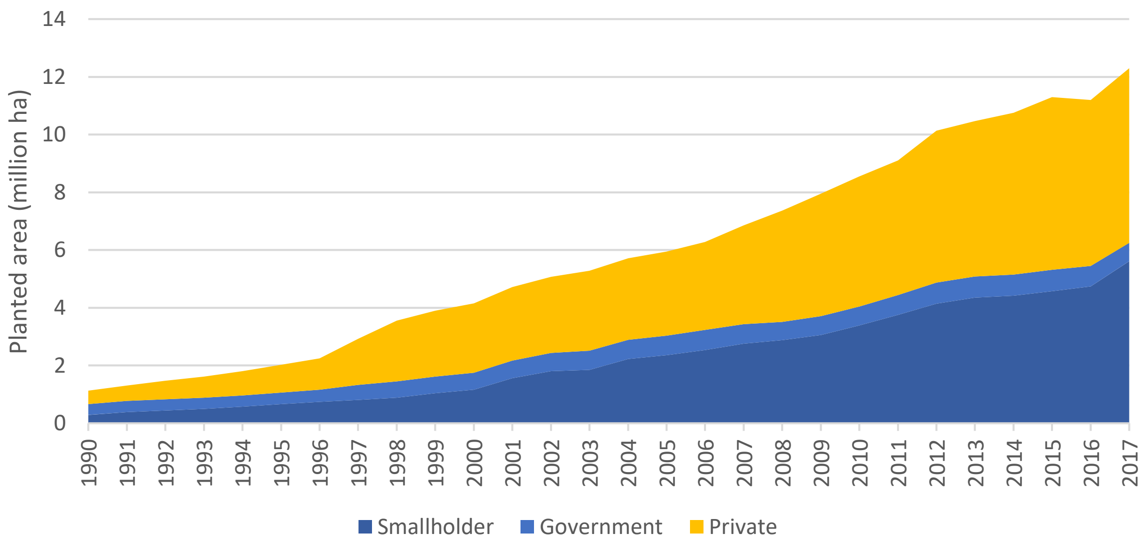

Figure 8. Oil palm planted area by producer classification, 1990-2016

Source: Directorate General of Estate Crops (2017). Notes: the classification is based on legal status. Private plantations are registered plantation companies, while smallholders are plantations with no legal status or owned by plantation families.

[5] The contracts have divestment obligation clause which requires the companies to sell a minimum of 51 percent ownership of the companies to domestic entities by the tenth year after they started commercial production. This process happened between 1999 and 2005 for these companies.

[6] UU No.4/2009 about Mineral and coal mining

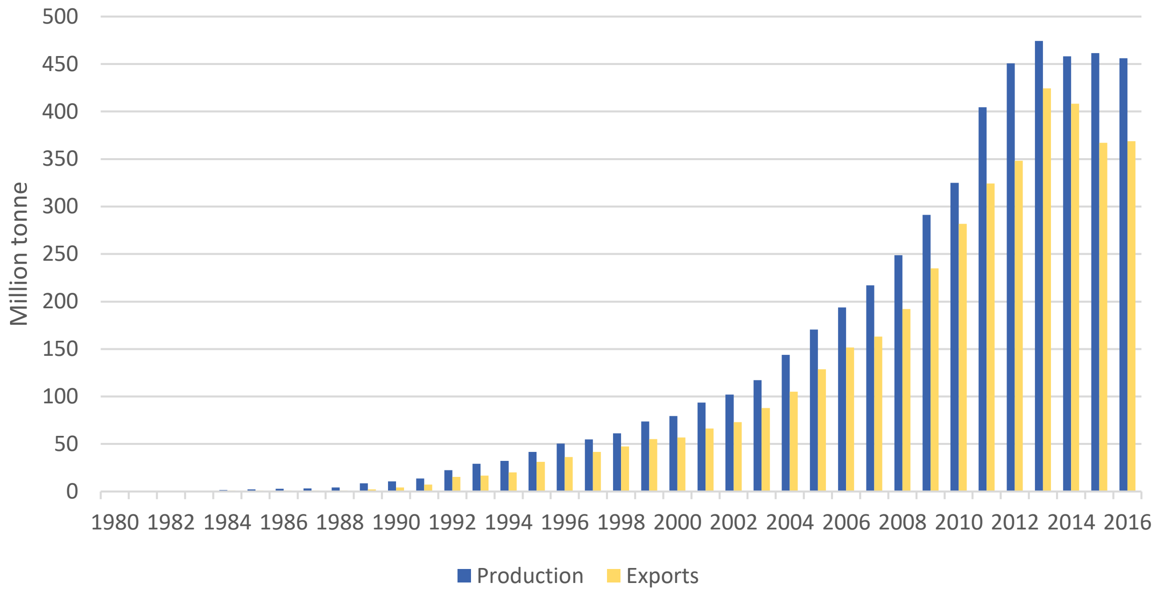

Figure 9. Indonesia coal production and export volume (1980-2016)
Source: International Energy Statistics data, U.S. Energy Information Administration data (2019).

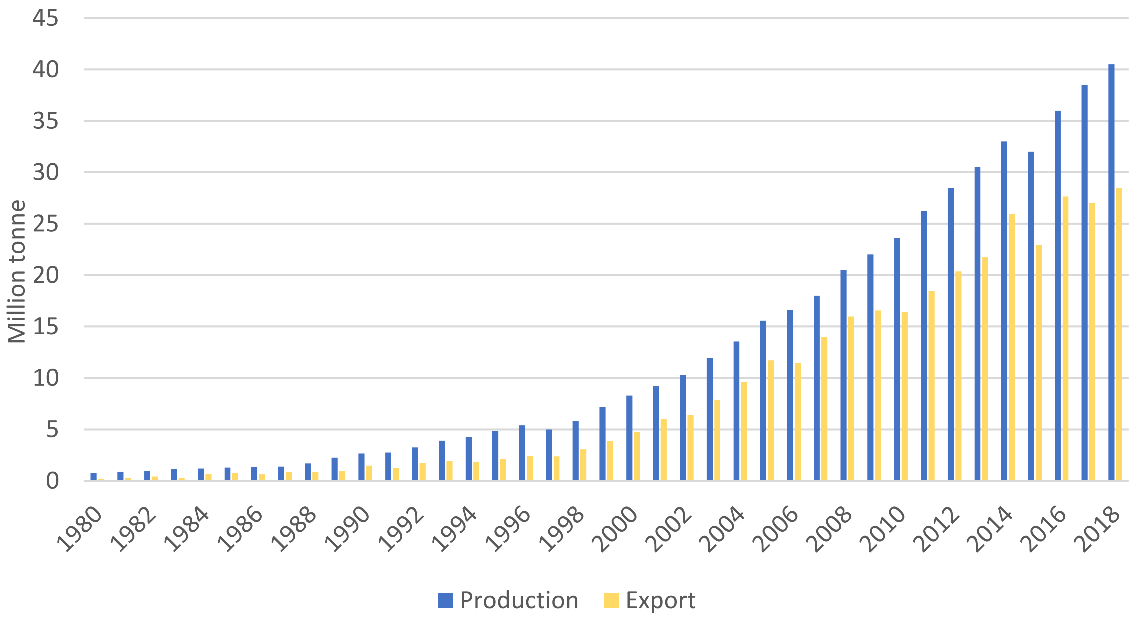

Figure 10. Indonesia palm oil production and export volume (1980-2018)
Source: Global Agriculture Information Network data, U.S. Department of Agriculture (2019).

4. Method and Data

I test whether the price of two commodities, palm oil and coal, affect poverty and welfare outcomes disproportionately in districts which have the means to produce these commodities (oil palm plantation and reserve of coal). The model is a panel fixed effect model with two variables of interest: the interaction between district coal exposure and international coal price, and the interaction between district palm oil exposure and international palm oil price. I use seven years of data in my analysis, from 2007 to 2013, which covers most of the 2000s global commodity boom.

I use 2007 as the first observation period because some of the required data are available at the district level only start from this year. Consequently, I use the 2007 district configuration for the whole observation period. This decision is important to note because the district administrative boundaries changed a lot during the period. Since the *Reformasi* in 1998, there has been a general trend toward the proliferation of new districts which breaks the initially bigger districts. I merge districts that have split after 2007 back into their original administrative border in 2007. This merging process applies to all relevant data that is used in this study.

