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JEL Classification: F18, F64, O44, Q54, Q56

Keywords: economic growth, methane emissions, sectoral analysis, threshold estimation

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Economic growth, sectoral structures, and environmental methane footprints *

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October 2019

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We analyze the impacts of economic growth on methane emissions per capita at the sectoral level for the period 1997–2014. We cover three stages of the supply chain, distinguishing between emissions embodied in production, final production, and consumption. We investigate the effects of economic growth on two components of methane emissions per capita, namely methane emissions per unit of value added and value added per capita. We uncover substantial heterogeneity across sectors. Economic growth led to expansions of economic activity in all sectors but reduced the methane intensity of sectoral value added in some sectors. In sectors that experienced pronounced reductions in methane intensity, economic growth did not strongly affect emissions per capita. However, in the absence of large methane-intensity gains, economic growth raised emission per capita substantially.

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1 Introduction

Economic growth entails changes in the level and composition of economic production and consumption patterns (Kuznets, 1973, Herrendorf et al., 2013). Both the level and the composition of economic activity affect environmental degradation and greenhouse gas emissions, what in turn may harm prospects for sustainable economic development in the future. Methane (CH_4) is one of the most important greenhouse gases and an important contributor to climate change. The global warming potential of anthropogenic methane emissions released between 1997–2011 was equivalent to about 84% of the global warming potential of Carbon Dioxide (CO_2), computed over a 20-year period (Fernández-Amador et al., 2018b).

An emerging literature has focused on quantifying the impact of economic growth on anthropogenic methane emissions. Burns et al. (1997), Rosa et al. (2004), and Jorgenson (2006) investigated the socio-economic drivers of methane emissions in a cross-sectional setting. The results of these studies suggest a statistically significant relationship between methane emissions and economic affluence, population size, production structures, foreign direct investment, forested area, and the ratification of international environmental treaties. Although the model specifications vary across the studies, GDP per capita (or GNP, respectively) was statistically significant in all three studies, with an implied income-elasticity of emissions in the range of 0.3–0.5.[1] Relying on panel data and accounting for country fixed effects, Jorgenson and Birkholz (2010) reported that the elasticity of methane emissions with respect to income per capita was somewhat lower (about 0.1–0.2) and decreased over time. These authose also confirmed that the production structure of the economy played an important role as a determinant of emissions. Using more recent panel data, Fernández-Amador et al. (2018a) detected a slightly higher income-elasticity of emissions per capita than Jorgenson and Birkholz (2010), ranging between 0.2 and 0.3, and identified a quantitatively smaller impact of economic growth on emissions at higher levels of economic development. The authors also showed that the binding emission constraints specified in the Kyoto Protocol for Annex I countries did not have the expected effects, partly because of the potential for emissions leakage.[2]

Anthropogenic methane emissions are mostly produced by few economic sectors such as cattle breeding, rice cultivation, extraction and transport of fossil fuels, and waste management (Fernández-Amador et al., 2018b). These emissions result from very heterogeneous processes with different scope for abatement. Accordingly, existing heterogeneity

[1] We cannot report the income-elasticity for Burns et al. (1997), who included methane emissions and GNP in levels rather than in logarithms.

[2] See Fernández-Amador et al. (2018b) for a recent, more general discussion of the literature on methane emissions.

of production structures across countries introduces cross-country asymmetries, as certain countries and sectors may be more vulnerable to caps on methane emissions. This will complicate international negotiations, as well as the design and implementation of environmental policies. Understanding the factors that determine emissions at the sectoral level, and particularly the role of economic growth, will help policy makers and negotiators assess options for achieving a reduction in emissions without compromising economic growth. It is thus essential to study the effect of economic growth and other socio-economic factors on sectoral methane emissions and to evaluate the potential impacts of improvements in emission intensities for the different economic sectors. Despite the implications for environmental policies, climate negotiations, and sustainable economic growth, hitherto no sectoral analysis of the socio-economic drivers of methane releases has been carried out.

This paper contributes novel findings concerning anthropogenic methane emissions in three respects. First, it provides a sectoral analysis of the determinants of emissions, distinguishing between emissions from seven broad economic sectors that add up to economy-wide methane releases. We use recently updated data on anthropogenic methane emissions for the period 1997–2014, available from Fernández-Amador et al. (2018b). The data covers a global sample of countries (in some cases aggregated to regions), representative for anthropogenic methane emissions worldwide. In the econometric analysis, we study the relationship between income per capita and sectoral methane emissions and test for the existence of different forms of non-linearities in the income–methane relationship while accounting for a large number of economic and political factors that may affect emissions.

Second, we decompose emissions per capita into sectoral emissions per unit of value added (sectoral methane intensity) and sectoral value added per capita (sectoral economic activity). Using these two components as dependent variables in subsequent regressions allows to break down the compound effect of economic growth on sectoral methane emissions per capita into its impacts on methane intensity and sectoral activity. Based on this analysis, we draw conclusions at the sectoral level concerning the extent of scale effects (via expansions of sectoral activity) and composition and technique effects of economic growth (via changes in methane intensity).[3]

Third, we evaluate the effectiveness of emission targets for Annex I members specified in the Kyoto Protocol and assess the impact of trade relations at the sectoral level.[4] Because the data that underlies our analysis distinguishes between emissions at three different stages of the supply chain, it permits to account for trade linkages and to assign the

[3] See Copeland and Taylor (2004) for a definition of scale, composition and technique effects.

[4] Annex I members are industrial countries and transition economies specified first in the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol defined emission constraints for all Annex I countries but Turkey in its Annex B. We evaluate whether the ratification of the Kyoto Protocol by Annex I members had a significant effect on methane emissions.

responsibility for emissions either to the direct producer (production inventories), the producer of final products accounting for emissions embodied in all domestic and imported intermediates (final production inventories), or the consumer of products containing embodied emissions (final consumption inventories). This allows to gain insights concerning potential reductions of emissions from production activities, for example in Annex I countries that ratified the Kyoto Protocol, and to evaluate whether potential emission cutbacks were reflected in consumption patterns.

Our results confirm substantial sectoral heterogeneity in (i) the relation between income and emissions; (ii) the reductions in methane intensity realized from economic growth; and (iii) the impact of economic and political determinants on methane releases. These sectoral differences have so far remained hidden. Although previous estimates suggest that economic growth resulted in higher economy-wide methane emissions (Burns et al., 1997, Rosa et al., 2004, Jorgenson, 2006, Jorgenson and Birkholz, 2010, Fernández-Amador et al., 2018a), we show that this was not the case for all economic sectors. Economic growth did not significantly affect CH_4 emissions per capita in sectors accounting for more than 40% of methane emissions between 1997 and 2014. However, economic growth induced higher emissions in the remaining sectors; especially, the transport sector and energy production were characterized by absence of decoupling. Moreover, the relationship between income per capita and emissions is piecewise-linear for most sectors and methane inventories. The changes in the income-elasticities of methane detected when higher levels of economic development are reached go in line with the process of structural transformation, in which the role of primary sectors declines while the industry and service sectors, and with them energy production, gain importance (Kuznets, 1973, Herrendorf et al., 2013).

Changes in methane intensity explained a large part of the developments in emissions per capita. Economic growth reduced the methane intensity of most (but not all) sectors, and this effect counteracted the increase in emissions resulting from sectoral expansions. The sectors in which emissions per capita increased most strongly with economic growth were also the ones characterized by the absence of significant methane intensity gains.

Moreover, the impact of environmental policy and other economic and political factors on methane emissions differed across sectors. The ratification of the Kyoto Protocol by Annex I countries was associated with less emissions per capita on the production side only in the transport and public administration sectors. At the same time, emissions derived from final production and consumption inventories increased for Annex I members in the agriculture and transport sectors, and were not significantly affected in the remaining sectors. The ratification of the Kyoto Protocol by Annex I members did not reduce their sectoral methane intensities. Altogether, these results indicate more methane-intensive imports by Annex I countries and are consistent with the existence of methane leakage. Finally, openness to international trade, where significant, was related to higher methane emissions.

The paper is organized as follows. The next section describes the data and provides descriptive statistics. The econometric specification is summarized in Section 3. Section 4 presents the results, and Section 5 concludes.

2 Data and descriptive statistics

Our analysis relies on a dataset on anthropogenic methane emissions recently developed by Fernández-Amador et al. (2018b). The dataset provides detailed information on emission from seven economic sectors in 187 economies (aggregated to 66 countries and 12 composite regions) for the years 1997, 2001, 2004, 2007, 2011, and 2014. The seven sectors include agriculture, livestock, energy, manufacturing, services, transport, and public administration. The data covers the level of emissions, emissions per capita, and emissions per unit of value added for three inventories: emissions embodied in production, in final production, and in consumption activities.[5]

Methane emissions released in the production process were primarily concentrated in the livestock, energy, and public administration (mainly waste management) sectors, which together amounted to 80% of total emissions between 1997 and 2014. These sectors' emissions were the result of very heterogeneous production processes. Much of the output of those sectors was used as intermediates to produce final products of other sectors, such that emissions embodied in final production and consumption (footprint inventories) were more evenly spread across sectors, and these three sectors only accounted for about 50% of total emissions (see Table 1).

There was considerable heterogeneity across sectors concerning the development of emissions over time. Between 1997 and 2014, total methane emissions grew by 18%. Emissions embodied in production grew above the average in the energy (33%), transport (21%), public administration (20%), and manufacturing (19%) sectors, while in the remaining sectors they increased by approximately 9%. The growth of emissions embodied in final production and consumption was especially high in the service (46%), energy (39%), man-

[5] Details on the country coverage and the composition of the seven sectors are provided in Tables A.1 and A.2 in the Online Appendix. The breakdown of total emissions to seven sectors was chosen to provide sufficient sectoral detail while avoiding the definition of sectors with insignificant shares of total emissions (see Tables A.3 and A.4 for sectoral emission shares). In a complementary analysis reported in Appendix C, we further split the agriculture sector into two subsectors (crops, and forestry and fishing) and the livestock sector into three subsectors (red meat, other livestock, and dairy). All monetary variables are measured in real terms.

