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Local economic impacts of an unconventional energy boom: the coal seam gas industry in Australia*

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Complementing the scarce economic literature about local impacts of energy extraction booms, this paper empirically investigates economic outcomes related to the new coal seam gas (CSG) industry located across southern Queensland. This Australian state has seen an unprecedented inflow of investments into the extraction of this previously unexploited unconventional natural gas over the last decade. We analyse census data to study income and employment effects associated with the CSG boom, exploiting the quasi-experimental conditions provided by CSG extraction areas (treatment regions) and regions without this development (control regions). Findings show that treatment regions have higher income growth than control areas during 2001–2011 for families residing locally and for individuals present on census night. Employment in the mining sector also shows higher growth as has non-mining employment in some areas. We include comparisons between CSG areas with no major mining history (the Surat basin) and CSG areas where mining was important before the CSG boom (the Bowen basin), to better understand boom effects in areas with different initial mining industry importance in their economies. Local job multipliers are also analysed for Surat basin CSG areas, where positive impacts (job spillovers) are restricted to construction and professional services jobs, while agricultural jobs have decreased.

Key words: Australia, coal seam gas, mining, resource boom, unconventional natural gas.

1. Introduction

As the world economy is in a phase of large and increasing demand for energy and new technology has eased the costs of extraction and transportation of natural resources, different regions across the globe are experiencing new investments targeting the extraction of fossil fuels. This energy scenario has converted previously uneconomic reservoirs into new potential sources of

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profit, transforming regions that were not related to fossil fuel extraction to the locus of large investments in drilling and mine openings. These new sources of wealth are commonly seen by markets and regional planners as employment generators and income boosters that can improve the living standards of a region. However, resource windfalls are not always translated to positive outcomes for communities hosting the resource extraction industry, as most of the generated income can flow out of the region as non-resident workers spend part of their incomes elsewhere, and employment numbers can be negatively affected in non-mining sectors. The so-called 'resource curse' is an outcome generally associated with national effects, but that can also occur in local areas (James and Aadland 2011).

Compared to the growing body of literature focusing on the economic impacts of resource windfalls at national levels, fewer studies have evaluated its potential impacts within countries. This is an important gap considering that, empirically, economic evaluations of resource booms can be much more reliable and informative than multinational studies (van der Ploeg 2011). Considering this point and improving empirical identification strategies by using the quasi-experimental conditions provided by resource endowments, recent economic studies have paid more attention to understanding the local consequences of resource booms. Starting with Black *et al.* (2005), who analyse local economic impacts of the coal boom and bust in the US, a handful of studies have provided evidence about economic effects associated with resource extraction booms at local levels (Marchand 2012; Weber 2012; Caselli and Michaels 2013). Our study follows this quasi-experimental literature and complements it by providing an analysis of impacts associated with a current boom of a newly exploited unconventional natural gas in Australia: coal seam gas (CSG), also known as coal bed-methane.

The CSG boom in Australia has occurred principally across southern Queensland, a region that during the last decade has seen an unprecedented inflow of investments into the extraction of this fossil fuel. Empirically exploiting the quasi-experimental conditions of the CSG development across the region, and using 2001 and 2011 census data at statistical local areas (SLAs) level (subregions within the state), we evaluate the boom by analysing how income and employment indicators behave between treatment regions (areas where CSG wells have been largely dug) and control regions (areas with no CSG development). In addition, considering the location of the CSG industry across the state (clustered over two basins: the Surat and Bowen basins), we also provide insights into the differential effect of the boom on areas where mining was not a common feature in the past (the Surat basin) versus regions with a mining industry that was well established before the CSG boom started (the Bowen basin). By focusing on these basins, we provide new evidence that complements previous studies analysing the impacts of resource extraction industries across these regions (Rolfe *et al.* 2011; Rolfe 2013).

2. Energy boom, local impacts and the CSG case

As a result of global economic and population growth, prices of non-renewable resources such as fossil fuels have risen during last decades. This scenario, together with a reduction in transportation costs (spurred by gas liquefaction technology and the use of large vessels for intercontinental trade) and new technologies for extraction (translated into more efficient drilling and extraction processes) has seen unexploited reservoirs of traditional and unconventional fossil fuels converted to profitable sources of energy. Under these conditions, unconventional natural gas sources such as shale gas, tight-gas and CSG have become new and increasingly important resources within the energy industry.