My empirical strategy uses cross-sectional variation based on commodity distribution across different districts, similar to Dube and Vargas (2013) for the case of Colombia. This strategy utilises the fact that each district has different exposure to each commodity, based on the capability of the district to produce the commodity. A district with a large coal reserve can benefit more from an increase in international coal price compared to a district with little or no coal reserve. Similarly, districts with large oil palm plantations can also benefit more from an increase in international palm oil price compared to districts that do not.

District exposure to commodities can certainly change, for example with the discovery (or depletion) of coal reserve and expansion of oil palm plantation. However, since the focus of this study is on the effect of international price, I keep the exposure level to be time-invariant and set at the earliest available period. This is done to minimise the feedback effect of production changes caused by price fluctuations. The time-invariant district exposure variables are then interacted with the annual average international price of each commodity. By doing so, annual price fluctuations at the global level affect each district differently based on how exposed the district is to the commodity.

The coal variable is the subsoil reserve of coal in the district in 2013, in log form. Data for district-level coal reserve is drawn from GeoRIMA (Geological Resources of Indonesia Mobile Application), an android-based mobile application developed by the Ministry of Energy and Mineral Resources (Centre for Mineral Coal and Geothermal Resources, 2019b). GeoRIMA is the only publicly available data for coal and mineral reserves at the district level in Indonesia. To my knowledge, this study is the first study to use this application for the purpose of measuring the welfare impacts of natural resources. As a mobile application, GeoRIMA is relatively easy to access, but its data have to be extracted manually. It includes data of potential reserves of minerals, coal and geothermal at the district and provincial level. The application only provides data from 2013 to 2016, so the pre-boom coal reserve data is not available. This can be problematic because it is possible that the search for a new reserve is a response to boom and record-high prices in the preceding period. Another alternative is to use district coal production because coal production is the actual number a district can gain from selling coal. However, coal production data is collected at the firm level, not the district level, and there are cases where a firm has mining sites in multiple districts. While it has its weaknesses, the 2013 district coal reserve is the best available data to capture a district coal exposure.

The palm oil variable is the size of oil palm plantation in the district, also in log form. Data of district oil palm plantation area come from Tree Crop Statistics of Indonesia for Oil Palm, produced by the Directorate General of Estate Crops in the Department of Agriculture and Indonesia's central statistics agency, Badan Pusat Statistik (BPS). This data are available through the World Bank's Indonesia

Database for Economic and Policy Research (DAPOER) in their main databank. Unlike coal, palm oil plantation size data is available at the beginning of the observation period (2007). Therefore, the expansion effect of palm oil plantation from the boom should be minimal. While data before 2007 are available, the district administration configuration that I use is based on the 2007 configuration, so it is impossible to go earlier than 2007. One possible concern for this variable is the factors that correlate with poverty might also correlate with the decision to open a plantation. These factors might include infrastructure, institutions, history and other unobservable. However, most of those factors should be accounted for by district fixed effects.

Time variations come from annual average prices of each commodity. I obtain price data from World Bank Commodities Price database and use the simple average if there is more than one price for a commodity. The price of coal and palm oil, like the price of any other commodity, is determined by both supply and demand factors. As a major producer,[7] changes in Indonesia's output of these commodities can affect international prices, which raise the concern that prices might be endogenous. However, in the case of the 2000s commodity boom, the most important driver for the record high international prices was China's rapid economic growth. Indonesia exports 80% of its coal[8] and 85% of its palm oil, which shows that the demand factor is mainly exogenous to the country. Reverse causality is also not a major concern since there is no reason to believe that poverty reduction in a district can affect the international price of coal and palm oil. While the factors that correlate poverty can also affect production expansion in both commodities, it is unlikely that those factors can affect the international price. Moreover, the unit of observation in this study is the district level, and it is unlikely for a district to be able to affect international prices.

For both commodities, I use nominal international prices converted to nominal rupiah value, in log form. While the actual prices that farmers and miners face differ from international prices, local prices do move in parallel with international prices. In the case of palm oil, the fresh fruit bunch (FFB) benchmark prices received by farmers are determined using a formula at the provincial level at least once a month by a committee set by the governor. The formula is based on the actual export price of palm oil received by a local CPO manufacturer, multiplied by a constant "K" index. The index is a proportion of how much the farmer should get from the company export price. Like the FFB price, the K index is also determined at least once a month by the governor's committee.[9] This mechanism is regulated through the Minister of Agriculture regulation, which is updated every few years. During the study period, there were two ministerial regulations[10], and they use the same formula to determine the FFB price. This formula means while there can be variations between provinces in the price that farmers receive, the price is always proportional to the international price.

Likewise, the coal benchmark price is also regulated and determined using a formula at least once a month. The benchmark price is determined by the director-general of mineral and coal at the national level. The formula is not as transparent as for CPO, but according to ministerial regulation,[11] it is based

[7] In 2018, Indonesia was the second biggest coal exporter and the biggest palm oil exporter. The country had 17 per cent share of global coal exports, and 54 per cent share of global palm oil exports.
[8] Ministry of Energy and Mineral Resources (ESDM).
[9] Price also varies based on the age of the oil palm tree to reflect the oil content of the fruit. This means FFB price per kg will increase as the oil palm tree gets older, up to the age of ten to twenty-year-old when the oil yield peaked, and then decline gradually.
[10] Permentan No.395/Kpts/OT.140/11/2005 and Permentan No.17/Permentan/OT.140/2/2010
[11] Permen ESDM No.17/2010 and Perdirjen Minerba No.515.K/32/DJB/2011

on market mechanism and international prices. Therefore, it is reasonable to use the international coal price in the model.

The panel fixed effect model is as follows:

$$Y_{kpt} = \alpha_k + \beta_t + \delta_p\beta_t + (Coal_{kp} \times CP_t)\theta + (Palm_{kp} \times PP_t)\rho + X_{kpt}\varphi + \varepsilon_{kpt} \quad (1)$$

Where $Coal_{kp}$ is the size of coal reserve of district k, island p (log form, time-invariant). CP_t is the average global price of coal in year t (converted to Rupiah, in log). Similarly, $Palm_{kp}$ is the size of palm oil plantation in district k, island p (log of hectares, time-invariant) and PP_t is the average global price of crude palm oil in year t (converted to Rupiah, in log). α_k are district-level fixed effects; β_t are year fixed effects; $X_{kpt}\varphi$ are time-varying controls, which includes literacy rate, employment share in agriculture and manufacturing, and access to electricity, sanitation, and clean water.

$\delta_p\beta_t$ are island-year fixed effects in Indonesia's six major islands (Sumatra, Java, Kalimantan, Sulawesi, Eastern Indonesia and Papua). These account for some potential omitted variables since commodities may be concentrated in particular regions, and other regional factors such as history and remoteness of the region. For example, Sumatera and Kalimantan soil characteristics are more suitable for palm oil than other regions and are historically the first region where oil palm was cultivated in Indonesia. Reflecting these characteristics, Sumatra and Kalimantan produced 97 per cent of Indonesia's palm oil[12] in 2007.

Y_{kpt} is the outcome of interest in district k, island p, in year t. My primary outcomes are district poverty rate, average monthly per capita household expenditure, and average monthly wage in the district. I also include several other output variables as extensions to the model to help explain the main results. The district poverty rate is the share of district population living below an expenditure-based poverty line, roughly equal to $25 US dollar per person per month. District poverty rates and average household expenditures are estimated from the consumption module of BPS' National Socioeconomic Survey (SUSENAS), both taken from DAPOER. SUSENAS is representative at the district level since 1993. One limitation with the household expenditure data, is that the 2008 data in DAPOER are missing, so this year is excluded from the regression for the model which has it as the outcome variable.[13] Average monthly wage is the average wage of paid employed workers in the district in the last month of the survey. This calculation excludes self-employed workers, non-paid workers and employers. It is calculated from BPS' national labour market survey (SAKERNAS), which is representative at the district level since 2007. The average wage can be disaggregated based on professions and sectors. In this study, I use the profession-based disaggregated average wage as outcome variables as an extension to the main model. Wage level at the 25th and 75th percentile in the district is also added as an outcome in the extension to show the estimated impact on wage inequality.