	CH_4 in Mt (CO_2e, 100y)	Sectoral contribution in % agr.	liv.	egy.	mfc.	ser.	trn.	pub.
				Production inventory				
1997	5987	9.24%	35.51%	23.08%	4.57%	0.71%	5.74%	21.16%
2001	5910	8.92%	36.54%	21.67%	5.14%	0.37%	6.20%	21.15%
2004	6234	8.52%	35.81%	24.11%	5.76%	0.34%	4.66%	20.80%
2007	6548	8.28%	35.33%	24.65%	5.69%	0.27%	4.82%	20.95%
2011	6921	8.60%	34.19%	24.62%	4.48%	0.67%	6.06%	21.37%
2014	7071	8.50%	32.90%	25.89%	4.61%	0.66%	5.90%	21.54%
Average	**6445**	**8.68%**	**35.05%**	**24.00%**	**5.04%**	**0.50%**	**5.56%**	**21.16%**
				Footprint inventories				
1997	5987	14.57%	26.35%	4.30%	14.22%	11.81%	4.63%	24.12%
2001	5910	15.12%	24.37%	5.61%	14.74%	10.88%	4.48%	24.80%
2004	6234	12.56%	24.61%	5.51%	15.26%	13.27%	4.31%	24.48%
2007	6548	12.10%	23.41%	5.34%	16.55%	13.48%	4.43%	24.69%
2011	6921	12.61%	22.87%	4.85%	15.43%	14.13%	4.78%	25.33%
2014	7071	12.87%	22.03%	5.06%	15.39%	14.57%	4.84%	25.24%
Average	**6445**	**13.30%**	**23.94%**	**5.11%**	**15.27%**	**13.02%**	**4.58%**	**24.78%**

Table 1: Sectoral contributions to total CH_4 emissions. Note: Mt. stands for Megatons, CO_2e, 100y stands for CO_2 equivalents based on a global warming potential over 100 years, using the conversion factor of 21 (IPCC, 2007). agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration. On a global level, sectoral methane emissions associated with final production and consumption (footprint inventories) are equal.

ufacturing (28%), public administration (24%) and transport (23%) sectors. Emissions grew very little in the agriculture sector (4%) while experienced a decline (of about 1%) in the livestock sector. Given this sectoral heterogeneity, it is essential to understand whether and which socio-economic drivers explain methane releases at the sectoral level.

In our empirical analysis, we include a set of baseline variables to explain sectoral methane emissions, which we consider the most important for our purpose. These variables include income per capita, the ratification of the Kyoto Protocol by Annex I countries, and openness to international trade. The inclusion of these variables is motivated by prior research on methane releases or greenhouse gas emissions in general. Income per capita has often been used to evaluate the effect of economic growth in models including individual fixed effects; and it was found to have a positive effect on methane emissions (Rosa et al., 2004, Jorgenson, 2006, Jorgenson and Birkholz, 2010, Fernández-Amador et al., 2018a). Fernández-Amador et al. (2018a) evaluated the effect of binding emission constraints specified in the Kyoto Protocol for Annex I members. These authors found an insignificant effect on methane releases from production but a significant and positive effect on footprint-based methane emissions. They also reported supportive evidence for a positive relation between openness to international trade and methane releases at the economy-wide level.[6]

Apart from the baseline regressors, we control for a set of economic and political variables. Together with individual and time fixed effects, the inclusion of the control variables should reduce potential omitted variable bias and capture heterogeneity concerning the drivers of methane emissions across economic sectors. Motivated by previous literature, we include food and fuel exports as a share of total exports (Jorgenson and Birkholz, 2010), the logarithm of population density (Torras and Boyce, 1998, Harbaugh et al., 2002, Frankel and Rose, 2005, Fernández-Amador et al., 2017), urbanization (motivated by Herrendorf et al., 2013, Jorgenson, 2006), fossil rents as a share of GDP (Richmond and Kaufmann, 1997, Fernández-Amador et al., 2017, 2018a), an indicator for political regimes (Frankel and Rose, 2005, Aichele and Felbermayr, 2012, Fernández-Amador et al., 2017), and development-group categories (Perrings and Ansuategi, 2000, Fernández-Amador et al., 2017).

Some variables may be endogenous with respect to methane emissions. In the econometric analysis, we explicitly account for potential endogeneity of income per capita and the ratification of the Kyoto Protocol by Annex I members. Economic growth will be endogenous if, for example, growth depends on a country's resource endowments or if environmental regulation limits a country's growth potential (e.g. Stern et al., 1996, Dinda, 2005, Frankel and Rose, 2005). Environmental regulation may be endogenous if countries decide to adopt it based on climate change vulnerability, endowments of renewable energy sources, patterns of comparative advantage, or prospects of decreasing emissions (e.g. Aichele and Felbermayr, 2012, 2015, Fernández-Amador et al., 2017). Our choice of instruments is based on Frankel and Rose (2005), Aichele and Felbermayr (2012, 2015), and Fernández-Amador et al. (2017, 2018a). We instrument current income per capita with three years lagged income per capita and the ratification of the Kyoto Protocol by Annex I members with their ratification of the Rome Statute of the International Criminal Court (ICC).[7]

[6] More generally, these baseline variables were also included in some studies focusing on other greenhouse gases. See e.g. Aichele and Felbermayr (2012, 2015), Cole and Elliott (2003), Cole (2004), Fernández-Amador et al. (2017), Frankel and Rose (2005), Harbaugh et al. (2002), Kearsley and Riddel (2010).

[7] In the econometric specifications including a squared income term, we instrument this term by using the square of lagged income per capita as additional instrument. In the threshold models, we instrument regime-specific effects of income per capita using regime-specific terms for lagged income per capita as instruments. We acknowledge that also international trade might by affected by reverse causality if the implementation of environmental regulation induces outsourcing of heavily polluting activities to other countries with less stringent regulations and from which the produced goods are imported. This potential endogeneity has been tackled in cross sectional studies on air pollutants using gravity estimators (e.g. Frankel and Rose, 2005, Managi et al., 2009). Yet, in our panel setup we cannot use the gravity-based trade instrument together with fixed effects, because the gravity framework makes use of time-invariant explanatory variables which are captured by the fixed effects in the main equation.

We source data on real income per capita adjusted for purchasing power parity, population density, the share of fossil fuel rents with respect to GDP, and urbanization from the World Development Indicators (WDI) database. Trade openness and the shares of food and fossil fuel exports with respect to total exports are based on data from Global Trade Analysis Project (GTAP). We obtain the political regime index from the Polity IV database, development categories of the Human Development Index (HDI) from the HDI database, and information concerning Annex I membership and the ratification of the Kyoto Protocol and the Rome Statute of the ICC from the UN Treaty Collection Database.[8]

3 Econometric specifications

The econometric identification of the determinants of CH_4 emissions is outlined below. We specifically address the form of the relationship between pollution and income per capita, since the failure to account for potential non-linearities between income and emissions could lead to omitted variable bias. In particular, we estimate specifications in which the income-elasticity of methane takes, alternatively, a polynomial and threshold (piecewise linear) form. In order to perform model selection, we test these non-linear specifications against the null of a linear effect of income on emissions. If the polynomial and threshold specifications both provide evidence against the linear model, we report the results of the model that minimizes the sum of squared residuals. If both non-linear specifications fail to reject linearity at the 10% significance level, we report the results of linear model specifications.[9]

3.1 Polynomial specification

The polynomial models of the determinants of CH_4 emissions take the form:

$$E_{it} = \beta_1 y_{it} + \beta_2 y_{it}^2 + \gamma_1 a_{it} + \gamma_2 t_{it} + Z_{it}'\delta + \nu_t + \mu_i + u_{it}. \quad (1)$$

E_{it} are (logged) sectoral CH_4 emissions per capita of region i in period t, y_{it} stands for the logarithm of real GDP per capita adjusted for purchasing power parity (PPP), a_{it} is a dummy variable equal to one for the ratification of the Kyoto Protocol by Annex I members, t_{it} measures openness to international trade, and Z_{it} is a vector of control

[8] A complete description of the data and a summary of data sources is available in Table A.5 in the Appendix. Summary statistics for the variables used are reported in Table A.6.

[9] The results of the regressions not reported in Section 4 are available from the authors upon request.

variables. ν_t and μ_i capture time and individual fixed effects (FE), and u_{it} is the error term. $\beta_1, \beta_2, \gamma_1$, and γ_2 are coefficient estimates and δ is a coefficient vector. The control variables, Z_{it}, comprise food exports and fuel exports as share of total exports, (logged) population density, urbanization, fossil rents as a share of GDP, a political regime index, and development group dummies.

We account for the potential endogeneity of income per capita, its square, and the ratification of the Kyoto Protocol by Annex I members following the instrumentation strategy described above, which has been established by previous literature (see Frankel and Rose, 2005, Aichele and Felbermayr, 2012, 2015, Fernández-Amador et al., 2017, 2018a). We estimate the instrumental variable (IV) regression models using 2-stage Generalized Methods of Moments (GMM).[10] We test for the statistical significance of the polynomial relationship between income and emissions by applying the (inverse) U-test developed by Lind and Mehlum (2010).

3.2 Threshold specification

Additionally, we consider the threshold (piecewise linear) specification

$$E_{it} = \beta_1 y_{it} I(q_{it} \leq \tau) + \beta_2 y_{it} I(q_{it} > \tau) + \gamma_1 a_{it} + \gamma_2 t_{it} + Z'_{it}\delta + \nu_t + \mu_i + u_{it}, \qquad (2)$$

where $I(\cdot)$ is an indicator function that determines regimes with different income elasticities. These regimes depend on whether the threshold variable q_{it} (in our case the logarithm of GDP per capita five years lagged) is smaller or larger than the threshold value τ. The threshold τ lies in the domain of q_{it}, ($\tau \in [q_{it}^{min}, q_{it}^{max}]$). The continuous threshold variable q_{it} is assumed to be exogenous. All other variables and parameters are defined as before.