As unconventional gas becomes profitable to exploit, regions that traditionally were not part of the energy industry locus are becoming strategic areas of production. This new source of wealth for richly endowed regions has raised questions about the real benefits and costs that resource extraction can bring. Past experience has shown that resource windfalls can bring important benefits in terms of employment, income and trading gains (Gregory 2012); however, economic outcomes are not always beneficial for nations or to the communities hosting the resource extraction industry, as consequences of the so-called natural resources curse and other unintended socioeconomic outcomes (van der Ploeg 2011).

The economic impacts of a resource extraction boom can create social concerns at national and regional scales. Nationally, concerns can relate to international corporations that export resource extraction-based profits overseas. Regionally, concerns often arise about the capacity of regions to retain resources (either the resource itself or the revenues generated by it) that are otherwise likely to flow to capital cities or other non-extractive regions of the country. Abstracting from the potential environmental externalities that can disrupt the functioning of local communities, common economic outcomes to evaluate in resource extraction regions are local jobs creation, both within the resource sector and in non-mining sectors (Marchand 2012), personal income (Weber 2012) and housing affordability (Hajkowicz *et al.* 2011).

Theory suggests that the main direct local impact of a resource boom is a sharp increase in the demand for labour to cover the expanding extractive sector, which will tend to rapidly increase local wages (Corden and Neary 1982). These potential employment and income effects are also likely to generate spillovers into other sectors as the additional income now available in local economies will tend to increase the consumption of non-tradables (local goods), generating employment in these sectors. By contrast, during a resource boom, adverse employment effects are likely in the local tradable sectors, namely manufacturing and agriculture, as potentially higher wages paid by mining can produce a migration of labour from these sectors to the extraction industry (Marchand 2012). Additional income effects, besides potential higher wages paid by the extraction firms, can be generated by the inflow of financial assets generated by these firms as local taxes and as payments for landowners' compensation. This last source is more likely to happen in the case of natural gas and oil, where wells are distributed across space and therefore across multiple private land sites. Although other socioeconomic consequences of resource windfalls, such as housing affordability, are likely to arise in local areas, we focus this study on testing these primary economic outcomes – income and employment – by employing ex-post econometric models that avoid the assumptions of ex-ante input–output models and allow us to observe changes over time (Kilkenny and Partridge 2009; Weber 2012).

2.1. Empirical evidence of resource windfalls' local impacts

The empirical economic literature includes many studies examining the economic impacts of natural resource windfalls at the national level, commonly employing multicountry samples in econometric models attempting to explain the occurrence, causes and potential consequences of the natural resource curse – see Frankel (2010) and van der Ploeg (2011) for surveys of this literature. In contrast, the availability of ex-post studies evaluating local impacts of resource booms is much less abundant. This is an important gap in the literature, as it has been stated that to better understand the real economic effects of natural resource windfalls 'The road forward might be to exploit variation within a country where variables that might confound the relationship between resources and macroeconomic outcomes do not vary and the danger of spurious correlation is minimized' (van der Ploeg 2011, p. 381). Thus, the main advantage of within-country studies is that they do not present the common confounding factors of cross-country models, such as openness to trade and institutional/political differences.

Although less problematic than cross-country models, the empirical identification of resource boom impacts remains a challenge in local-level studies. Providing a novel approach to address this issue, Black *et al*. (2005) use the quasi-experimental conditions of the coal industry in the US to evaluate the impacts of the coal boom and bust of the 1970s and 1980s across US counties. Based on the percentage of earnings of local economies coming from the coal industry, these authors find that the coal boom translated into more jobs and income for local dwellers, while the bust decreased economic growth. Using a similar approach, Marchand (2012) analyses local effects of the energy price boom (and bust) in provinces of Western Canada, also finding higher income growth and employment levels in areas hosting the energy industry versus comparable provinces elsewhere in Canada during the boom.

Also using quasi-experimental frameworks, Caselli and Michaels (2013) find for Brazilian municipalities that once oil was discovered and extraction had started, the services sector of the local economy expanded and household income increased by 10 per cent (Caselli and Michaels 2013). Analysing a different fossil fuel commodity, Weber (2012) studied the natural gas boom in the US, observing how expansion of gas production affected employment, income and poverty across counties in the states of Wyoming, Texas and Colorado between 1998 and 2008. He found that the natural gas boom produced a mild income effect across counties hosting the industry, which appeared to be more focused on households in the upper half of the income distribution. On employment, Weber (2012) found that for each extra million dollars generated by the gas industry, there were 2.35 more jobs generated in the average production county.