The last outcome in the model is the district inflation rate. However, BPS does not collect inflation data at the district level. They calculate the consumer price index in 71 cities and districts all over Indonesia and construct the inflation rate based on these cities and districts. For districts that are not part of the 71 cities and districts where consumer price data are collected, I use the data from the

[12] Secretariat of Directorate General of Estates (Ditjen Perkebunan) Indonesia, 2007

[13] The results with 2008 data included (Appendix 2.4., p.38) are consistent with the main results. I extract the data directly from SUSENAS and construct the per capita household expenditure with the same method as DAPOER. The.

closest district based on physical distance (in Km). This method has some weaknesses, particularly because closer physical distance does not always equate to better connectivity. If two neighbouring districts are separated by mountain or river, and not connected directly by road, consumer price in these districts can be substantially different from each other. This factor cannot be accounted for using the physical distance method used in this study. Nevertheless, without better data quality, this is the best approximation for price level changes that can be used in this study.

Based on the model specification, coefficient θ captures the differential effect of coal price on the district level outcome in districts producing more coal and ρ measures the differential effect of palm oil price on the district level outcome in districts cultivating more palm oil. However, it is important to remember that the interpretation of both of these coefficients depends on the size of the commodity exposure (i.e. the size of coal reserve or oil palm plantation) in the district.

5. Results

The fixed-effect panel regression results are presented in Table 1 and Table 2, where Table 1 presents results without any control variable, and Table 2 includes several time-varying controls. The addition of control variables only causes small changes in the magnitude of the coefficients and does not change the significance level or the signs of the results.

Table 1. The effect of coal and palm oil prices on welfare (Panel Fixed-effect OLS, no control variable)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile real wage	Log of 75th percentile real wage
Exposure to CPO x log CPO price	-0.518***	0.004	0.094	0.014*	0.007	0.016*	0.011*
	(0.114)	(0.006)	(0.130)	(0.008)	(0.007)	(0.009)	(0.007)
Exposure to coal x log coal price	-0.243***	0.019**	0.235*	0.001	0.012*	0.014	0.010
	(0.084)	(0.009)	(0.121)	(0.007)	(0.006)	(0.009)	(0.006)
Observations	3130	2658	2673	3130	3105	3100	3105
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample period	2007-2013	2007-2013	2008-2013	2007-2013	2007-2013	2007-2013	2007-2013

[1]Excludes 2008 data; [2]Excludes 2007 data

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is s*ignificant at the 1 per cent level*; **** is s*ignificant at the 5 per cent level*; *** is s*ignificant at the 10 per cent level*

Table 2. The effect of coal and palm oil prices on welfare (Panel Fixed-effect OLS, with control variables)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile wage	Log of 75th percentile wage
Exposure to CPO x log CPO price	-0.424***	0.001	0.099	0.016**	0.009	0.018**	0.015**
	(0.112)	(0.006)	(0.132)	(0.008)	(0.007)	(0.009)	(0.007)
Exposure to coal x log coal price	-0.264***	0.020**	0.245**	0.002	0.012*	0.013	0.010
	(0.083)	(0.010)	(0.120)	(0.007)	(0.006)	(0.010)	(0.007)
Observations	3119	2652	2666	3119	3094	3089	3094
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	450	449	446	450	449	449	449
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2008-2013	2007-2013
Controls: Literacy rate, employment share in agriculture and manufacturing (except for total employment), household access to electricity, sanitation, and clean water							

[1]Excludes 2008 data; [2]Excludes 2007 data

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is s*ignificant at the 1 per cent level*; **** is s*ignificant at the 5 per cent level*; *** is s*ignificant at the 10 per cent level*

Column (1) of Table 1 and Table 2 show that the price of coal and palm oil both have a significant district poverty alleviation effect. The effects of both commodities are significant at the one per cent level. However, interpreting the coefficient is not a straightforward process because the interpretation depends on the exposure level, (i.e. the size of palm oil plantation or coal reserve in the district). To gauge the magnitude of the coefficients in Table 2, consider the increase in CPO price from 2007 to 2008 when the international CPO price increase by 0.25 log points (from USD780 per metric ton to USD948 per metric ton). For the average palm oil district, in which the palm oil plantation size is 36 thousand hectares, the coefficient (-0.424) implies that the price increase reduced the poverty rate by 1.11 percentage point relative to districts with no palm oil plantation. Similarly, consider the coal price increase from 2007 to 2008 by 0.71 log points (from USD64 per ton to USD123 per ton). In the average coal-producing district, with an average reserve of 826 million metric ton, this price increase translates into 1.26 percentage point decrease in poverty rate compared to a district without coal. Since the national poverty rate only declined by 0.87 percentage point (from 12.52 to 11.65 per cent) between 2007 and 2008, the estimated additional poverty rate decline in districts which have coal mine or oil palm plantation is relatively large.

The results for household expenditure, inflation rate and average district wage are only statistically significant for coal. To understand the magnitude of the effect, again consider the coal price increase from 2007 to 2008 and the average coal district with coal reserve of 826 million metric ton. The price increase will increase household expenditure by 9.5%, increase inflation by 1.17 percentage points, and increase the average district wage by 5.7% compared to non-coal districts. Considering the coal price approximately doubled from 2007 to 2008, the elasticities of these outcome variables are inelastic. In contrast, the estimated impact on total employment is only significant for palm oil. In an average palm oil district, the palm oil price district increases total employment by 4.2% compared to non-palm oil districts.

These results highlight the difference between coal and palm oil in how the gain from the commodity boom is distributed. While the poverty impacts are significant in both commodities, the impact on per capita household expenditure is only significant in coal. It implies the expenditure impact of palm oil price is concentrated in the lower end of the income distribution. In other words, an increase in palm oil price benefits the poor disproportionately as compared to coal. Furthermore, the positive and significant employment impact in palm oil shows its relatively labour-intensive production process. If the newly created jobs pay relatively lower wage than the prevailing average wage, the average wage need not increase and can even decline. This is not necessarily a bad outcome, especially if the oil palm sector employs previously unemployed people. This reasoning is also supported by the wage distribution impact results. Conversely, coal does not generate much employment but increases the district average household expenditure.

Inflation is another indicator through which commodity prices may affect welfare. The results indicate that it is positively affected by coal price, but not by palm oil price. It is important to note that these results are in terms of comparison with non-resource-producing districts; that is, there is no significant difference in inflation between coal or palm oil districts with other districts. Taken together with the poverty impact, the results provide no evidence for the initial concern that poverty might increase if real income falls as consumer price rise faster than income.[14] What the results show instead is that, in the case of coal, real household expenditure is still positively affected by coal price despite it also causing higher inflation rate. In the case of palm oil, price does not significantly affect either real household expenditure nor consumer prices, which also disprove the earlier concerns.

As expected, the estimated impacts on wage distribution are only significant in the case of palm oil. The fact that palm oil price only significantly affects wage at the lower (25th percentile) and upper (75th percentile) end of the distributions but not the overall average wage might be related with the kind of jobs and sectors that are directly affected by the sector. In contrast, coal price significantly affects average wage, but not its distribution.

To explore the detailed impact on employment and wages, Figure 3, Table 4, and Table 5 present the results of regressions where the outcomes are employment and the average real wage of each sector and profession in the district. Table 3 and Table 4 suggest that the employment and average real wage of most sectors are not significantly affected by either coal or palm oil price, with a few exceptions. Unsurprisingly, palm oil price appears to positively affect employment in agriculture and the social sector (Table 3). The sector also significantly increases the wage in finance and decreases the wage in the social sector[15] (Table 4), both in real terms. Results on profession-based wage (Table 5) show that palm oil price has a positive and significant impact on the average real wage in agriculture, animal husbandry, and forestry, and production and related worker, transport equipment operators, and labourers. Again, these results are expected since palm oil plantations directly employ workers in these types of jobs.

The palm oil sector is a relatively labour-intensive sector and directly employs agricultural workers and labourers. Therefore, it is reasonable to conclude that the significant impact of a palm oil price on wages at the 25th percentile is related with the direct employment effect on agricultural workers and

[14] Results for the estimated effect on nominal wages are in Appendix B (p.146)

[15] The finance sector includes financial institutions, real estates, rental businesses and corporate services, while the social sector includes the government, education, healthcare, and entertainment.

labourers in the palm oil sector. Taken together with the employment results, the positive and significant effect on wages of directly related jobs suggests that palm oil price affect wages through increased labour demand. Furthermore, the spillover effect on the wage of other job types is minimal.