To allow for potential endogeneity of income per capita and the ratification of the Kyoto Protocol by Annex I members, we follow Caner and Hansen (2004) and estimate IV-FE threshold models using the instruments described above. We regress the endogenous variables on the exogenous variables and instruments to obtain the predicted values of the endogenous variables. Then, we regress E_{it} on these predicted values and the exogenous controls and estimate the threshold parameter τ, which is treated as unknown (see Hansen 1999, 2000).

[10] In the main text, we report only the results from the IV regressions. The results of uninstrumented regressions are reported in Tables B.10 to B.15 in Online Appendix B. We test for the relevance of instruments in each regression by checking whether the instruments' coefficients have the expected sign and are statistically significant at conventional levels. The results of the first-stage regressions are not reported due to space constraints but are available from the authors.

The least squares estimator for the threshold τ is defined as minimizing the concentrated sum of squared errors (conditioned on τ), where minimization is based on a grid search over the domain of the threshold variable q_{it}. To avoid regimes with too few observations, we restrict the search over the domain of q_{it} such that at least 10% of the observations lie in each regime. Given a threshold estimate $\hat{\tau}$, we use a likelihood ratio (LR) test with the null hypothesis of the non-existence of the threshold. Since this test is non-standard, we use a bootstrap procedure based on Hansen (1996) to simulate the asymptotic distribution and to construct the *p*-values (see Hansen, 1999, for details). $\hat{\tau}$ is a consistent estimator of τ, but its asymptotic distribution is also non-standard. Therefore, following Hansen (1996), we define the 99% confidence interval for $\hat{\tau}$ as the non-rejection region of an LR test with the null of no statistically significant difference between a proposal for τ and $\hat{\tau}$ at the 1% significance level. Finally, we estimate the coefficients of the second-stage by 2-stage GMM, conditioned on the estimate for the threshold $\hat{\tau}$.

3.3 Decomposition of methane per capita

A more detailed picture of the channels through which economic growth affects methane emissions is obtained by splitting methane per capita into methane emissions per unit of value added (methane intensity) and value added (VA) per capita (see equation (3)).

$$\underbrace{\frac{CH_4^s}{pop}}_{\text{methane per capita}} = \underbrace{\frac{CH_4^s}{VA^s}}_{\text{methane intensity}} \cdot \underbrace{\frac{VA^s}{pop}}_{\text{VA per capita}} \tag{3}$$

Using (the logarithm of) these two terms as dependent variables in subsequent regressions contributes additional insights. On the one hand, the patterns detected for methane per capita may be influenced by changes in methane intensity within sectors—that is, changes in methane efficiency or compositional changes within the seven broad sectors under investigation. In this vein, the income-elasticity of methane intensity captures the composition and technique effects of economic growth as defined in Copeland and Taylor (2004).[11] On the other hand, methane per capita is also affected by expansions or contractions of sectoral activity. Thus, the income-elasticity of sectoral value added per capita is a proxy for scale effects of economic growth as described in Copeland and Taylor (2004). In this spirit, we carry out the analysis as above described for methane per capita also for value added per capita and methane intensity as alternative dependent variables.

[11] The composition effect at the sectoral level is influenced by changes in the composition of subsectors (with different methane intensities) that form part of the seven aggregate economic sectors reported in the database.

4 Results

4.1 Methane per capita

Table 2 presents the regression results of the IV-FE estimations for (the logarithm of) methane emissions per capita derived from production (Panel 1), final production (Panel 2), and consumption activities (Panel 3) as dependent variables. The table reports the coefficients and standard errors of the baseline regressors and several test statistics.[12] There is remarkable heterogeneity at the sectoral level in terms of (i) functional form; (ii) threshold values; (iii) magnitude and statistical significance of income-elasticities; and (iv) impacts of climate agreements and economic factors on methane emissions.

Regarding the functional form, most sectors were characterized by a (threshold) piecewise-linear relationship between income and methane emissions per capita (see the bootstrap p-value, testing the H_0 of linearity).[13] Only in the livestock and manufacturing sectors for production-based methane inventories, we did not find evidence for non-linearities. The threshold values that define income-regimes with different income-elasticities of methane differed largely across sectors. In most cases, the thresholds were narrowly defined, as indicated by their confidence intervals, what highlights that this form of non-linearity may fit the data better than other forms of non-linearity such as polynomial or smooth transition specifications. The thresholds thresholds were estimated at high income levels in agriculture, livestock, energy, and public administration, while manufacturing, services, and transport were characterized by moderate to low threshold values.[14]

The estimated income-elasticities reveal some interesting patterns. First, the income-elasticity decreased when passing through the income-threshold from the lower to the higher income-regime in the primary sectors, transport, and public administration. By contrast, the income-elasticity increased when moving from the lower to the higher income-regime in the energy, manufacturing, and service sectors. This sectoral pattern is consistent with the declining role of primary sectors and the rising importance of industrialization, which is accompanied by increased demand for energy, in the course of economic develop-

[12] The results for the full list of regressors are available in Tables B.1 to B.3 in the Online Appendix. The corresponding results for FE estimations are presented in Tables B.10 to B.12.

[13] The polynomial model did not provide evidence for a non-linear relationship for any of the sectors and inventories reported in Table 2. For the transport sector, both income terms were statistically significant, suggesting an inverse-U relationship between income and emissions; yet the (inverse) U-test by Lind and Mehlum (2010) did not reject the null hypothesis of a monotone or U shape (p-value 0.122). The only exception to this in the complementary analysis in Appendix C, is the consumption-inventory in the red meat subsector of the livestock sector, in which the effect of income on emissions followed a U-shape.

[14] Exceptions to this general pattern were the production inventories in agriculture and energy and to some extent the final production inventory in the transport sector.

	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
Panel 1: CH_4 per capita embodied in production							
ln(Income), reg.1	0.491 **	0.176	0.725 ***	-0.007	0.857	1.819 ***	0.297 **
	(0.205)	(0.158)	(0.187)	(0.406)	(0.819)	(0.639)	(0.123)
ln(Income), reg.2	0.424 **		0.762 ***		0.631	1.727 ***	0.275 **
	(0.192)		(0.183)		(0.747)	(0.612)	(0.128)
Annex I	-0.178	0.736	0.067	0.179	0.768	-0.424 *	-0.192 *
	(0.227)	(0.731)	(0.160)	(0.299)	(0.534)	(0.257)	(0.101)
Openness	0.303 ***	0.614	0.191 *	-0.109	0.269	0.151	0.011
	(0.078)	(0.451)	(0.105)	(0.161)	(0.355)	(0.245)	(0.077)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Threshold (value)	8.086		8.842		7.652	7.689	10.489
99% CI lower bound	8.047		8.803		7.652	7.652	10.487
99% CI upper bound	8.245		8.994		7.652	7.901	10.490
Bootstrap p-value	0.018		0.004		0.000	0.002	0.000
Wald equal. coeff. (p)	0.007		0.003		0.018	0.005	0.004
N regime 1/2	69/399	468	129/339	468	47/421	49/419	392/76
Panel 2: CH_4 per capita embodied in final production							
ln(Income), reg.1	0.297	0.079	0.027	0.376	0.241	1.174 ***	0.343 ***
	(0.231)	(0.137)	(0.231)	(0.260)	(0.318)	(0.334)	(0.080)
ln(Income), reg.2	0.253	0.058	0.061	0.437 **	0.293	1.147 ***	0.327 ***
	(0.231)	(0.141)	(0.232)	(0.221)	(0.305)	(0.331)	(0.081)
Annex I	0.320 *	0.088	-0.135	-0.110	0.234	0.576 **	-0.078
	(0.190)	(0.255)	(0.244)	(0.222)	(0.179)	(0.239)	(0.098)
Openness	-0.112	0.153 **	0.062	0.192 **	-0.019	0.244	0.103
	(0.107)	(0.072)	(0.196)	(0.084)	(0.144)	(0.163)	(0.081)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Threshold (value)	9.952	10.415	10.222	8.055	7.963	9.669	10.443
99% CI lower bound	9.939	10.236	10.008	8.051	7.901	9.500	10.405
99% CI upper bound	9.955	10.604	10.314	8.055	8.137	9.828	10.526
Bootstrap p-value	0.000	0.014	0.010	0.000	0.010	0.040	0.000
Wald equal. coeff. (p)	0.001	0.043	0.002	0.290	0.002	0.027	0.005
N regime 1/2	293/175	370/98	329/139	68/400	63/405	249/219	377/91
Panel 3: CH_4 per capita embodied in consumption							
ln(Income), reg.1	0.413 **	0.150	0.154	0.509 **	0.246	1.546 ***	0.248 **
	(0.190)	(0.161)	(0.276)	(0.245)	(0.307)	(0.367)	(0.118)
ln(Income), reg.2	0.385 **	0.128	0.187	0.571 ***	0.297	1.498 ***	0.269 **
	(0.189)	(0.165)	(0.275)	(0.206)	(0.294)	(0.351)	(0.113)
Annex I	0.531 ***	-0.128	-0.081	0.155	0.184	0.687 ***	-0.191 *
	(0.183)	(0.224)	(0.284)	(0.141)	(0.162)	(0.206)	(0.110)
Openness	0.079	0.087	0.040	0.002	-0.043	0.193	0.109
	(0.092)	(0.105)	(0.202)	(0.096)	(0.162)	(0.169)	(0.086)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Threshold (value)	9.947	10.302	10.166	8.055	7.963	7.689	9.493
99% CI lower bound	9.929	10.241	7.652	8.055	7.901	7.652	9.493
99% CI upper bound	9.968	10.539	10.609	8.055	8.100	7.802	9.508
Bootstrap p-value	0.006	0.000	0.006	0.000	0.004	0.020	0.000
Wald equal. coeff. (p)	0.001	0.067	0.021	0.257	0.002	0.095	0.016
N regime 1/2	290/178	341/127	317/151	68/400	63/405	49/419	219/249

Table 2: IV-FE results: CH_4 per capita. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). CI stands for confidence interval and N is the number of observations. Cluster robust standard errors (Stock and Watson, 2008) in parentheses. Panel 1: The threshold estimate and the lower bound of the CI for services, and the lower bound of the CI for transport are truncated at 7.652 as a result of the 10% trimming. Panel 3: The bounds of the threshold CI for energy, and the lower bound of the CI for transport are truncated at 7.652 and 10.609. All regressions include additional control variables. The results for the full list of regressors are available in Tables B.1 to B.3 in the Online Appendix.

ment (see Kuznets, 1973, Herrendorf et al., 2013). A notable exception to this pattern was the service sector in production inventories, for which the income-elasticity of emissions strongly decreased (by 0.22 percentage points) when moving to the higher income-regime. This decrease may be partly driven by a declining methane content per unit of value added associated with economic development, either through methane efficiency gains or through composition effects, issues that we will pick up again below.[15] In all other sector–inventory combinations, the difference in income-elasticities across income-regimes was usually far below 0.1 percentage points. Despite its small magnitude, this difference was statistically significant in most cases (see the Wald tests of the equality of coefficients).