To contribute to this literature and shed some light on a current resource boom, we employ a quasi-experimental approach to study the CSG development in Australia. We differ from these previous studies in two points. First, we analyse a previously unexploited unconventional natural gas (CSG). Second, we compare the impacts of CSG development on a region that has a history of mining (the Bowen basin) with that of a region in which little mining has previously occurred (the Surat basin).

2.2. Australia and the CSG industry in Queensland

Mining has historically played a major role in the Australian economy and continues to do so (Schandl *et al.* 2008). Mining exports have grown from around a third to around a half of all Australian exports (by value) over recent decades (Reeson *et al.* 2012). The mining boom from the early 2000s to the time of writing has raised concerns amongst policy analysts over how the boom has affected the nation, beyond the profit margins of individual companies and their shareholders (Richardson and Denniss 2011). Debates over the two/three speed economy effect (Corden 2012) and distributing royalties to regions are examples of public concern over the need to carefully manage resource endowments to ensure a wider distribution of economic benefits (Measham *et al.* 2013). Accordingly, the new booming CSG industry in Queensland offers many opportunities and challenges.

In Australia, Queensland possesses around 95 per cent of the country's total economic demonstrated resources (EDR) of CSG. This reservoir was reported to be 15.1 trillion cubic feet in 2008 (Geoscience Australia (GA) and Australian Bureau of Agricultural and Resource Economics (ABARE) 2010). Despite this large reservoir, CSG has only recently become part of the resource extraction portfolio in Queensland. As a consequence of high international prices and better technologies, commencing in early 2000s, the CSG industry started operating in different areas of the state, but especially in the Surat and Bowen basins (Figure 1). The Surat basin encompasses more than 60 per cent, and the Bowen basin around 35 per cent of Australia's total CSG EDR known by 2008 (GA and ABARE 2010). This CSG boom has meant the development of over 4000 wells in Queensland to 2011, but the boom is far from over. As of 2008, only around 1 per cent of the total

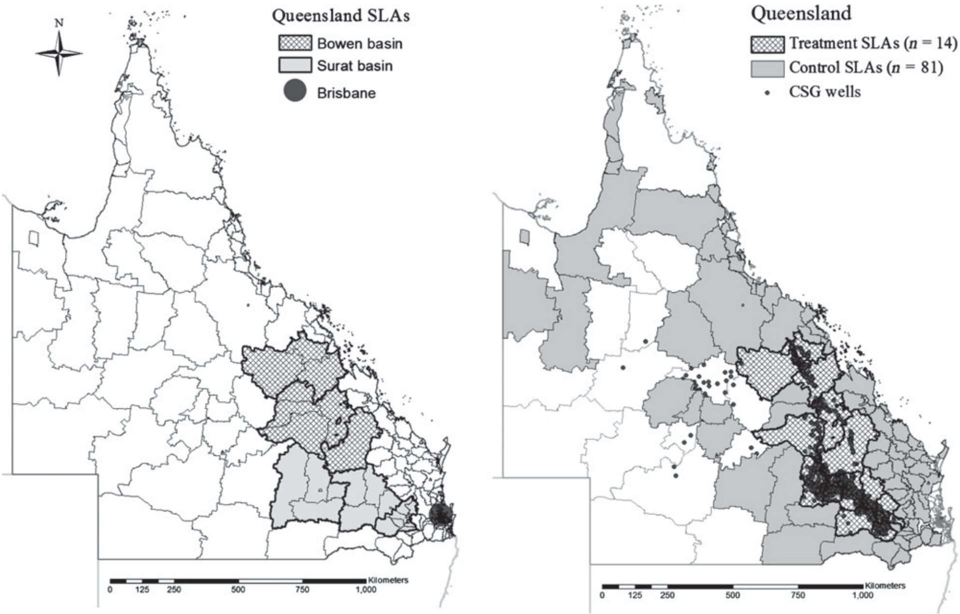

Figure 1 Queensland statistical local areas (SLAs) and location of Bowen and Surat basins, control and treatment groups, and coal seam gas (CSG) wells to 2012. The Bowen basin is defined by the LGAs of Banana, Central Highlands, Isaac and Woorabinda. The Surat basin is defined by the local government areas of Maranoa, Toowoomba and Western Downs (bolded borders). Source: Own elaboration with data from Australian Bureau of Statistics (2012) and Department of Natural Resources and Mines of the Queensland Government (2012).

reservoir had been exploited (GA and ABARE 2010) and new evidence has suggested that the CSG EDR can even double previous estimates (GA 2012).