In comparison, coal price positively affects employment in the mining sector and the transportation sector, while negatively affects manufacturing employment (Table 3). The impact on manufacturing employment can be viewed as an indication of a possible local Dutch disease, but it must be interpreted carefully since manufacturing jobs are not generally located in the same districts as mining. In terms of wage, coal price does not significantly affect the real wage in any sector, but positively affects clerical profession wages.

Table 3. The effect of coal and palm oil prices on district employment, by sectors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variables	Agriculture	Mining	Manufacturing	Utility	Construction	Trade, Hotel & Restaurant	Transport and Communication	Finance	Social
Exposure to CPO x log CPO price	0.050**	-0.045	0.033	-0.139	0.029	0.030	-0.010	0.006	0.047**
	(0.020)	(0.087)	(0.037)	(0.103)	(0.030)	(0.023)	(0.027)	(0.075)	(0.023)
Exposure to coal x log coal price	0.031	0.215**	-0.190*	0.076	0.081	0.055	0.087*	0.049	0.024
	(0.020)	(0.087)	(0.109)	(0.118)	(0.070)	(0.037)	(0.046)	(0.140)	(0.038)
Observations	3119	3119	3119	3119	3119	3119	3119	3119	3119
District & island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	450	450	450	450	450	450	450	450	450
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013
Controls: Literacy rate, household access to electricity, sanitation, and clean water									

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is *significant at the 1 per cent level*; **** is *significant at the 5 per cent level*; *** is *significant at the 10 per cent level*

Table 4. The effect of coal and palm oil prices on district real wage by sectors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variables	Agriculture	Mining	Manufacturing	Utility	Construction	Trade, Hotel & Restaurant	Transport and Communication	Finance	Social
Exposure to CPO x log CPO price	0.018*	-0.004	0.017	0.006	0.012	-0.006	0.001	0.039*	-0.011
	(0.011)	(0.023)	(0.016)	(0.030)	(0.010)	(0.010)	(0.011)	(0.021)	(0.007)
Exposure to coal x log coal price	0.006	-0.015	0.006	0.068	-0.006	0.011	0.013	0.041	0.001
	(0.010)	(0.015)	(0.016)	(0.044)	(0.017)	(0.012)	(0.012)	(0.030)	(0.007)
Observations	3090	2699	3050	2164	3074	3078	3073	2940	3094
District & island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	449	445	446	444	448	449	448	447	449
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013
Controls: Literacy rate, employment share in agriculture and manufacturing, household access to electricity, sanitation, and clean water									

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. Regression excludes districts which have no worker in the specified sector.

Table 5. The effect of coal and palm oil prices on district average wages, by type of profession

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variables	Professional, technical, and related	Administrative and managerial	Clerical and related	Sales	Services	Agriculture, animal husbandry, and forestry	Production worker, transport operators and labourers	Others
Exposure to CPO x log CPO price	-0.003	0.011	-0.003	-0.013	0.024	0.020*	0.016*	-0.027*
	(0.012)	(0.030)	(0.010)	(0.011)	(0.016)	(0.011)	(0.008)	(0.015)
Exposure to coal x log coal price	-0.008	-0.027	0.029***	-0.005	0.001	0.012	0.002	-0.000
	(0.025)	(0.025)	(0.010)	(0.016)	(0.017)	(0.012)	(0.007)	(0.022)
Observations	2986	2871	2986	2980	2966	2991	2988	2738
District & island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	433	433	433	433	433	433	433	430
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013
Controls: Literacy rate, employment share in agriculture and manufacturing, household access to electricity, sanitation, and clean water								

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. Regression excludes districts which have no worker in the specified profession. ***** is s*ignificant at the 1 per cent level*; **** is s*ignificant at the 5 per cent level*; *** is s*ignificant at the 10 per cent level.*

6. Robustness checks and Extensions

There are several robustness checks and extensions that I apply to the model. The first one is to include the lag of the coal and palm oil interaction variable to the model. This check is to test if there is any lagged effect of prices on the welfare outcomes. It would be expected that there is a lagged response in the outcome variables, such as poverty, household expenditure, and wages because they need time to adjust after the exogenous commodity prices change. The model specification is similar to the main model, with the only difference is it includes three years lag value of the coal and palm oil variable in the model. Equation 2 is the model specification, and the results are presented in Table 6.

$$Y_{kpt} = \alpha_k + \beta_t + \delta_p t + (Palm_{kp} \times PP_t)\rho_0 + (Palm_{kp} \times PP_{t-1})\rho_1 + \cdots + (Palm_{kp} \times PP_{t-3})\rho_3 + (Coal_{kp} \times CP_t)\theta_0 + (Coal_{kp} \times CP_{t-1})\theta_1 + \cdots + (Coal_{kp} \times CP_{t-3})\theta_3 + X_{kpt}\varphi + \varepsilon_{kpt} \quad (2)$$

Where PP_{t-1} to PP_{t-3} are the lag value of palm oil price from one year to three years, and CP_{t-1} to CP_{t-3} are the lag value of coal price CP_t.

Results in Table 6 are generally consistent with the main results in Table 2. For poverty, palm oil price appears to affect poverty for three years before the effect subsides. The cumulative effect is, therefore, larger than suggested in the main model. Coal price, on the other hand, only significantly affect poverty in the same year, with no significant coefficient for the lagged variables. The employment effect results are only significant for palm oil, and only in its second and third-year lag, suggesting the need for an adjustment period before palm oil price can affect total employment. The other results, including household expenditure and inflation, are less precise, with no significant effect in the same year. The results for the average wage are consistent with the main results, where palm oil price does not significantly affect average district wage while coal price has a positive and significant impact. Interestingly, although the cumulative effect is still positive, coal seems to have a negative lag effect. The impacts on wage distributions also confirm the main results, where palm oil has positive and significant impacts on wage at the 25th and 75th percentile. Coal, on the contrary, have a negative cumulative effect on wage both at the 25th and 75th percentile.

Table 6. Robustness check (1): lag of palm oil and coal interaction variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile real wage	Log of 75th percentile real wage
Exposure to CPO x log CPO price	-0.305**	0.007	0.465	-0.006	0.003	0.027**	0.019*
	(0.143)	(0.018)	(0.289)	(0.007)	(0.009)	(0.014)	(0.010)
L1. Exposure to CPO x log CPO price	-0.093	0.006	-0.206*	0.001	0.004	-0.002	0.003
	(0.058)	(0.005)	(0.109)	(0.003)	(0.005)	(0.007)	(0.005)
L2. Exposure to CPO x log CPO price	-0.170***	-0.005	0.232	-0.008*	-0.009	-0.002	-0.002
	(0.059)	(0.006)	(0.193)	(0.005)	(0.007)	(0.009)	(0.006)
L3. Exposure to CPO x log CPO price	0.057	-0.003	-0.216	0.011***	0.005	-0.003	-0.003
	(0.066)	(0.008)	(0.216)	(0.004)	(0.006)	(0.009)	(0.006)
Exposure to coal x log coal price	-0.291***	0.027	-0.094	0.003	0.013**	0.012	0.009
	(0.084)	(0.018)	(0.237)	(0.007)	(0.006)	(0.009)	(0.007)
L1. Exposure to coal x log coal price	-0.067	-0.005	-0.115	-0.000	-0.009**	-0.002	-0.012***
	(0.055)	(0.004)	(0.102)	(0.003)	(0.004)	(0.005)	(0.004)
L2. Exposure to coal x log coal price	-0.028	0.003	-0.166**	0.003	-0.001	-0.012**	-0.003
	(0.051)	(0.004)	(0.075)	(0.004)	(0.003)	(0.005)	(0.003)
L3. Exposure to coal x log coal price	0.023	-0.004	0.134	0.002	-0.002	0.002	-0.000
	(0.039)	(0.006)	(0.144)	(0.003)	(0.005)	(0.006)	(0.005)
Observations	3119	2652	2666	3119	3094	3089	3094
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	450	449	449	450	449	449	449
Sample period	2007-2013	2007-2013	2008-2013	2007-2013	2007-2013	2007-2013	2007-2013

Controls: Literacy rate, employment share in agriculture and manufacturing, household access to electricity, sanitation, and clean water

[1]Excludes 2008 data; [2]Excludes 2007 data

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. *** is *significant at the 1 per cent level*; ** is *significant at the 5 per cent level*; * is *significant at the 10 per cent level*

Two other specifications are also applied to address time-series related issues, and they are put in the appendix. The first one is with all variables in first-differenced form (Appendix 6.10.6), and the second one is with autoregressive structure (Appendix 6.10.7). These results are also consistent with the main results.