Turning to quantitative differences in the income-elasticities as we move down the supply chain (i.e. from production to final production and to consumption inventories), the general pattern was a decrease in income-elasticities from production to final production, and a slight renewed increase from final production to consumption-based inventories.[16] This pattern suggests that production and consumption activities—and CH_4 embodied in them—were significantly influenced by income per capita, whereas economic growth did not strongly affect methane emissions embodied in the final stage of production.

The magnitude and the statistical significance of the estimated income-elasticities differed widely across sectors. Interestingly, we could not reject the null hypothesis of coupling of emissions in some sectors (i.e. the income-elasticity was not significantly different from one, indicating the absence of decoupling).[17] For the production of energy, the absence of decoupling could not be rejected, since the income-elasticity was not statistically different from one at conventional significance levels. Also in the transport sector the income-elasticity of CH_4 emissions was very high and consistently larger than one for all CH_4 inventories. In this sector, a one percent increase in income per capita led to an expansion of CH_4 emissions per capita by between 1.1 (final production) and 1.8 (production) percent, which points to the absence of decoupling. The high elasticity in the transport sector may be a result of the effect of energy on it. Specifically, methane releases from the transportation sector are mainly related to pipelines and auxiliary transportation activities associated with the energy sector. Additionally, the main input of the transport sector, which is accounted in final production and consumption inventories, is energy.

[15] Another exception was the public administration sector for the consumption inventory, where the income-elasticity increased when moving to the higher income-regime.

[16] The public administration sector was an exception, with the income-elasticity being the highest for the final production inventory and the lowest for consumption-based CH_4 emissions.

[17] Relative decoupling occurs when emissions increase less than proportional with economic growth, whereas absolute decoupling refers to a situation in which economic growth does not affect or decreases emissions (see OECD, 2002, Jackson, 2009).

By contrast, there is evidence for relative decoupling—i.e. a positive and statistically significant income-elasticity that is also significantly smaller than one—in agriculture, manufacturing, and public administration.[18] In these sectors, a one percent increase in income per capita entailed an increase in emissions per capita of roughly 0.3 (public administration) to 0.5 percent (manufacturing). Finally, for other sectors the income-elasticity of emissions was not statistically different from zero and thus we could not reject absolute decoupling. This applied to the livestock and service sectors, and to footprint-based emissions in the energy sector. Altogether, the sectors in which income growth did not significantly affect CH_4 emissions accounted for about 40% of emissions from production and consumption, and for 55% of final production.[19]

Regarding the other covariates, the ratification of the Kyoto Protocol significantly lowered CH_4 emissions derived from production in Annex I countries in the transport and public administration sectors only. For footprint-based emissions (final production and consumption inventories), by contrast, Kyoto ratification had the opposite effect in the agriculture and transport sectors, where emissions were higher in Annex I countries than in their non-Annex I counterparts and in non-ratifying countries. The only footprint-based inventory in which Kyoto ratification significantly reduced CH_4 emissions in Annex I countries was the consumption inventory in the public administration sector.[20] Taken together, these findings are supportive of a CH_4-reducing effect of the Kyoto Protocol for Annex I members disappeared when moving down the supply chain (or, respectively, that its effect reversed to inducing higher footprint-based emissions) and suggest that imports by Annex I countries were relatively methane-intensive. Concerning trade openness, we found a positive and statistically significant relation to emissions from the agriculture and energy sectors (production inventories), and the livestock and manufacturing sectors (final production inventories). The effects of the control variables, which are reported in Tables B.1 to B.3 in the Online Appendix, varied in magnitude and statistical significance across sectors, confirming the heterogeneity of drivers of CH_4 emissions at the sectoral level.

In order to address whether the effects of the baseline variables were affected by collinearity with some of the controls, we tested the sensitivity of our results to the exclusion of the control variables. The main results remained qualitatively the same, with one notable

[18] Exceptions were the final production inventory for agriculture, and the production inventory for manufacturing, with a statistically insignificant income-elasticity. The results for the agriculture sector were mostly driven by the crops subsector as reported in Appendix C.

[19] For production inventories, this applies to the livestock, manufacturing, and service sectors; for final production inventories these sectors are agriculture, livestock, energy, and services; and for consumption inventories, it applies to the livestock, energy, and services sectors.

[20] The ratification of the Kyoto Protocol by Annex I countries is also associated with less CH_4 emissions embodied in consumption in the red meat subsector of the livestock sector (see Appendix C).

exception: We could not reject linearity between income and CH_4 per capita for the final production inventory in the transport sector (p-value: 0.106).[21]

4.2 Results for VA per capita and methane intensity

Table 3 presents the regression results for (the logarithm of) sectoral value added per capita as dependent variable. The effect of income per capita was positive and highly statistically significant in all sectors, with a particularly strong effect on the transport and manufacturing sectors, and on energy production.[22] These positive income-elasticities underline the scale effect of economic growth on emissions, which predicts that as income rises, sectors will expand, contributing to an increase in economy-wide emissions (see Copeland and Taylor, 2004, Stern, 2004). Countries facing binding emission constraints as specified in the Kyoto Protocol downsized sectoral value added particularly from the primary sectors and manufacturing but increased value added from services. Furthermore, value added embodied in the consumption of transport services increased in Annex I countries. Trade openness was related to a decrease in value added per capita from the livestock and service sectors.

Turning to the results for (the logarithm of) methane per unit of value added as dependent variable (Table 4), we observe that income per capita was negatively connected to methane intensity in many, but not all, sectors. A negative income-elasticity of methane intensity is compatible with composition and technique effects of economic growth, which predict that as income per capita raises, the composition of the sector may change in a way that makes it less emission intensive (composition effect) and/or more environmentally friendly methods of production are developed (technique effect). Our results suggest that composition and technique effects were present in many but not all economic sectors.

Regarding the functional form of the relationship between income per capita and CH_4 intensity, there is evidence for a piecewise linear linear in all but three sector–inventory combinations. In two sectors (livestock and energy) we could not reject a linear relationship

[21] Some differences in terms of statistical significance levels occurred, from which we should note three. First, the income-elasticity of emissions embodied in final production in the agriculture sector turned statistically significant. Second, the effect of the ratification of the Kyoto Protocol by Annex I members changed its statistical significance in some sectors: It remained positive but turned statistically significant in the service sector (production-based emissions), and it turned insignificant in the public administration sector (all emission inventories). Third, trade openness remained negative but turned statistically significant in the agriculture sector (final production inventory). Additionally, we detected an increase in the income-elasticity when surpassing the income-threshold in the final production inventories of the agriculture, transport, and public administration sectors. The results are available upon request.

[22] These effects were also very strong in the red meat subsector of the livestock sector, and for production in the forestry and fishing subsector of the agriculture sector (see Appendix C).