The enormous growth in CSG development observed since the mid-2000s can be considered an important boom for both the Surat and Bowen basins, and is worth analysing in detail. For our analysis, we consider regions where the CSG industry is located as 'treatment areas' receiving this exogenous shock (CSG boom) and contrast their economic outcomes to comparable regions of Queensland not participating in the CSG boom. In addition, as mentioned, one important attribute of our case study is the differences that the Surat basin has compared with the Bowen basin in terms of mining history. Given their contexts, we can evaluate the economic impacts of the boom over areas that had no major mining activity, namely the Surat basin, to areas with a large mining presence before the boom, which is the case of the Bowen basin.

3. Methods

To evaluate local economic impacts associated with CSG development in southern Queensland, we exploit the empirical quasi-experimental conditions that this energy extraction development presents. This boom can be considered a quasi-experiment for evaluation purposes because of three main

Table 1 Descriptive statistics and coal seam gas (CSG) wells across groups and for the whole state

	Treatment SLAs on Surat Basin (n = 8) Mean (SD)	Treatment SLAs on Bowen Basin (n = 6) Mean (SD)	Control group SLAs (n = 81) Mean (SD)	All Queensland
Median per capita income, 2001 ($, weekly)	355.1 (97.9)	516.2 (115.9)	312.3 (82.2)	359
Median family income, 2001 ($, weekly)	746.3 (122.1)	1205.5 (246.2)	727.1 (182.7)	871
Share of agriculture in total employment, 2001	0.394 (0.105)	0.193 (0.117)	0.212 (0.142)	0.049
Share of manufacturing in total employment, 2001	0.058 (0.042)	0.033 (0.018)	0.076 (0.043)	0.105
Share of mining in total employment, 2001	0.015 (0.015)	0.249 (0.149)	0.023 (0.055)	0.012
Total mining employment, 2001	19.9 (15.3)	842.8 (538.4)	72.4 (257.9)	19,286
Number of CSG wells to 2011†	2976	1765	160	4934

†Data derived using ArcGIS 9.1. CSG wells include exploratory, appraisal and extraction wells. The 160 CSG wells in the control group are scattered across 21 different statistical local areas (SLAs). ($) Australian Dollars in nominal values. Source: Own calculations with data from Department of Natural Resources and Mines of the Queensland Government (2012) and Office of Economic and Statistical Research (2012).

(nonendogenous) characteristics: it is happening over natural CSG reservoirs, it has been triggered by external (mostly non-Australian) demand and it has been exploited by investments by companies that are not based in the area of extraction (non-local investments). Given these characteristics, we claim that the treatment effect of the CSG boom can be captured by identifying regions with a high number of extraction points (CSG wells). We approach this idea by identifying the location of CSG wells, based on geospatial data available from the Department of Natural Resources and Mines of the Queensland Government (2012), across SLAs of Queensland.[1] SLAs are subregions of local government areas (LGAs) in Australia and, for this study, we use SLA 2011 boundaries, for which census time series data are available for 2001, 2006 and 2011 (Office of Economic and Statistical Research (OESR) 2012). Figure 1(a) shows the distribution of the SLAs across the state and Figure 1(b) shows the location of CSG wells established between 2001 and 2011.

Table 1 records, in numbers, the CSG wells shown in Figure 1(b). The various wells in Queensland are scattered across 43 different SLAs. As mentioned, to select our treatment region, we focused on SLAs encompassing the large majority of the CSG-related wells in our data. From the 43 SLAs with wells, the upper third (14 SLAs) include 96 per cent of the total wells in the state. We select these 14 SLAs as our treatment group. Given that CSG development has been most rapid since the mid-2000s, we can infer the

[1] These wells include exploration, appraisal and extraction wells.

economic impacts by comparing changes in indicators for the period 2001 to 2011 between this treatment group and a control group (CG).