The second robustness check is to include exposure and time-trend interaction as a control variable. By including this variable, the model controls for the effect of a general commodity boom, which occurred throughout the observation period. This check is to address concerns that the estimated effects are the result of a general production expansion period, which may have happened regardless of the international commodity price. The modified model with exposure and time-trend interaction variables is specified in Equation 3.

$$Y_{kpt} = \alpha_k + \beta_t + \delta_p t + \left(Palm_{kp} \times PP_t\right)\rho + \left(Coal_{kp} \times CP_t\right)\theta + \left(Palm_{kp} \times TT_t\right)\gamma_2 + \left(Coal_{kp} \times TT_t\right)\gamma_1 + X_{kpt}\varphi + \varepsilon_{kpt} \quad (3)$$

Where TT is the time trend variable, which ranges from 0 to 6 (from 2007 to 2013). The coefficient γ_1 and γ_2 estimate the general boom period effect to districts with exposure to coal or palm oil. The results are presented in Table 7.

Results in Table 7 are generally consistent with the main results, with the new variables only significant in a few cases. The CPO-time-trend interaction is significant in the results for district poverty rate, while coal-time-trend interaction is significant for the average real wage, as well as the 25th and 75th percentile real wage. Despite the modification, the commodity price effects are still consistent with the main results. Interestingly, the magnitude of the palm oil price effect on poverty is comparatively smaller in this model than the main results.

Table 7. Robustness check (2): Exposure and time-trend interaction

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile real wage	Log of 75th percentile real wage
Exposure to CPO x log CPO price	-0.149*	0.001	0.140	0.008**	0.016**	0.032***	0.020***
	(0.086)	(0.007)	(0.117)	(0.003)	(0.006)	(0.008)	(0.006)
Exposure to coal x log coal price	-0.286***	0.024*	0.238*	0.002	0.015**	0.017*	0.014**
	(0.072)	(0.013)	(0.138)	(0.006)	(0.006)	(0.009)	(0.007)
Exposure to CPO x time-trend	-0.027***	0.000	-0.003	0.000	-0.001	-0.001	-0.000
	(0.010)	(0.000)	(0.008)	(0.000)	(0.001)	(0.001)	(0.001)
Exposure to coal x time-trend	-0.004	0.001	-0.001	0.001	-0.002**	-0.002*	-0.002**
	(0.013)	(0.001)	(0.012)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	3119	2652	2666	3119	3094	3089	3094
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	450	449	449	450	449	449	449
Sample period	2007-2013	2007-2013	2008-2013	2007-2013	2007-2013	2007-2013	2007-2013

Controls: Literacy rate, employment share in agriculture and manufacturing, household access to electricity, sanitation, and clean water

[1]Excludes 2008 data; [2]Excludes 2007 data

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is s*ignificant at the 1 per cent level*; **** is s*ignificant at the 5 per cent level*; *** is s*ignificant at the 10 per cent level*

The last robustness check is to aggregate the observation to the province level. This model checks if the commodity price effect is also present at the province level. Since not all districts within a province have coal or palm oil, the province-wide effect might be limited. For this check, I only run regressions for poverty, total employment and average real wages. These estimated outcomes should be able to show if there is any spillover commodity prices impact from districts that have coal or palm oil to the province level.

The aggregation process depends on how the variable is constructed. In the case of poverty, the number of people living under the poverty line in the district is summed with other districts in the same province and then divide it by the province population. The process is similar in the case of total employment, where the total number of people employed in each district is summed with other districts within each province. For province average real wage, the variable is constructed from weighted individual-level labour force data. For the province level palm oil and coal exposure, I use the total size of palm oil plantation and total coal reserve in the province. The model is specified in Equation 4, and the results are presented in Table 8.

$$Y_{ipt} = \alpha_i + \beta_t + \delta_p t + (Coal_{ip} \times CP_t)\theta + (Palm_{ip} \times PP_t)\rho + X_{ipt}\varphi + \varepsilon_{kpt} \quad (4)$$

The specification is exactly the same as the main model, with the only exception being that instead of using subscript k that represents the district, Equation 4 uses subscript i which represents the province. The results in Table 8 are different from the other results in that both palm oil and coal prices have no significant effect on poverty, employment or average wage. The results show no evidence for spillover effects for all outcomes from districts with coal or palm oil to the rest of the province. It is possible that these districts are too small compared to the whole province to have province-wide effects. However, the results have to be interpreted carefully since the aggregation process also substantially reduce the observation number to only 224.

Table 8. Robustness check (3): panel regression with data aggregated to province level

	(1)	(2)	(3)
Dependent variables	Poverty rate (%)	Log total employment	Log average real wage
Exposure to CPO x log CPO price	-0.243	0.010	-0.001
	(0.242)	(0.009)	(0.008)
Exposure to coal x log coal price	0.116	0.006	-0.003
	(0.179)	(0.007)	(0.006)
Observations	224	224	224
Province and island fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Provinces	32	32	32
Sample period	2007-2013	2007-2013	2007-2013

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. *** is s*ignificant at the 1 per cent level*; ** is s*ignificant at the 5 per cent level*; * is s*ignificant at the 10 per cent level*

Based on these three robustness checks, I find that the main results in Table 2 are robust to modifications in the specifications. The main results are consistent with the model which include the lags of the coal and palm oil variables. Moreover, the results reveal that palm oil price affects poverty for three years before the effect subsides thus having larger cumulative effect than suggested in the main results. The regression results with time-trend interaction are also consistent with the main results in terms of the sign of the estimated impacts. This suggests that the price effect is more important than the general boom effect. Lastly, the province-level estimates do not have any statistically significant coefficient. While the estimation is problematic because it uses a substantially smaller sample, it also suggests that the effects of commodity prices are only concentrated in the districts that have those resources.

7. Discussion

This section relates the results to the theory and explores several possible explanations for the main findings. In the case of palm oil, the price has a statistically significant negative impact on district poverty rate and a positive impact on employment, but no statistically significant impact on household expenditure, inflation rate, and average wages in districts that produce palm oil. Furthermore, it significantly increases wages in the 25th and 75th percentiles, while also significantly increases the wage of professions that are directly related to the sector, including agricultural workers and labourers. These findings confirm some of the predictions of the theory.

Firstly, a price increase can benefit the poor through the direct mechanism by creating employment and increasing wages. This mechanism is supported by the findings that total employment effect is positive and significant in districts that produce palm oil. This is also confirmed by the positive impact on agricultural workers and labourer wages. However, the average real wage and average real household expenditure are not significantly affected. The first possible explanation is there might be enough people who are looking for jobs in palm oil districts, similar to 'labour surplus' in Lewis (1954) model, that the overall average wage does not need to increase to attract workers from other districts. If this is the case, it is still a good outcome, because commodity price increase creates employment opportunity for people who are otherwise unemployed. Another possible explanation is these newly created jobs employ local residents that used to commute to other districts to work. Since the new jobs are mainly in the low-paying professions (Figure 11), the average real wage and average household expenditure do not need to increase significantly. Still, the price boom appears to disproportionately benefit people in the lower end of the income distribution, as shown by the wage distribution impacts.

Another possible explanation for the limited impact on average household expenditure it the quality of jobs that are created in the palm oil sector. A study by Coxhead and Shrestha (2016) finds that a higher intensity of palm oil productions predicts diminished formal employment, which in turn predicts lower earnings. While I do not find evidence for lower earnings, the informal employment created by the palm oil sectors might partly explain the limited estimated impact on average per capita expenditure and average wage.

Secondly, the indirect mechanism through spillover effect into other sectors appears to be weak. Wages in other sectors are not significantly affected by the palm oil price. The inflation effect of palm oil price also appears to be neutral. Again, this suggests that the number of people looking for jobs in the district is sufficient to fulfil the increased labour demand in the palm oil sector so that other sectors do not need to increase wages to retain or attract workers. This is not surprising considering Indonesia is a lower-middle-income country which has not passed the Lewis turning point during the period. While it is interesting to speculate whether the indirect mechanism, through fiscal or institutional impacts, plays a role in alleviating poverty, there is not enough information to do so.