	Dependent variable: VA per capita embodied in production in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
	Panel 1: Value added per capita embodied in production in:						
ln(Income), reg.1	1.003 ***	0.738 ***	1.335***	1.231 ***	1.097***	1.817 ***	0.900 **
	(0.209)	(0.166)	(0.327)	(0.194)	(0.108)	(0.640)	(0.389)
ln(Income), reg.2	0.982 ***	0.719 ***		1.217 ***		1.735 ***	0.933 **
	(0.207)	(0.163)		(0.192)		(0.573)	(0.375)
Annex I	-0.340 **	-0.422 **	0.338	-0.566 ***	0.205	-0.035	-0.154
	(0.167)	(0.191)	(0.303)	(0.161)	(0.127)	(0.256)	(0.321)
Openness	-0.132	-0.320 ***	0.219	-0.018	-0.287**	-0.273	-0.170
	(0.091)	(0.116)	(0.221)	(0.163)	(0.115)	(0.176)	(0.126)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Threshold (value)	9.509	9.493		10.173		10.222	9.508
99% CI lower bound	9.433	7.652		10.101		10.192	9.493
99% CI upper bound	9.556	10.609		10.452		10.314	9.684
Bootstrap *p*-value	0.036	0.044		0.002		0.000	0.018
Wald equal. coeff. (p)	0.001	0.045		0.117		0.299	0.103
N regime 1/2	222/246	219/249	468	318/150	468	329/139	221/247
	Panel 2: Value added per capita embodied in final production in:						
ln(Income), reg.1	0.934 ***	0.779***	0.775 ***	1.398 ***	1.031***	1.160 ***	0.835 **
	(0.189)	(0.184)	(0.207)	(0.177)	(0.146)	(0.237)	(0.403)
ln(Income), reg.2	0.912 ***		0.725 ***	1.374 ***		1.212 ***	0.869 **
	(0.189)		(0.204)	(0.177)		(0.225)	(0.389)
Annex I	-0.189	-0.668***	0.003	-0.253 *	0.372**	0.290	-0.189
	(0.118)	(0.165)	(0.222)	(0.154)	(0.154)	(0.193)	(0.276)
Openness	-0.071	-0.210**	0.132	0.238	-0.319**	-0.121	-0.169
	(0.118)	(0.103)	(0.149)	(0.157)	(0.144)	(0.128)	(0.138)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Threshold (value)	10.008		9.079	10.258		8.047	9.559
99% CI lower bound	9.927		9.019	10.233		8.026	9.493
99% CI upper bound	10.101		9.139	10.359		8.137	9.684
Bootstrap *p*-value	0.000		0.000	0.000		0.050	0.010
Wald equal. coeff. (p)	0.008		0.001	0.009		0.011	0.083
N regime 1/2	301/167	468	157/311	336/132	468	66/402	231/237
	Panel 3: Value added per capita embodied in consumption in:						
ln(Income), reg.1	0.972 ***	0.777 ***	0.743 ***	1.340 ***	1.022***	1.254 ***	0.880 **
	(0.158)	(0.181)	(0.180)	(0.147)	(0.136)	(0.214)	(0.374)
ln(Income), reg.2	0.951 ***	0.755 ***	0.703 ***	1.311 ***		1.309 ***	0.910 **
	(0.159)	(0.185)	(0.180)	(0.148)		(0.202)	(0.363)
Annex I	0.070	-0.503 ***	-0.060	0.190	0.296**	0.516 ***	-0.187
	(0.150)	(0.183)	(0.210)	(0.170)	(0.142)	(0.188)	(0.252)
Openness	-0.029	-0.079	0.062	0.002	-0.362***	-0.142	-0.155
	(0.127)	(0.114)	(0.151)	(0.116)	(0.139)	(0.129)	(0.134)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Threshold (value)	10.023	10.306	9.079	10.421		8.047	9.559
99% CI lower bound	9.988	10.251	8.762	10.382		7.963	9.493
99% CI upper bound	10.101	10.377	9.139	10.431		8.100	9.690
Bootstrap *p*-value	0.004	0.000	0.012	0.042		0.090	0.006
Wald equal. coeff. (p)	0.001	0.063	0.017	0.000		0.005	0.072
N regime 1/2	304/164	343/125	157/311	371/97	468	66/402	231/237

Table 3: IV-FE results: Value added per capita. Note: Abbreviations as in Table 2. Panel 1: The bounds of the threshold CI for livestock are truncated at 7.652 and 10.609 as a result of the 10% trimming. All regressions include additional control variables. The results for the full list of regressors are available in Tables B.7 to B.9 in the Online Appendix.

	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
	Panel 1: CH_4 per unit of VA embodied in production in:						
ln(Income), reg.1	-0.347	-0.468*	-0.503	-1.154 **	-0.257	11.745**	-0.800 **
	(0.217)	(0.257)	(0.315)	(0.487)	(0.813)	(5.252)	(0.343)
ln(Income), reg.2	-0.425 **			-1.181 **	-0.479		-0.776 **
	(0.209)			(0.462)	(0.736)		(0.346)
ln(Income), squared						-0.701**	
						(0.320)	
Annex I	0.099	1.125	-0.287	0.772 **	0.563	0.098	0.032
	(0.287)	(0.787)	(0.351)	(0.356)	(0.536)	(0.398)	(0.395)
Openness	0.452 ***	0.938*	-0.050	-0.060	0.555	0.207	0.180
	(0.104)	(0.536)	(0.234)	(0.274)	(0.402)	(0.209)	(0.164)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Thresh. (value); [TP]	8.055			8.086	7.652	[8.374]	9.777
99% CI lower bound	8.047			7.652	7.652		7.652
99% CI upper bound	8.086			10.609	7.652		10.609
Bootstrap *p*-value	0.002			0.034	0.002		0.014
Wald equal. coeff. (p)	0.008			0.556	0.030		0.068
U-Test (p)						0.025	
N reg. 1/2; [%N<TP]	68/400	468	468	69/399	47/421	468 [16.5%]	270/198
	Panel 2: CH_4 per unit of VA embodied in final production in:						
ln(Income), reg.1	-0.611 ***	-0.550 ***	-0.673 **	-1.010 ***	-0.549 **	-0.120	-0.518
	(0.220)	(0.190)	(0.292)	(0.157)	(0.271)	(0.306)	(0.386)
ln(Income), reg.2	-0.591 ***	-0.580 ***	-0.619 **	-0.951 ***	-0.522 *	-0.170	-0.539
	(0.223)	(0.183)	(0.292)	(0.149)	(0.274)	(0.295)	(0.373)
Annex I	0.448 *	0.595 **	-0.241	0.229	-0.254	0.346 *	0.073
	(0.251)	(0.236)	(0.246)	(0.181)	(0.181)	(0.205)	(0.257)
Openness	-0.055	0.398 ***	-0.130	-0.063	0.356 ***	0.353 ***	0.282 ***
	(0.140)	(0.118)	(0.192)	(0.105)	(0.088)	(0.132)	(0.098)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Threshold (value)	10.470	8.055	10.131	8.217	10.455	8.055	9.559
99% CI lower bound	10.445	8.047	10.085	8.100	10.388	8.047	7.652
99% CI upper bound	10.489	8.086	10.184	8.257	10.489	8.086	10.609
Bootstrap *p*-value	0.016	0.004	0.040	0.000	0.070	0.006	0.044
Wald equal. coeff. (p)	0.070	0.176	0.002	0.008	0.006	0.021	0.248
N regime 1/2	385/83	68/400	314/154	74/394	384/84	68/400	231/237
	Panel 3: CH_4 per unit of VA embodied in consumption in:						
ln(Income), reg.1	-0.489 *	-0.512 ***	-0.548 *	-0.670 ***	-0.547 **	0.036	-0.761 ***
	(0.258)	(0.182)	(0.288)	(0.101)	(0.262)	(0.259)	(0.267)
ln(Income), reg.2	-0.525 **	-0.547 ***	-0.498 *	-0.650 ***	-0.524 **	-0.010	-0.746 ***
	(0.248)	(0.174)	(0.288)	(0.101)	(0.264)	(0.247)	(0.266)
Annex I	0.491 ***	0.348 *	-0.074	-0.018	-0.214	0.195	0.054
	(0.176)	(0.200)	(0.278)	(0.145)	(0.168)	(0.162)	(0.211)
Openness	0.121	0.186 *	-0.046	0.017	0.371 ***	0.309 ***	0.245 **
	(0.112)	(0.107)	(0.204)	(0.083)	(0.085)	(0.089)	(0.096)
Additional controls	yes	yes	yes	yes	yes	yes	yes
Threshold (value)	8.051	8.055	10.101	10.377	10.455	8.055	9.459
99% CI lower bound	8.047	8.047	10.013	10.241	10.369	8.047	7.652
99% CI upper bound	8.086	8.086	10.184	10.380	10.513	8.086	10.609
Bootstrap *p*-value	0.016	0.004	0.010	0.032	0.068	0.002	0.028
Wald equal. coeff. (p)	0.061	0.102	0.004	0.000	0.012	0.030	0.161
N regime 1/2	67/401	68/400	312/156	358/110	384/84	68/400	212/256

Table 4: IV-FE results: CH_4 per unit of value added. Note: TP stands for the value of the turning point. U-Test (p) is the *p*-value of the test for a polynomial relationship developed by Lind and Mehlum (2010). %N<TP refers to the share of observations before the TP. Other abbreviations as in Table 2. Panel 1: The threshold estimate and the lower bound of the CI for services, and the bounds of the CI for manufacturing and public administration are truncated at 7.652 and 10.609 as a result of the 10% trimming. Panels 2 and 3: The bounds of the CI for public administration are similarly truncated. All regressions include additional control variables. The results for the full list of regressors are available in Tables B.4 to B.6 in the Online Appendix.

in production activities. In contrast, the relationship followed an inverse-U shape in the production inventories of the transport sector, such that the CH_4 intensity of transport increased at low levels of economic development but decreased after a turning-point had been reached. This polynomial relationship is statistically significant, as indicated by the (inverse-U) test of Lind and Mehlum (2010). The turning-point was identified at a log-income per capita of about 8.4 (i.e. about 4,400 constant PPP dollars), suggesting that 16.5% of the observations in our sample faced a positive income-elasticity, whereas for the richer 83.5% income growth reduced the CH_4 content of value added embodied in production.[23]

Looking at the piecewise-linear regressions, the identified income-thresholds did not correspond in general to the ones detected for CH_4 per capita. High threshold values for CH_4 intensities were estimated in the energy, service, and public administration sectors, whereas lower values were identified for the primary sectors, manufacturing, and transport.[24] The differences in the threshold estimates between Table 2, where the dependent variable is methane per capita, and Table 4, where the dependent variable is CH_4 per value added, can be explained by the developments in sectoral value added per capita that accompany economic development (see Table 3).

The direction of the change in income-elasticities when moving from one income-regime to the other was more in line with the findings for CH_4 per capita.[25] Notably, the difference in the income-elasticities across regimes was usually small but statistically significant in many sectors. Like for CH_4 per capita, the only larger change in the income-elasticity across regimes was observed for services production (0.22 percentage points). Also the change in income-elasticities when moving down the supply chain was in line with the pattern found for CH_4 per capita. We observe an increase in the (negative) income-elasticity when moving from production to final production inventories, and a renewed decrease when moving from final production to consumption.[26] Taken together, our results suggest that the changes in the income-elasticity of CH_4 intensities, at least partly, determined the corresponding changes in the income-elasticity of CH_4 per capita.

[23] We did not detect a polynomial relationship in any of the other sector–inventory combinations, since either the income-terms were not statistically significant or the (inverse) U-test by Lind and Mehlum (2010) did not reject the null hypothesis of a monotone or U shape. One exception is the forestry and fishing subsector within the agriculture sector, in which we detected evidence for a U-shaped relationship between income and emission intensity (see Appendix C).