To create the CG, we selected Queensland SLAs based on one main criterion: population density in 2001 (the base year). This is a variable that is more informative than total population considering that SLA sizes vary across space. Among the 475 SLAs in Queensland, population density in 2001 varied from 0.004 to 5483.762 persons per square kilometre. In our treatment group, population density varies from 0.109 (d_1) to 3.896 (d_2), so we decided to trim our CG to SLAs in the 2001 population density range of $\frac{1}{2}d_1 \leq \text{CG} \leq 2d_2$.[2] With this approach, we remove sparsely habited and highly dense SLAs from our analysis sample. Our CG is then formed by 81 SLAs, which including the treatment SLAs gives us a cross-sectional sample of 95 SLAs (sample 1 in Table 2) containing 15 per cent of the state's total population in 2001.[3]

3.1. Variables and models

We evaluate the boom potential impacts on economic indicators considering data availability from the Australian censuses. Thus, we focus our attention on understanding changes in median total personal income, median total family income and mining and non-mining employment between 2001 and 2011, with statistics reported in Table 1 for 2001. We also include state-level values for comparison purposes in Table 1. We chose 2001 as the starting point because most of the CSG development in Australia started during the mid-2000s, so economic consequences in the extraction regions should be observable looking at changes between 2001 and 2011 (at least changes occurring in the medium-term). We hypothesise that the CSG boom will have positive and significant effects on each of these indicators.

Our empirical strategy includes covariates that may affect the changes in income and employment indicators across space. By controlling for potential endogeneity in the covariates by using beginning of the period levels, we use a model given by:

$$\ln(y_{2011,i}) - \ln(y_{2001,i}) = \alpha + \beta T_i + \theta' \mathbf{X}_{2001,i} + \varphi d_i + e_i, \qquad (1)$$

where i denotes an SLA and e is an idiosyncratic error term. T is our binary treatment variable receiving the value of 1 if the SLA belongs to one of the 14 treatment SLAs, and 0 otherwise. y is our outcome of interest (either income

[2] We also excluded SLAs corresponding to islands from our analysis: Torres Strait SLAs, Mornington and Moreton Island. Alternative results using different criteria to select our CGs (robustness check) are available in the online Supporting Information.

[3] The trim actually gave us 77 SLAs, but to reach exactly the 15 per cent of Queensland population in 2001, we included four extra SLAs in our sample: the next two ranked SLAs in both the top and bottom limits of our population density range. A list of all SLAs included in our control and treatment groups is available on the online Supporting Information.

Table 2 Differential growth in income and employment between treatment and control groups

Indicator	Sample 1: SLAs trimmed by population density	Sample 2: sample 1 excluding Bowen basin SLAs	Sample 3: sample 2 excluding Mining-Boom SLAs
Median per capita income growth (2001–2011)	0.237 (0.074)***	0.163 (0.093)*	0.185 (0.087)**
Median family income growth (2001–2011)	0.152 (0.049)***	0.110 (0.064)*	0.124 (0.060)**
Mining employment growth (2001–2011)	0.313 (0.173)*	0.437 (0.157)***	0.449 (0.185)**
Local goods sector employment growth (2001–2011)	0.321 (0.129)**	0.330 (0.169)*	0.293 (0.175)
Observations	95	86	48

Notes: $*P < 0.10$; $**P < 0.05$; $***P < 0.01$. Values are OLS estimations for treatment effects (coefficient β in equation (1)). Results can be directly interpreted as the per cent difference, between treatment and control group, in the respective indicator's growth rate. All regressions control for 2001 levels of population density, median per capita income, percentage of people with university degree, shares of agricultural and manufacturing employment, and the distance (kilometre) of the respective statistical local area (SLA) to Brisbane (complete set of results provided in online Supporting Information). Robust clustered standard errors at local government area levels are in parentheses. Local goods sector includes employment in the Australian Bureau of Statistics categories of construction, professional services, retail trade, accommodation, rental agencies, transport and 'other services'.

or employment levels) and $\mathbf{X}$ a set of control variables given by 2001 levels of the median per capita income, population density and the proportion of the population with university degrees. We also include in $\mathbf{X}$ the share of employment in the agricultural and manufacturing sectors (see Table 1 for summary statistics). The covariates in $\mathbf{X}$ are included to control for initial levels of income, agglomeration effects, human capital and the importance of agriculture and manufacturing across local economies, respectively. d is the distance (in kilometres) of the respective SLA to Brisbane, the capital and largest city in Queensland.[4] We include d to control for the spillover and agglomeration effects that the Brisbane economy spatially produces over the rest of the state.

At the end, our primary interest lies in the direction (sign) and significance to be obtained for β, which will signal the associated CSG boom effect. Thus, the estimated coefficient will show the difference *treatment – control* in terms of the analysed dependent variables. In other words, it will measure the differential growth that the treatment (CSG boom) SLAs have on their income and employment 2001–2011 change, compared to the change in these indicators across control (non-CSG boom) SLAs.

[4] The distance is measured from the geographic centroid of each SLA polygon to the polygon of the LGA of Brisbane.