For coal, an increase in its price has a negative and significant impact on the district poverty rate and positive impacts on local average per capita expenditure, inflation, and the average real wage in districts that have coal reserve. Coal has a positive effect on all other outcomes except for employment and wage distribution. Unlike palm oil, the direct mechanism in the coal sector leads to an increase in overall district average wage without significantly affecting total employment. Employment impact is only positive and significant in the mining sector itself, which does not generate large employment in the first place, and the transportation sector. This significant impact on real wage might be because the kinds of jobs that are created are likely to have wages that are above the average district wage. The results in Table 5 confirm this hypothesis as it shows that coal price only significantly affects the wage of the clerical and related profession. This profession already has an average wage that is higher than the overall average wage nationally, both in 2007 and 2013 (Figure 11).

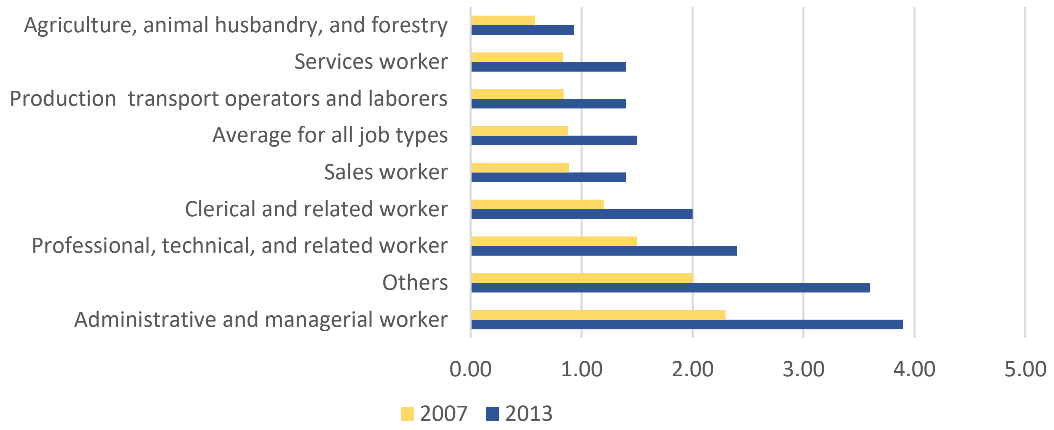

Figure 11. The average wage in each job type, all districts between 2007 and 2013 (in million Rupiah)

Source: author's calculation based on SAKERNAS data. Notes: Data is calculated as the average of all district average wage, not at the individual level.

Another possible explanation is the local Dutch disease effect, which suggests that the mining sector increases the district real wage (across all sectors) to attract workers from other tradable sectors in the district, such as manufacturing. This explanation is supported by the evidence that coal price has a negative impact on manufacturing employment. However, there is no evidence that coal price increases the mining sector real wage more than any other sector.

Migration can also partly explain these results. As mentioned, this study only measures the wage and employment impacts, not migration impact. It is possible that an increase in the demand for workers in other professions can be fulfilled by local residents, but not in the clerical and related profession. This leads to an increase in wage in this profession to attract workers from outside the district. Moreover, since the wage in this profession is higher than the overall average wage, this profession probably requires a certain level of education or training, which might not be available among the local residents. If that is the case, the increase in average per capita household expenditure and average wage may be partly the result of higher than average paid migrants into the district.

It also is important to note that the inflation impact of coal price is positive and significant. This impact, however, does not neutralise or reverse the poverty alleviation impact of the price. This suggests that the poor still benefit from the positive price shock even though the average wage of low paying professions are not significantly affected. This can be the result of new employment opportunities to previously unemployed residents or can also be the results of an indirect mechanism. Coal is a natural resource that is regulated under Indonesia's revenue-sharing arrangement. This means that the local governments of districts that produce coal receive sizeable extra revenue when compared with districts that do not. If they use the extra natural resource revenue from the price increase to improve public service, local residents can benefit indirectly from the sector and help the district in reducing the poverty rate.

There are two caveats to these results. The first caveat is that this study does not attempt to measure the impact on capital owners. Just like any other natural resources, coal and palm oil create a rent on the immobile factors. In the case of coal, the immobile factor is the mine and the area surrounding it, and in the case of palm oil, it is the land that is used as oil palm plantation. In both cases, the owners of the immobile factor should collect the rent from commodity production. This means the owners of these immobile factors should disproportionately be affected by commodity prices. While these impacts are undeniably important, they are not the focus of this study. Data that can measure the outcome for this impact, such as land prices, are also not available at the district level. Instead, this study offers an observation on the impact of commodity prices on labour, the mobile factor.

The second caveat is the possibility of a demand bust following the boom. The discussion so far has been focusing on the scenario of a boom, a period of record-high prices for coal and palm oil. The model assumes that the impact of a commodity price decrease is symmetrical to a price increase. Whether this is true or not is an empirical question. Nevertheless, the results suggest that a fall in commodity price by the same size as the increase can reverse the poverty alleviation impact of the boom.

How do the findings of this study compare with other similar studies? As discussed, the findings of previous studies on the sub-national poverty impact of commodity production have been mixed. A review of fifteen sub-national panel studies on the impact of the extractive sector on poverty by Gamu et al. (2015) discovers that eight studies find positive impacts, four studies find negative impacts, and three studies find mixed impacts. These studies use various methods and country cases and are not directly comparable to this study. However, the findings in this study are unique because it focuses on the impact of international prices. This study is also different because it provides evidence that while mining and agricultural commodity both have poverty alleviation impact, they work through different mechanisms.

8. Conclusion and policy implications

This study estimates the welfare impact of coal and palm oil prices on districts that produce them in Indonesia. To do so, I exploit the within-country cross-sectional variation in exposure to each commodity, interacted with exogenous changes in global commodity prices. Each district is affected by coal and palm oil prices at a different level depending on how much it produces (i.e. exposed to) them. Firstly, I establish the mechanisms through which global commodity prices can affect poverty, per capita household expenditure and wages. I identify two possible mechanisms, the first one is through direct employment effect, and the second one is through spillover effect into other sectors. Secondly, I estimate the impacts using panel fixed-effect regression on district-level data in Indonesia.

I find that a price increase of coal and palm oil both have significant poverty alleviation impact. As mentioned, the impact depends on the exposure level of the district to each commodity. For example, from 2007 to 2008, a 0.25 log point of palm oil price increase (from USD780 per metric ton to USD948 per metric ton) is estimated to reduce the poverty rate by 1.11 percentage points in an average palm oil district with plantation size of 36 thousand hectares. Similarly, coal price increase during the same period by 0.71 log points (from USD64 per ton to USD123 per ton) is estimated to decrease poverty rate by 1.26 percentage points in a coal district with coal reserve of 826 million metric ton.

A significant effect on total district employment is only found in the case of palm oil, but sectoral employment effects are significant in sectors and professions that are directly related to both commodities (e.g. mining employment in the case of coal). I also find that average household expenditure, inflation and average wage are only significantly affected by coal price, but not palm oil price, in districts that produce them. Moreover, palm oil price affects the wage distributions at district 25th and 75th percentile wage, while coal price does not. These findings are robust in various specifications. Similar to the employment impact, the palm oil price has a positive impact on wage in professions that are closely related to the sector, including agricultural workers and labourers. In comparison, coal price only significantly affects the wage of the clerical and related profession.

These findings suggest that in the case of palm oil, direct employment effect is more important with minimal spillover effect into other sectors. A possible explanation for the not significant average wage impact is the sector may have employed local residents previously looking for work. Thus the average wage does not need to change. One of the consequences is palm oil price increase disproportionately benefits the poor by creating employment, albeit in a lower-paying profession such as agricultural worker. In the case of coal, the significant average wage and household expenditure impact of coal price suggests that the sector create jobs that pay relatively higher wages. The findings also suggest that the sector may have attracted migrants from outside the district to fulfil increased demand for highly skilled workers. Furthermore, coal district enjoys natural resource revenues that are shared between the central government and the local government. Coal districts can use natural resource windfall to improve welfare by increasing public service.

These findings also highlight the differences between coal and palm oil, two important export commodities for Indonesia. Coal is a point source resource, and palm oil is a diffuse resource. Although caution must be taken in making broad generalisations in regard to these two kinds of resources, the findings show that they are different. Not only are they different in terms of welfare, employment, and wage impacts, they also use different mechanisms to affect poverty and welfare in their local areas.