[24] The three exceptions to this broad pattern were the production-inventory for services, the final production inventory for agriculture, and the consumption-inventory for manufacturing.

[25] The only two exceptions were the production inventory for public administration and final production in agriculture, where the income-elasticity of CH_4 intensity was higher (i.e. less negative) in the second regime.

[26] One exception was the manufacturing sector, where the elasticity also decreased when moving from production to final production. Furthermore, like for CH_4 per capita, public administration followed the reverse pattern.

The magnitude of the income-elasticities of CH_4 intensity was relatively large (in absolute value) for the manufacturing sector, where a one percent increase in income per capita led to a more than proportional decrease in CH_4 intensity.[27] Also public administration was characterized by a rather high income-elasticity of CH_4 intensity in production and consumption (between -0.75 and -0.8). More moderate elasticities were found in the primary sectors, energy, and services, ranging between -0.42 (agricultural production) and -0.67 (final production of energy). By contrast, economic growth did not lead to significant reductions of CH_4 intensities in the transport sector, in service and energy production, and for the final production inventory in public administration. Noteworthy, relating these findings to the results in tables 2 and 3, we observe that whenever the income-elasticity of CH_4 intensity was statistically insignificant, the corresponding income-elasticity of CH_4 per capita was rather high; in other words, economic growth led to an increase in CH_4 emissions per capita especially in sectors that were not able to reduce their CH_4 intensity. By contrast, sectors that reduced the CH_4 intensity as the economy grew were able to (at least partially) counterbalance the increase of emissions arising from sectoral expansions.

The effects of the remaining explanatory variables varied across sectors and CH_4 inventories. Surprisingly, whenever the coefficient of Annex I was statistically significant, it was positive. Thus, the insignificant (or sometimes negative) effect of the Kyoto Protocol ratification by Annex I members detected in Table 2 for production-based inventories was likely driven by a reduction of sectoral value added per capita in Annex I countries, rather than by a decrease in their CH_4 intensity. This is also supported by the findings in Table 3. Trade openness showed a positive and statistically significant relationship with the CH_4 intensity of production in the two agricultural sectors, and with the footprint-based emission inventories in the livestock, service, transport, and public administration sectors. Again, the effects of the control variables varied considerably across sectors.

The results of the robustness check in which we included only the baseline regressors were in line with the findings of the main analysis. The main difference was that in the robustness check we found evidence for a threshold effect for energy production, but not for manufacturing production.[28]

[27] For CH_4 embodied in consumption this decrease was somewhat smaller (about 0.65 percent). Looking at the subsectors of agriculture and livestock, the income-elasticity was also very large (in absolute value) for the forestry and fishing subsector of the agriculture sector, and the red meat subsector of the livestock sector, as reported in Appendix C.

[28] Three changes in statistical significance levels can be highlighted. First, the income-elasticity of the consumption inventory for energy turned insignificant, whereas the income-elasticity of the final production inventory of public administration lost significance. Second, the negative coefficient of Annex I membership in the final production of services turned statistically significant. Third, openness was statistically significant also in the production inventory in the service sector.

5 Conclusion

Our analysis of the determinants of sectoral methane emissions between 1997 and 2014 shows that there is considerable heterogeneity in the relationship between economic growth and methane emissions at the sectoral level. Interestingly, emissions per capita were not significantly affected by income per capita in sectors accounting for more than 40% of total methane emissions—a result that had remained hidden in previous analyses focusing on aggregate emissions. In these sectors, absolute decoupling could not be rejected. In the remaining sectors, economic growth significantly raised emissions per capita, although the magnitude of this increase varied across sectors. In some sectors, the increase was less than proportional, indicating relative decoupling, whereas in the transport sector and in energy production we could not reject that emissions per capita grew at least as fast as income per capita. Our results imply that there is a trade-off between economic growth and pollution from methane emissions in some but not all sectors. That is, emission targets in certain economic sectors do not necessarily compromise economic growth while these targets, when applied to other sectors, may constrain economic growth.

There is evidence for a piecewise-linear relationship between income per capita and emissions in most sectors. The changes in the income-elasticity of methane induced by economic development are compatible with the process of structural change, whereby the share of economic activity in primary sectors declines and the shares of industry, services, and energy production increase. Accordingly, as structural change advances, the importance of primary sectors in total methane emissions is likely to decline, while the importance of secondary and tertiary sectors will increase. The changes in the sectoral structures of countries will affect their methane releases and their potential to reach emission mitigation targets. Thus, national development strategies that promote specific economic sectors should also be evaluated in terms of their potential impact on methane emissions. In general, methane-efficiency gains cannot be automatically implied from economic development in any economic sector since the detected changes in income-elasticities with rising income per capita are mostly of very small magnitude.

Our results document that the effect of income per capita on emissions per capita results from the interplay of its effect on sectoral expansions (a proxy for scale effects) and on emission intensities (a proxy for composition and technique effects). On the one side, economic growth was connected to expansions of economic activity in all sectors, which were particularly large in the transport and manufacturing sectors, as well as in energy production. On the other side, it also led to reductions in sectoral emission intensities, albeit this effect was insignificant in the transport sector and in the production of energy and services.[29] In general, realized gains in methane intensity were not large enough to outweigh the scale effect of economic growth, and in line with the economywide findings by Fernández-Amador et al. (2018a), there is no evidence for an environmental Kuznets' curve in methane emissions at the sectoral level. Moreover, those sectors experiencing large sectoral expansions and not significant gains in emission intensities (transport and energy production) were characterized by absence of decoupling of emissions per capita. Interestingly, the large expansion of value added per capita in the manufacturing sector did not result in a high income-elasticity of methane emissions per capita, because significant methane intensity gains could be realized at the same time. In this respect, the sectoral emission mitigation potential should be evaluated to find cost-effective abatement strategies (see also Höglund-Isaksson, 2012). Policy should promote technology transfers and financial assistance to implement more environmentally friendly production techniques, focusing on countries and sectors with larger scope for improvements in order to strengthen methane efficiency gains that have the potential to counterbalance the effects of increases in economic activity.

The effectiveness of the Kyoto Protocol differed across economic sectors. Significant reductions in emission per capita could be realized only in production of the transport and public administration sectors. Nevertheless, these gains were not driven by improvements in methane intensity but by a reduction of economic activity in these sectors. The Kyoto Protocol also resulted in increased emissions from final production or consumption in some sectors, indicating that imports of Annex I countries were relatively methane-intensive. Moreover, trade openness was related to higher emissions in certain sectors. Taken together, these results may be supportive for methane leakage and point to the ineffectiveness of the Kyoto Protocol. Thus, in order to be effective, environmental regulation has to either be implemented globally or, when global agreements are unlikely, it has to be designed to explicitly account for emissions embodied in trade to avoid potential emission leakage.

Overall, the sectoral heterogeneity found in the determinants of methane emissions may complicate the design and implementation of environmental instruments to reduce methane emissions. On the international level, this sectoral heterogeneity may erode the chances of reaching successful international cooperation. Sectoral heterogeneity introduces transaction costs associated with existing asymmetries in economic structures and preferences across and within nations (Libecap, 2014). International cooperation is influenced by such transaction costs which must be overcome to reach an agreement. The larger the

[29] For the production inventory in the transport sector, the methane intensity increased with economic growth at low levels of GDP per capita but decreased with economic growth after an income per capita of about 4,400 constant PPP dollars had been reached. The effect was statistically significant.

heterogeneity in economic structures or preferences, the lower the probability for international cooperation to cope with the problem of global negative externalities. Moreover, international agreements on policy instruments to combat global warming must address these sectoral particularities and promote assistance especially to countries that are likely to expand economic activity in methane-intensive sectors with advancing economic development. On the national level, environmental policy instruments must take into account the diverse nature of the processes that are responsible for methane emissions and act at the sectoral level with specific designs that account for the existence of international trade linkages.

Finally, the remarkable differences between methane and CO_2 emissions call for separate environmental regulation for different greenhouse gases. The sectoral structure of methane emissions differs considerably from the sectoral patterns of CO_2 releases. The economic processes involved in methane and CO_2 emissions, as well as their relationship with economic growth, differ substantially, too. These differences will affect the position that countries will take in international climate negotiations on different greenhouse gases. Accordingly, separate regulation may speed up negotiations on specific gases on the one hand, and, on the other hand, allow for more precisely targeted emission reduction policies and facilitate international cooperation in crucial sectors.

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References

Aichele, R., Felbermayr, G., 2012. Kyoto and the carbon footprint of nations. Journal of Environmental Economics and Management 63, 336 – 354.

Aichele, R., Felbermayr, G., 2015. Kyoto and carbon leakage: An empirical analysis of the carbon content of bilateral trade. The Review of Economics and Statistics 97, 104 – 115.

Burns, T., Davis, B., Kick, E., 1997. Position in the world-system and national emissions of greenhouse gases. Journal of World-Systems Research 3, 432–466.

Caner, M., Hansen, B., 2004. Instrumental variable estimation of a threshold model. Econometric Theory 20, 813 – 843.

Cole, M. A., 2004. Trade, the pollution haven hypothesis and the environmental Kuznets curve: Examining the linkages. Ecological Economics 48, 71 – 81.

Cole, M. A., Elliott, R. J., 2003. Determining the trade-environment composition effect: the role of capital, labor and environmental regulations. Journal of Environmental Economics and Management 46, 363 – 383.

Copeland, B., Taylor, M., 2004. Trade, growth, and the environment. Journal of Economic Literature 42, 7 – 71.

Dinda, S., 2005. A theoretical basis for the environmental Kuznets curve. Ecological Economics 53, 403 – 413.

Fernández-Amador, O., Francois, J. F., Oberdabernig, D. A., Tomberger, P., 2017. Carbon dioxide emissions and economic growth: An assessment based on production and consumption emission inventories. Ecological Economics 135, 269 – 279.

Fernández-Amador, O., Francois, J. F., Oberdabernig, D. A., Tomberger, P., 2018a. Empirical estimates of the methane–income elasticity. Economics Letters 171, 137–139.