3.2. Local employment multipliers from the CSG boom

We are also interested in evaluating the potential positive and/or negative employment local multiplier (spillover) effects of the CSG boom. The resource curse literature claims that one negative effect of resource extraction booms is the migration of labour from the traded sector (local manufacturing and agriculture) to the resource extraction industry. On the other hand, positive spillover effects are expected in employment in non-tradable goods (local goods) sectors. Demands for local goods increase because of the new mine businesses coming to local areas, as well as new miners. To analyse this point, we employ an estimation by following the specification provided by Moretti (2010), which captures the number of jobs in different sectors created by new tradable goods sector employment – in our case, mining. Thus, we apply the following estimation,

$$\ln(Es_{2011,i,s}) - \ln(Es_{2001,i,s}) = \alpha + \psi\big(\ln(Em_{2011,i}) - \ln(Em_{2001,i,s})\big) + e_i, \quad (2)$$

where Es is total non-mining employment in a particular sector s, and Em is total mining employment.[5] The coefficients to be obtained from the different regressions (one regression for each sector) will indicate the elasticity of the respective sectoral job growth to changes in mining employment in the same region, from which we can calculate the respective new jobs added by each additional mining job created (Moretti 2010). Also following Moretti (2010), we employ a two-stage least square (2SLS) specification to estimate these elasticities, but based on an instrumental variable (IV) identifying the treatment areas as in Black *et al*. (2005) and Marchand (2012). This IV procedure is done to empirically isolate the change in mining employment associated with the treatment, that is, the CSG industry development. Thus, to capture the treatment effect in (2), we use the number of CSG wells located across SLAs as the IV.

3.3. Considering the resource extraction baseline: Bowen versus Surat basins

It is important to make two distinctions about the basins where the CSG development has been taking place. The Bowen basin is an area where other types of mining, including the extraction of conventional energy resources, have been a common feature for decades. As seen in Table 1, in 2001, the share of employment in the mining industry across the Bowen treatment SLAs was 0.23, which clearly signals dependence on resource extraction in the local economy. On the other hand, the percentage of mining employment was only around 1 per cent in the treatment SLAs belonging to the Surat basin, an area in which mining industry activity has been limited before the CSG boom.

[5] We used ($Es(m)$ + 1) across all observations to avoid problems when transforming data to logarithms.

Considering these 'resource extraction' initial conditions, it is worth analysing whether the CSG boom has been associated with fewer or more effects across the Surat and Bowen basins. We empirically check this in alternative regressions that exclude Bowen basin SLAs from our sample. Thus, we removed six and three Bowen basin SLAs from our treatment and CGs, respectively, obtaining a set of 86 SLAs (sample 2 in Table 2).

3.4. Other resource boom regions

An important issue to consider when analysing a particular resource boom, such as that involving CSG, is the potential increase in other resource extraction industries across the CG. The main idea of our quasi-experimental approach is to evaluate CSG boom effects by comparing treatment areas to areas without this energy resource that could act as counterfactuals, which may show us what would have occurred in the CSG areas in the absence of the boom. So, to better distinguish the potential CSG boom effect in local economies, it is important to consider counterfactuals not showing a similar boom, even if they come from different types of mining.

In recent years, the state of Queensland, as well as the rest of Australia, has experienced a considerable mining boom. According to census data, people working directly for the mining industry in Queensland increased 174 per cent (135 per cent in Australia) between 2001 and 2011 (Australian Bureau of Statistics 2012). To consider SLAs that have not experienced important mining boom economic effects, we provide alternative estimations for a sample, trimming our comparison group by excluding SLAs where the growth in mining employment has been higher than the state total change between 2001 and 2011 (>170 per cent). We denote these removed regions as Mining-Boom SLAs, and their exclusion leaves us with a subsample of 48 SLAs (sample 3 in Table 2).[6]

All results provided in the following section are estimated using clustered standard errors to control for the potential spatial autocorrelation within functional economic regions. In our case, we define these functional regions by LGAs, which are subregions that nest all SLAs across the state. There are 48, 44 and 32 LGAs in samples 1, 2 and 3, respectively.

4. Results

We report in Table 2 results for the coefficient β in equation (1); a complete set of results is provided in online Supporting Information. Results show the differential growth that the CSG boom areas (treatment) are experiencing in contrast to comparable areas where the CSG boom has not taken place

[6] Important to have in consideration is that, given the nature of our data, some of these excluded SLAs are not necessarily hosting mines, but are places where miners were residing at Census night.