The results also show the need for further study to directly measure the employment, migration, capital return, and fiscal impacts of commodity prices. These topics are not within the scope of this study, but they are an integral part of understanding the mechanism of commodity booms. Understanding them will help commodity producers, many of which are developing countries, to formulate the appropriate policy response to commodity booms.

The findings of this study have several policy implications. Firstly, the district governments have an important role in optimizing the benefit of commodity booms. Much of the policy discussion today still focuses on national policy for natural resources. My results show that the welfare impacts of commodity prices are significant at the local level, which means local government need to have the willingness and capability to maximise the welfare benefit of the boom.

Secondly, while the palm oil sector is not an extractive sector, a scheme of revenue sharing similar to other extractive natural resources might be beneficial. So far, the closest scheme that has been in effect for palm oil is the automatic export tax based on the international price. However, the export tax is a national scheme and is geared to make sure a sufficient level of domestic supply for palm oil.

A revenue-sharing scheme with the local governments is needed so that they can improve public service and enhance the indirect mechanism of the palm oil sector through the fiscal effect.

Thirdly, the national and local government need to respond properly to the global trend towards better environmental protection. I have not touched on the issue of environment in this paper, but both coal and palm oil are in the centre of environmental debates around the world. This trend is a good thing and should not be fought, but the government must carefully assess the welfare impact of any policy to respond to this trend since both coal and palm oil are central to people's livelihood in many parts of the country. Lastly, while this study focuses on the booming part of the commodity price cycle, policies to prepare for the bust must start before the boom ends. If the local and national government are not prepared, the welfare gain from the boom can disappear in a painful adjustment period.

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10. Appendix A: Data

10.1. Main explanatory variables

- Palm oil and coal international price
  Data for the international price of both commodities are from the World Bank pink sheet, available from the World Bank website. Data are available from 1960 both at monthly average and annual average, and in nominal and real 2010 United States dollar. For palm oil, the World Bank uses CIF Rotterdam price. For coal, the price is the simple average of Australia and South Africa coal price, because they have the longest time-series data. The study uses the nominal price of both commodities so that they can be converted into Rupiah.
- Oil palm plantation size
  Plantation size data are collected by the Directorate General of Estate Crops in the Department of Agriculture and Indonesia statistical agency, *Badan Pusat Statistik* (BPS). For 2007 to 2013, the data is available through the World Bank's Indonesia Database for Economic and Policy Research (Indo-DAPOER) in their main databank.
- Coal reserve
  Data for district-level coal reserve come from GeoRIMA (Geological Resources of Indonesia Mobile Application), an android based mobile application developed by the Ministry of Energy and Mineral Resources. GeoRIMA is the only publicly available data for coal and mineral reserve at the district level in Indonesia. As a mobile application, GeoRIMA is relatively easy to access, but its data must be extracted manually. It includes data of potential reserve of mineral, coal and geothermal at the district and provincial level. The downside is, the application only provides data from 2013 to 2016, so the pre-boom coal reserve data is not available.

10.2. Outcomes

- District poverty rate
  The poverty rate is measured as the share of district population living below an expenditure-based poverty line, roughly equal to $25 US dollar per person per month. The rate is estimated using BPS' National Socioeconomic Survey (SUSENAS), implemented at least annually and is representative at the district level. All poverty rate data are taken from Indo-DAPOER. In cases where there were district splitting during the period, I recalculate the poverty data into the 2007 district configuration by summing the number of people under the poverty line of the split districts and divide it by the total population of the split districts.
- Real household expenditure per capita
  It is calculated from SUSENAS as the sum expenditure from the consumption module divided by the household members. All data are also taken from Indo-DAPOER. In the case of district splitting, I use the simple average of the split districts. It is deflated into real value using the CPI of the closest district where data are available (see inflation rate data description).
- Inflation rate
  The inflation rate is calculated using CPI data, collected by BPS for 71 cities and districts. BPS periodically increase the number of cities and districts where they collect the CPI data, but the number was 71 throughout the study period. If CPI data are not collected for the district, I assign the inflation rate of the closest district (by the physical distance of district central point) where inflation data are collected.
- District total employment
  Total employment is the number of people employed within a district. Employment includes both the formal and informal sectors, as well as both paid and unpaid. It is calculated from the National Labour Force Survey (SAKERNAS) data, collected by BPS at least annually and is representative at the district level since 2007. The survey is conducted at the individual level and asks questions about employment and wages. Data are available from Indo-DAPOER.
- District average real wage
  The average real wage is calculated using the monthly wage paid to people employed in a paid job, both formal and informal. It only includes wages received and excludes other sources of income, such as profit or rent. The average value is weighted using the individual weight provided by BPS. It is calculated from SAKERNAS data and converted into real value using CPI.
- 25^{th} and 75^{th} percentile real wage
  Like average real wage, it is calculated using monthly wage paid to people employed in a paid job. To get each percentile value, I use the individual weight provided by BPS. The data are also from SAKERNAS.
- Employment by sector
  It is the district total number of people employed in each of the nine sectors. Data are from SAKERNAS, available from Indo-DAPOER.
- Average real wage by sector
  It is also calculated using monthly wage paid to people employed in a paid job. A weighted average value in each sector is calculated using the provided individual weight. Data are from SAKERNAS.
- Average real wage by profession

It is similar to average real wage by sector, but individuals are grouped based on professions instead of sectors. Data are from SAKERNAS.

10.3. Control variables

- Over-15 literacy rate
  Calculated from SUSENAS, via Indo-DAPOER.
- Agricultural and manufacturing employment share
  Calculated from SAKERNAS, using standard classification, via Indo-DAPOER
- Household to electricity, sanitation, and clean water
  Each one is calculated from SUSENAS, as a share of household in the district, via Indo-DAPOER.

11. Appendix B: Other robustness checks

11.1. Sectoral nominal wage as outcomes

Table 9 The effect of coal and palm oil price on nominal wage by sectors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variables	Agriculture	Mining	Manufacturing	Utility	Construction	Trade, Hotel & Restaurant	Transport and Communication	Finance	Social
Exposure to CPO x log CPO price	0.018*	-0.003	0.017	0.005	0.012	-0.005	0.001	0.039*	-0.011
	(0.011)	(0.023)	(0.016)	(0.030)	(0.009)	(0.010)	(0.011)	(0.021)	(0.007)
Exposure to coal x log coal price	0.008	-0.014	0.006	0.071	-0.005	0.011	0.014	0.042	0.003
	(0.010)	(0.015)	(0.015)	(0.044)	(0.017)	(0.011)	(0.012)	(0.030)	(0.007)
Observations	3090	2699	3050	2164	3074	3078	3073	2940	3094
District & island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	449	445	446	444	448	449	448	447	449
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013
Controls: Literacy rate, agricultural employment share, manufacturing employment share, household access to electricity, sanitation, and clean water									

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. **** is significant at the 1 per cent level*; *** is significant at the 5 per cent level*; ** is significant at the 10 per cent level*

11.2. Using real commodity price, but deflated using district CPI

Table 10 The effect of coal and palm oil price (real, deflated using district-level CPI) on welfare (Panel Fixed-effect OLS, with control variables)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile wage	Log of 75th percentile wage
Exposure to CPO x log CPO price	0.217**	0.013**	-0.358***	0.005	0.018***	0.034***	0.018***
	(0.098)	(0.006)	(0.084)	(0.003)	(0.006)	(0.008)	(0.006)
Exposure to coal x log coal price	-0.251***	0.019	0.205***	-0.006	0.023***	0.017**	0.022***
	(0.057)	(0.013)	(0.077)	(0.003)	(0.006)	(0.008)	(0.007)
Observations	3095	2652	2666	3095	3094	3089	3094
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	449	449	446	449	449	449	449
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2008-2013	2007-2013
Controls: Literacy rate, employment share in agriculture and manufacturing (except for total employment), household access to electricity, sanitation, and clean water							

[1]Excludes 2008 data; [2]Excludes 2007 data; Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. **** is significant at the 1 per cent level*; *** is significant at the 5 per cent level*; ** is significant at the 10 per cent level*

11.3. Exposure level adjusted by population

10.3.1 Main outcome

Table 11 The effect of coal and palm oil price (real, deflated using district-level CPI) on welfare (Panel Fixed-effect OLS, with control variables)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile wage	Log of 75th percentile wage
Exposure to CPO x log CPO price	-4.579*	-0.032	-1.184	0.537***	0.451**	0.491*	0.593***
	(2.587)	(0.148)	(3.443)	(0.170)	(0.204)	(0.258)	(0.180)
Exposure to coal x log coal price	-97.378**	2.820	122.499***	3.159	0.126	0.364	0.242
	(46.036)	(7.957)	(26.831)	(2.865)	(3.471)	(4.651)	(3.442)
Observations	3083	2627	2636	3083	3064	3059	3083
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	444	444	444	444	444	444	444
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2008-2013	2007-2013