Fernández-Amador, O., Francois, J. F., Oberdabernig, D. A., Tomberger, P., 2018b. The methane footprint of nations: Evidence from global panel data. WTI Working Papers No. 01/2018, 1–24.

Frankel, J., Rose, A., 2005. Is trade good for the environment? Sorting out the causality. The Review of Economics and Statistics 87, 85 – 91.

Hansen, B., 1996. Inference when a nuisance parameter is not identified under the null hypothesis. Econometrica 64, 413 – 430.

Hansen, B., 1999. Threshold effects in non-dynamic panels: Estimation, testing and inference. Journal of Econometrics 93, 345 – 368.

Hansen, B., 2000. Sample splitting and threshold estimation. Econometrica 68, 575 – 603.

Harbaugh, W. T., Levinson, A., Wilson, D. M., 2002. Reexamining the empirical evidence for an environmental Kuznets curve. The Review of Economics and Statistics 84, 541 – 551.

Herrendorf, B., Rogerson, R., Valentinyi, A., 2013. Growth and structural transformation. NBER working paper No. 18996.

Höglund-Isaksson, L., 2012. Global anthropogenic methane emissions 2005?2030: technical mitigation potentials and costs. Atmospheric Chemistry and Physics 12 (19), 9079–9096.

IPCC, 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Cambridge University Press.

Jackson, T., 2009. Prosperity without Growth: Economics for a Finite Planet. Earthscan, London.

Jorgenson, A., 2006. Global warming and the neglected greenhouse gas: a cross-national study of methane emissions intensity, 1995. Social Forces 84, 1777 – 1796.

Jorgenson, A., Birkholz, R., 2010. Assessing the causes of anthropogenic methane emissions in comparative perspective, 1990 - 2005. Ecological Economics 69, 2634 – 2643.

Kearsley, A., Riddel, M., 2010. A further inquiry into the pollution heaven hypothesis and the environmental Kuznets curve. Ecological Economics 69, 905 – 919.

Kuznets, S., 1973. Modern economic growth: Findings and reflections. The American Economic Review 63, 247 – 258.

Libecap, G., 2014. Addressing global environmental externalities: Transaction costs considerations. Journal of Economic Literature 52, 424 – 479.

Lind, J. T., Mehlum, H., 2010. With or without U? The appropriate test for a U-shaped relationship. Oxford Bulletin of Economics and Statistics 72, 109 – 118.

Managi, S., Hibiki, A., Tsurumi, T., 2009. Does trade openness improve environmental quality? Journal of Environmental Economics and Management 58, 346 – 363.

OECD, 2002. Indicators to measure decoupling of environmental pressure from economic growth.

Perrings, C., Ansuategi, A., 2000. Sustainability, growth and development. Journal of Economic Studies 27 (1/2), 19–54.

Richmond, A., Kaufmann, R., 1997. Is there a turturn point in the relationship between income and energy use and/or carbon emissions? Ecological Economics 56, 176–189.

Rosa, E., York, R., Dietz, T., 2004. Tracking the anthropogenic drivers of ecological impacts. Ambio 33, 509 – 512.

Stern, D., 2004. The rise and fall of the environmental Kuznets curve. World Development 32, 1419 – 1439.

Stern, D. I., Common, M. S., Barbier, E. B., 1996. Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development. World Development 24, 1151 – 1160.

Stock, J., Watson, M., 2008. Heteroskedastiticy-robust standard errors for fixed effects panel data regression. Econometrica 76, 155–174.

Torras, M., Boyce, J. K., 1998. Income, inequality, and pollution: a reassessment of the environmental Kuznets curve. Ecological Economics 25, 147 – 160.

Online Appendices

A Data tables

Aggregate	Countries and regions included
	Single Countries and Regions:
The 66 single countries and regions	Albania, Argentina, Australia, Austria, Belgium, Bangladesh, Bulgaria, Brazil, Botswana, Canada, Chile, China, Colombia, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malawi, Malaysia, Malta, Mexico, Morocco, Mozambique, Netherlands, New Zealand, Peru, Philippines, Poland, Portugal, Romania, Russia, Singapore, Slovakia, Slovenia, Spain, Sri Lanka, Sweden, Switzerland, Taiwan, Tanzania, Thailand, Turkey, Uganda, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Zambia, Zimbabwe
	The 12 Composite Regions:
Rest of Andean Pact	Bolivia and Ecuador
Central America, Caribbean	Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Cayman Islands, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Saint Helena, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, and Virgin Islands (US,GB).
Rest of EFTA	Iceland, Liechtenstein and Norway.
Rest of Former Soviet Union	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.
Middle East	Bahrain, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen.
Rest of North Africa	Algeria, Egypt, Libya and Tunisia
Other Southern Africa	Angola and Congo (DPR)
Rest of South African Customs Union	Lesotho, Namibia, South Africa and Swaziland
Rest of South America	Guyana, Paraguay and Suriname
Rest of South Asia (RSA)	Bhutan, Maldives, Nepal and Pakistan
Rest of Sub-Saharan Africa (SSA)	Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Mali, Mauritania, Mauritius, Mayotte, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan and Togo
Rest of World	Afghanistan, American Samoa, Andorra, Bosnia and Herzegovina, Brunei Darussalam, Cambodia, China, Macao SAR, Cook Islands, Democratic People's Republic of Korea, Falkland Islands (Malvinas), Faroe Islands, Fiji, French Guiana, French Polynesia, Gibraltar, Greenland, Guam, Isle of Man, Kiribati, Lao People's Democratic, Republic, Marshall Islands, Micronesia (Federated States of), Mongolia, Montenegro, Myanmar, Nauru, New Caledonia, Niue, Norfolk Island, Northern Mariana Islands, Occupied Palestinian, Territory, Palau, Papua New Guinea, Pitcairn Islands, Samoa, Serbia, Solomon Islands, The former Yugoslav Republic of Macedonia, Timor-Leste, Tokelau, Tonga, Tuvalu, Vanuatu and Wallis and Futuna Islands.

Table A.1: Countries and composite regions in the database.

Final Dem. Sector	**Detailed Sectors**
Agriculture (agr.)	Paddy rice (pdr); Wheat (wht); Cereal grains nec (gro); Vegetables, fruit, nuts (v_f); Oil seeds (osd); Sugar cane, sugar beet (c_b); Plant-based fibers (pfb); Crops nec (ocr); Forestry (frs); Fishing (fsh); Sugar (sgr); Food products nec (ofd); Beverages and tobacco products (b_t); Vegetable oils and fats (vol); Processed rice (pcr);
Livestock (liv.)	Cattle, sheep, goats, horses (ctl); Animal products nec (oap); Raw milk (rmk); Wool, silk-worm cocoons (wol); Meat: cattle, sheep, goats, horse (cmt); Meat products nec (omt); Dairy products (mil);
Manufacturing (mfc.)	Textiles (tex); Wearing apparel (wap); Leather products (lea); Wood products (lum); Paper products, publishing (ppp); Chemical, rubber, plastic products (crp); Mineral products nec (nmm); Ferrous metals (i_s); Metals nec (nfm); Metal products (fmp); Motor vehicles and parts (mvh); Petroleum, coal products (p_c); Transport equipment nec (otn); Electronic equipment (ele); Machinery and equipment nec (ome); Manufactures nec (omf);
Transport (trn.)	Transport nec (otp); Sea transport (wtp); Air transport (atp);
Services (ser.)	Water utility services (wtr); Construction (cns); Trade and distribution (trd); Communication (cmn); Financial services nec (ofi); Insurance (isr); Business services nec (obs); Recreation and other services (ros); Dwellings (dwe);
Energy (egy.)	Coal (coa); Oil (oil); Gas (gas); Minerals nec (omn); Electricity (ely); Gas manufacture, distribution (gdt);
Public Administration (pub.)	Public Administration (osg);

Table A.2: Subsectors of the seven broad economic sectors.