(control). This 'treatment effect' is reported for median total personal and family income and for mining and non-tradable (local goods) sectoral employment. Thus, the values reported are equal to the differential growth on the 2001 to 2011 change in these indicators between treatment and CGs, other things being equal.

The first two rows in Table 2 report the income effect related to the CSG boom. Evidence shows that between 2001 and 2011 the median personal (family) income in the treatment areas has increased 24 per cent (15 per cent) more than in the control SLAs of sample 1. Interestingly, the differential effect is somewhat less pronounced (in magnitude and significance) when we consider only Surat basin SLAs in our treatment group.

Our results for employment show that mining employment has grown 31 per cent more in the average treatment SLAs compared to the comparison group. In this case, the effect over the Surat basin is more pronounced (in magnitude and statistical significance), where mining employment has grown around 45 per cent more than in comparable rural areas of Queensland. Looking at the growth in non-mining employment, our results show that treatment SLAs reported a 32 per cent higher increase in non-mining employment compared to the CG. However, these results are less statistically significant when the Bowen basin is removed from the analysis, and indistinguishable from zero when removing Mining-Boom SLAs from the CG (sample 3).

This last result would suggest that the CSG development in the Surat basin area has not produced gains in terms of employment in non-mining sectors, compared to similar regions of Queensland. Taking into account that the Surat basin is where the CSG boom has been more pronounced (considering the number of wells and the growth in mining employment in the area), to further analyse this statistically insignificant effect, we break down the local goods sector into construction, professional services, retail trade, accommodation and food services and other services, and estimate local job multipliers for each of these sectors (as described in Section 3.2) for sample 3.

Table 3 reports the 2SLS results of CSG employment spillovers for sample 3. For the case of local goods employment, only two sectors show statistically significant elasticities at the 10 per cent level: construction and professional services. The elasticity reported for construction indicates that a 10 per cent increase in the number of mining jobs in an SLA is associated with an 8.3 per cent increase in construction employment. Since on average (over the sample) there were 1.7 construction jobs for each mining job in 2001, the estimated elasticity implies that for each additional CSG job in a given SLA, 1.4 jobs are created in the construction sector in the same SLA. In the case of professional services, there were only 0.6 jobs in this sector for each mining job in 2001, which translates that for each new CSG job in an SLA, 0.4 new professional services jobs were created in the SLA. Elasticities for retail trade, hospitality and other services are statistically indistinguishable from zero.

Table 3 Coal seam gas (CSG) employment spillovers over different sectors

	Elasticity	Additional job for each new CSG job
Local goods sector		
Construction	0.832 (0.426)*	1.414
Professional services	0.704 (0.259)**	0.422
Retail trade	0.011 (0.140)	0.024
Accommodation and food services	0.375 (0.263)	0.471
Other services	−0.385 (0.247)	−0.890
Tradable goods sector		
Manufacturing	0.068 (0.199)	0.160
Agriculture	−0.314 (0.182)*	−1.790

Notes: *$P < 0.10$; **$P < 0.05$. Elasticity values are two-stage least square estimations for coefficient β in equation (2). The number of CSG wells in an statistical local area is used as instrument for the log change of mining employment. Values are estimated using sample 3 ($n = 48$). F-stat first-stage = 10.74. Robust clustered standard errors at Local Government Area levels are in parentheses. Other services sector includes employment in the Australian Bureau of Statistics categories of rental agencies, transport and 'other services'.

In the last two rows of Table 3, we include manufacturing and agriculture (tradable goods sector) estimations to evaluate potential migration of labour from these sectors to the labour-demanding CSG industry. While the results do not show a statistically significant effect of job spillovers in the manufacturing sector, there is evidence of an out-flow of agricultural labour, although the result is barely significant at the 10 per cent level (P-value = 0.093). Considering that, on average, there were 5.7 agricultural jobs per each mining job in 2001, the negative estimated elasticity implies that for each additional CSG job in a given SLA, around 1.8 jobs were lost in the agriculture sector in the same SLA.

5. Discussion of results

The results demonstrate that the CSG boom is associated with higher income growth in areas hosting the industry, compared to non-CSG regions. One important issue to consider when interpreting these results, though, is that the 2001–2011 Australian census time series data are only available based on place of enumeration. Therefore, in the case of personal income, results may overestimate the CSG boom income effect at the local level, as mining workers residing temporarily in CSG areas may pull the median upward. Several studies have considered this issue, whereby local residents are potentially excluded from income benefits due to the high number of non-resident workers who take their income back to their normal place of residence (Rolfe *et al.* 2007; Measham *et al.* 2013). However, income effects are also significant for families residing in the region. This is an important consideration, given that the family income indicator does not consider families with members residing outside of the household surveyed (OESR

2012), so the associated income effect from the CSG development is indeed showing higher growth for families residing locally.