Controls: Literacy rate, employment share in agriculture and manufacturing (except for total employment), household access to electricity, sanitation, and clean water

[1]Excludes 2008 data; [2]Excludes 2007 data; Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is *significant at the 1 per cent level*; **** is *significant at the 5 per cent level*; *** is *significant at the 10 per cent level*

Note: Exposure to CPO = Size of oil palm plantation in the district in 2007 divided by population in 2007
Exposure to coal = Size of district coal reserve in 2013 divided by population in 2007

10.3.2 Sectoral employment as outcomes

Table 12 The effect of coal and palm oil price on sectoral employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variables	Agriculture	Mining	Manufacturing	Utility	Construction	Trade, Hotel & Restaurant	Transport and Communication	Finance	Social
Exposure to CPO x log CPO price	1.214***	0.013	0.954	-0.281	0.045	-0.031	-1.110	0.591	1.454***
	(0.381)	(1.625)	(0.971)	(2.452)	(0.697)	(0.735)	(0.927)	(1.379)	(0.508)
Exposure to coal x log coal price	13.963***	63.686***	-31.711	-48.254	19.203	24.291*	20.588	64.412	20.861*
	(4.211)	(20.933)	(44.358)	(59.629)	(13.361)	(12.582)	(13.519)	(45.296)	(10.955)
Observations	3090	2699	3050	2164	3074	3078	3073	2940	3094
District & island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	449	445	446	444	448	449	448	447	449
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013

Controls: Literacy rate, agricultural employment share, manufacturing employment share, household access to electricity, sanitation, and clean water

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is *significant at the 1 per cent level*; **** is *significant at the 5 per cent level*; *** is *significant at the 10 per cent level*

11.4. Other measures of CPO exposure, based on average for the whole period and the final year

Table 13 The effect of coal and palm oil price on welfare (Panel Fixed-effect OLS, with control variables), CPO exposure based on average 2007-2013 plantation size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile wage	Log of 75th percentile wage
Exposure to CPO x log CPO price	-0.433***	0.002	0.148	0.005	0.009	0.019**	0.014*
	(0.116)	(0.006)	(0.135)	(0.006)	(0.007)	(0.009)	(0.007)
Exposure to coal x log coal price	-0.265***	0.020*	0.237*	0.004	0.012*	0.013	0.010
	(0.083)	(0.010)	(0.121)	(0.007)	(0.006)	(0.010)	(0.007)
Observations	3095	2652	2666	3095	3094	3089	3094
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	449	449	446	449	449	449	449
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2008-2013	2007-2013

Controls: Literacy rate, employment share in agriculture and manufacturing (except for total employment), household access to electricity, sanitation, and clean water

[1]Excludes 2008 data; [2]Excludes 2007 data; Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is s*ignificant at the 1 per cent level*; **** is s*ignificant at the 5 per cent level*; *** is s*ignificant at the 10 per cent level*

Table 14 The effect of coal and palm oil price on welfare (Panel Fixed-effect OLS, with control variables), CPO exposure based on 2013 plantation size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile wage	Log of 75th percentile wage
Exposure to CPO x log CPO price	-0.440***	0.003	0.115	0.004	0.009	0.020**	0.013*
	(0.114)	(0.006)	(0.131)	(0.006)	(0.007)	(0.010)	(0.007)
Exposure to coal x log coal price	-0.267***	0.019*	0.244**	0.004	0.012*	0.014	0.011
	(0.082)	(0.010)	(0.121)	(0.007)	(0.006)	(0.010)	(0.007)
Observations	3119	2652	2666	3119	3094	3089	3094
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	450	449	446	450	449	449	449
Sample period	2007-2013	2007-2013	2007-2013	2007-2013	2007-2013	2008-2013	2007-2013

Controls: Literacy rate, employment share in agriculture and manufacturing (except for total employment), household access to electricity, sanitation, and clean water

[1]Excludes 2008 data; [2]Excludes 2007 data; Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is s*ignificant at the 1 per cent level*; **** is s*ignificant at the 5 per cent level*; *** is s*ignificant at the 10 per cent level*

11.5. Include 2008 for household expenditure regression

In the main model, 2008 data for household expenditure are excluded because there are irregularities in the data. Indo-DAPOER also excludes the 2008 data.

Table 15 The effect of coal and palm oil price on welfare (Panel Fixed-effect OLS, with control variables), CPO exposure based on 2013 plantation size

	(1)	(2)
Dependent variables	Log real Household expenditure (exclude 2008)	Log real Household expenditure (include 2008)
Exposure to CPO x log CPO price	0.001	0.001
	(0.006)	(0.005)
Exposure to coal x log coal price	0.020**	0.011**
	(0.010)	(0.005)
Observations	2652	3119
District and Island fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Districts	449	450
Sample period	2007-2013	2007-2013

Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is *significant at the 1 per cent level*; **** is *significant at the 5 per cent level*; *** is *significant at the 10 per cent level*

11.6. All variables in first-difference form

The model exploits the time-series variation in the data (in a panel setting). First-differenced estimates make sure that time-series issues are under control.

Table 16 The effect of coal and palm oil price on welfare, all variables first-differenced (Panel Fixed-effect OLS, with control variables)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile wage	Log of 75th percentile wage
Exposure to CPO x log CPO price	-0.054	0.039***	1.167***	0.005**	0.013***	0.021***	0.020***
	(0.043)	(0.004)	(0.082)	(0.003)	(0.004)	(0.005)	(0.004)
Exposure to coal x log coal price	-0.245***	0.015	0.448**	-0.001	0.008	0.001	0.005
	(0.050)	(0.014)	(0.185)	(0.005)	(0.006)	(0.009)	(0.006)
Observations	2662	1772	2214	2666	2637	2632	2637
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Districts	450	446	446	450	446	446	446
Sample period	2008-2013	2009-2013	2008-2013	2008-2013	2008-2013	2008-2013	2008-2013
Controls: Literacy rate, employment share in agriculture and manufacturing (except for total employment), household access to electricity, sanitation, and clean water							

[1]Excludes 2008 data; [2]Excludes 2007 data; Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is *significant at the 1 per cent level*; **** is *significant at the 5 per cent level*; *** is *significant at the 10 per cent level*

11.7. Autoregressive model

This specification includes the lag of the dependent variable as a predictor. To avoid the Nickell bias, the regression was done without including the fixed effects.

Table 17 The effect of coal and palm oil price on welfare, autoregressive model, without fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variables	Poverty rate (%)	Log real Household expenditure[1]	Inflation (%)[2]	Log total employment	Log average real wage	Log of 25th percentile wage	Log of 75th percentile wage
L1 of Dependent variable	0.63828***	0.76237***	0.10061***	0.53241***	0.81610***	0.80778***	0.81529***
	(0.131)	(0.017)	(0.014)	(0.152)	(0.017)	(0.019)	(0.020)
Exposure to CPO x log CPO price	-0.00858*	0.00028***	0.00027	0.00042	0.00016***	0.00046***	0.00019***
	(0.005)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Exposure to coal x log coal price	-0.01164*	0.00055***	0.00101	-0.00080	0.00027**	0.00032**	0.00027**
	(0.006)	(0.000)	(0.002)	(0.001)	(0.000)	(0.000)	(0.000)
Observations	2671	1776	2223	2671	2646	2640	2646
District and Island fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	No	No	No	No	No	No	No
Districts	450	446	446	450	446	446	446
Sample period	2008-2013	2009-2013	2008-2013	2008-2013	2008-2013	2008-2013	2008-2013
Controls: Literacy rate, employment share in agriculture and manufacturing, household access to electricity, sanitation, and clean water							

[1]Excludes 2008 data; [2]Excludes 2007 data; Notes: robust standard errors clustered by districts are in parentheses. Exposure to CPO is the size of oil palm plantation in the district in log form. Exposure to coal is the size of coal reserve in the district in log form. ***** is s*ignificant at the 1 per cent level*; **** is s*ignificant at the 5 per cent level*; *** is s*ignificant at the 10 per cent level*