One interesting point in the income effect results is that the effect is higher in magnitude in sample 1 (for both personal and family incomes), which can be explained by higher income increases in the Bowen basin SLAs. Considering that the Bowen basin hosts other types of mining on a substantial scale, especially compared to the relative lack of mining in the Surat basin (Table 1), this last effect could be the result of expansions of other mining activities in the area that can be increasing income beyond the CSG effect.

When looking at mining employment effects, the results are in line with expectations. However, again, it is important to note the differences in magnitude and significance of the effect between the Bowen and Surat basins. After excluding the Bowen basin SLAs from the sample, the differential growth increases noticeably, suggesting that Surat basin SLAs have grown more in terms of mining employment. This result clearly signals that the initial condition of the Surat basin has allowed the industry to grow more rapidly than in the Bowen basin, which is also encouraged by more reservoirs concentrated in the Surat area. In this regard, the Surat basin faces more challenges in terms of accommodating this rapidly growing number of workers, many of whom come from other areas of the state and country.

On the other hand, Table 2 shows that non-mining employment has increased in the average CSG SLA by 32 per cent, compared to the CG. However, in this case, the result of sample 3 shows that job spillovers into non-mining employment is not statistically significant. This result is at least intriguing, considering that the same sample shows the highest growth in mining employment. However, after breaking non-mining employment in different sectors, it can be noticed that local multipliers are taking effect for construction and professional services sectors, as shown in Table 3. Thus, our evidence suggests that the CSG boom is at least generating more construction employment and jobs related to the provision of technical services such as electricians and mechanics. Interestingly, even considering the growing number of miners working in the area, retail trade and other local services jobs do not show strong growth in the studied Surat basin SLAs, compared to the control SLAs in sample 3.

Also regarding job multipliers across local economies, one important theme in the literature is migration out of manufacturing employment. However, results found for sample 3 show no effect on this sector (statistically non-significant multiplier). On the other hand, although statistically not strong, there is some evidence suggesting that agricultural jobs have been negatively affected by the CSG boom. This last result shows how people employed in agriculture, between 2001 and 2011, have either migrated out of the area or reallocated into the CSG industry or into the construction and professional services sectors. In addition, this negative spillover can also be explained by a transition to more mechanised agriculture in the area, as higher labour costs and higher income levels generated by the CSG boom might trigger technological change towards less labour intensive agriculture. More research is encouraged on this issue, especially considering the overlapping of CSG production in agricultural land across Queensland.

6. Conclusions

The growth in CSG development in southern Queensland has been occurring very quickly, and is likely to continue. Better understanding of the current impacts is a key issue in addressing benefits and potential conflicts in the areas affected. Based on the analysis of the quasi-experimental conditions presented by CSG development, this study identifies income and employment (in mining and non-mining activities) effects associated with the CSG boom. In the average SLA hosting the CSG industry, family income grew by 12–15 per cent more than in comparable areas of Queensland during the decade 2001–2011. Employment in the mining sector has also grown faster across the CSG region. However, local job multipliers into other non-mining areas are less consistent across space. Looking in detail at the Surat basin, where most CSG wells have been placed, results suggest that only positive job spillovers from the CSG industry to the construction and professional services sectors have occurred, while the agricultural sector has seen a reduction in jobs.

Overall, the analysis demonstrates that the CSG regions of the Surat and Bowen basins show benefits in terms of income and employment compared to non-CSG regions. However, further research is needed to provide a fuller picture of the extent to which these regions experience overall advantage from their CSG endowments. Future studies could consider how incomes are distributed between households, how higher incomes may be offset by increased housing costs and other local socioeconomic challenges likely to arise as consequences of natural resource booms.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Data S1. The STATA do file (.do) that provides in detail all the code needed to replicate estimates presented in tables across the paper and the Supporting Information tables.

Data S2. A STATA data file (.dta) that contains all the raw data used in the study.

Table S1. List of the 14 treatment SLAs, divided by basins.

Table S2. List of the 81 SLAs used as control group (sample 1).

Table S3. Full set of results, income and employment growth models, 2001 to 2011 (complement of Table 2 in paper).

Tables S4 to S39. Robustness check: tables of results for model (1) considering different samples based on alternative methods to select the control groups.