Sector		1997	2001	2004	2007	2011	2014
Agriculture; Crops	pdr	8.20	8.29	7.83	7.66	7.61	7.52
Agriculture; Crops	wht	0.15	0.10	0.10	0.10	0.13	0.13
Agriculture; Crops	gro	0.20	0.15	0.16	0.16	0.20	0.21
Agriculture; Crops	v_f	0.23	0.10	0.14	0.12	0.20	0.20
Agriculture; Crops	osd	0.04	0.01	0.02	0.02	0.04	0.04
Agriculture; Crops	c_b	0.03	0.02	0.02	0.02	0.03	0.03
Agriculture; Crops	pfb	0.03	0.02	0.02	0.02	0.03	0.03
Agriculture; Crops	ocr	0.07	0.03	0.03	0.03	0.07	0.07
Agriculture; Crops	vol	–	–	–	–	–	–
Agriculture; Crops	pcr	–	–	–	–	–	–
Agriculture; Crops	sgr	–	–	–	–	–	–
Agriculture; Crops	ofd	–	–	–	–	–	–
Agriculture; Crops	b_t	–	–	–	–	–	–
Agriculture; Forestry and Fishing	frs	0.07	0.06	0.04	0.04	0.07	0.07
Agriculture; Forestry and Fishing	fsh	0.21	0.13	0.16	0.10	0.21	0.20
Livestock; Red Meat	ctl	27.23	28.25	27.71	27.36	26.31	25.23
Livestock; Red Meat	cmt	–	–	–	–	–	–
Livestock; Red Meat	wol	0.01	0.01	0.01	0.01	0.01	0.01
Livestock; Other Livestock	oap	1.72	1.78	1.72	1.71	1.69	1.70
Livestock; Other Livestock	omt	–	–	–	–	–	–
Livestock; Dairy	rmk	6.55	6.50	6.37	6.26	6.18	5.97
Livestock; Dairy	mil	–	–	–	–	–	–
Manufacturing	tex	–	–	–	–	–	–
Manufacturing	wap	–	–	–	–	–	–
Manufacturing	lea	–	–	–	–	–	–
Manufacturing	lum	–	–	–	–	–	–
Manufacturing	ppp	0.01	0.01	0.01	0.01	0.01	0.01
Manufacturing	p_c	4.39	4.95	5.56	5.47	4.23	4.35
Manufacturing	crp	0.10	0.11	0.12	0.13	0.15	0.16
Manufacturing	nmm	0.03	0.02	0.03	0.03	0.03	0.03
Manufacturing	i_s	0.03	0.03	0.03	0.04	0.04	0.04
Manufacturing	nfm	0.01	0.01	0.01	0.01	0.01	0.01
Manufacturing	fmp	–	–	–	–	–	–
Manufacturing	mvh	–	–	–	–	–	–
Manufacturing	otn	–	–	–	–	–	–
Manufacturing	ele	–	–	–	–	–	–
Manufacturing	ome	–	–	–	–	–	–
Manufacturing	omf	–	–	–	–	–	–
Transport	otp	5.53	5.99	4.44	4.61	5.85	5.69
Transport	wtp	0.15	0.17	0.18	0.17	0.16	0.17
Transport	atp	0.05	0.05	0.04	0.04	0.04	0.05
Services	wtr	0.04	0.13	0.10	0.08	0.04	0.04
Services	cns	–	–	–	0.01	–	–
Services	trd	0.31	0.08	0.10	0.07	0.31	0.30
Services	cmn	0.05	0.05	0.03	0.03	0.05	0.05
Services	ofi	0.03	0.03	0.03	0.02	0.02	0.02
Services	isr	0.02	0.01	0.01	0.01	0.01	0.01
Services	obs	0.17	0.03	0.04	0.05	0.15	0.14
Services	ros	0.09	0.03	0.02	0.02	0.08	0.08
Services	dwe	–	–	–	–	–	–
Energy	coa	9.19	9.95	11.19	12.18	12.99	13.56
Energy	oil	8.54	6.42	7.93	7.32	6.75	7.01
Energy	gas	2.28	2.08	1.93	2.16	2.07	2.07
Energy	omn	0.01	–	–	0.01	0.01	0.01
Energy	ely	0.03	0.03	0.04	0.04	0.05	0.05
Energy	gdt	3.03	3.19	3.02	2.95	2.75	3.19
Public Administration	osg	21.16	21.15	20.80	20.95	21.37	21.54

Table A.3: Sector shares of CH_4 emissions (in %): production inventory. For sector abbreviations, see Table A.2.

Sector		1997	2001	2004	2007	2011	2014
Agriculture; Crops	pdr	2.75	1.58	0.98	0.75	0.92	0.67
Agriculture; Crops	wht	0.27	0.42	0.07	0.07	0.08	0.07
Agriculture; Crops	gro	0.17	0.39	0.38	0.37	0.40	0.38
Agriculture; Crops	v_f	0.92	1.10	0.99	0.87	0.85	0.85
Agriculture; Crops	osd	0.14	0.45	0.18	0.25	0.23	0.23
Agriculture; Crops	c_b	0.09	0.08	0.03	0.01	0.01	0.01
Agriculture; Crops	pfb	0.08	0.04	0.03	0.05	0.07	0.06
Agriculture; Crops	ocr	0.24	0.55	0.40	0.36	0.36	0.33
Agriculture; Crops	vol	0.51	0.45	0.40	0.50	0.53	0.45
Agriculture; Crops	pcr	4.95	5.61	5.06	4.80	4.75	5.24
Agriculture; Crops	sgr	0.41	0.21	0.15	0.15	0.16	0.16
Agriculture; Crops	ofd	2.64	3.04	2.84	2.93	3.10	3.24
Agriculture; Crops	b_t	0.92	0.91	0.76	0.76	0.86	0.84
Agriculture; Forestry and Fishing	frs	0.10	0.06	0.05	0.05	0.06	0.06
Agriculture; Forestry and Fishing	fsh	0.37	0.23	0.25	0.18	0.24	0.28
Livestock; Red Meat	ctl	8.44	6.05	5.91	5.25	4.89	4.67
Livestock; Red Meat	cmt	9.22	8.47	10.38	10.12	10.07	9.68
Livestock; Red Meat	wol	0.02	0.07	0.05	0.05	0.06	0.05
Livestock; Other Livestock	oap	1.28	1.63	1.39	1.24	1.07	1.00
Livestock; Other Livestock	omt	2.29	2.84	1.62	1.55	1.54	1.56
Livestock; Dairy	rmk	2.69	2.60	2.59	2.29	2.30	2.12
Livestock; Dairy	mil	2.42	2.72	2.67	2.91	2.93	2.96
Manufacturing	tex	0.73	0.64	0.60	0.71	0.59	0.55
Manufacturing	wap	0.79	0.83	0.77	0.92	1.01	0.99
Manufacturing	lea	1.66	1.46	1.55	2.21	2.00	1.94
Manufacturing	lum	0.29	0.26	0.14	0.18	0.10	0.11
Manufacturing	ppp	0.28	0.25	0.26	0.25	0.25	0.28
Manufacturing	p_c	4.22	5.07	5.55	5.34	4.09	4.19
Manufacturing	crp	1.43	1.31	1.29	1.35	1.36	1.47
Manufacturing	nmm	0.21	0.20	0.19	0.14	0.14	0.16
Manufacturing	i_s	0.03	0.07	0.05	0.06	0.06	0.06
Manufacturing	nfm	0.04	0.06	0.04	0.05	0.05	0.07
Manufacturing	fmp	0.26	0.26	0.23	0.25	0.22	0.27
Manufacturing	mvh	1.05	1.04	1.05	1.22	1.31	1.38
Manufacturing	otn	0.32	0.30	0.31	0.34	0.44	0.40
Manufacturing	ele	0.69	0.77	0.87	0.79	0.88	0.89
Manufacturing	ome	1.39	1.38	1.59	1.96	2.11	2.07
Manufacturing	omf	0.85	0.84	0.77	0.80	0.82	0.57
Transport	otp	3.71	3.69	3.36	3.49	3.87	3.92
Transport	wtp	0.30	0.28	0.33	0.31	0.32	0.32
Transport	atp	0.62	0.51	0.62	0.63	0.60	0.60
Services	wtr	0.15	0.12	0.17	0.18	0.20	0.19
Services	cns	4.42	3.80	5.08	5.48	6.23	6.66
Services	trd	3.54	3.48	4.67	4.52	4.33	4.26
Services	cmn	0.21	0.21	0.27	0.28	0.30	0.31
Services	ofi	0.21	0.20	0.26	0.25	0.24	0.28
Services	isr	0.17	0.20	0.15	0.17	0.17	0.16
Services	obs	0.88	0.72	0.71	0.78	0.87	0.92
Services	ros	1.95	1.92	1.74	1.62	1.55	1.59
Services	dwe	0.28	0.23	0.22	0.20	0.23	0.22
Energy	coa	0.67	1.07	0.95	0.78	0.50	0.49
Energy	oil	0.01	0.03	0.06	0.05	0.05	0.03
Energy	gas	0.19	0.38	0.26	0.21	0.16	0.15
Energy	omn	0.01	0.01	0.02	0.02	0.02	0.02
Energy	ely	2.48	2.79	2.74	2.83	2.82	2.90
Energy	gdt	0.94	1.34	1.48	1.45	1.30	1.46
Public Administration	osg	24.12	24.8	24.48	24.69	25.33	25.24

Table A.4: Sector shares of CH_4 emissions (in %): final production and consumption inventories. For sector abbreviations, see Table A.2.

Variable	Description	Source
	Dependent variables	
ln(CH_4 pc), prod.	Log of production based CH_4 emissions per capita.	Fernández-Amador et al. (2018b)
ln(CH_4 pc), fin. prod.	Log of final production based CH_4 emissions per capita.	Fernández-Amador et al. (2018b)
ln(CH_4 pc), cons.	Log of consumption based CH_4 emissions per capita.	Fernández-Amador et al. (2018b)
ln(CH_4 per VA), prod.	Log of production based CH_4 emissions per unit of value added.	Fernández-Amador et al. (2018b)
ln(CH_4 per VA), fin. prod.	Log of final production based CH_4 emissions per unit of value added.	Fernández-Amador et al. (2018b)
ln(CH_4 per VA), cons.	Log of production-based CH_4 emissions per unit of value added.	Fernández-Amador et al. (2018b)
ln(VA pc), prod.	Log of production based value added per capita.	Fernández-Amador et al. (2018b)
ln(VA pc), fin. prod.	Log of final production based value added per capita.	Fernández-Amador et al. (2018b)
ln(VA pc), cons.	Log of consumption based value added per capita.	Fernández-Amador et al. (2018b)
	Baseline regressors and control variables	
ln(Income pc)	Log of real GDP (PPP) per capita.	WDI
Annex I	Dummy = 1 for ratification of the Kyoto Protocol by Annex I members of the UNFCCC.	UN
Openness	Trade openness calculated as (X+M)/GDP.	GTAP
Food exports	Share of exports from food sectors (agriculture, livestock, food processing) in total exports.	GTAP
Fuel exports	Share of exports from fossil fuel sectors (coal, gas, oil, minerals, petrochemicals) in total exports.	GTAP
ln(Pop. density)	Log of number of inhabitants per square kilometer.	WDI
Urbanization	Share of total population living in cities.	WDI
Fossil rents	Rents from fossil fuel production (including coal, gas and oil) as share of GDP.	WDI
Polity IV	Index of democracy (10) vs. autocracy (–10).	Polity IV
HDI	Development categories ranging from 1 to 4 (highest to lowest) based on categories used in the Human Development Report (2016).	HDI database/UN
	Variables used for instrumentation and threshold variable	
ICC ratification	Dummy = 1 for ratification of the Rome Statute of the ICC by Annex I members	UN
ln(Income pc), lag 3	Lagged real GDP (PPP) per capita (3 lags).	WDI
ln(Income pc), lag 5	Lagged real GDP (PPP) per capita (5 lags; threshold variable).	WDI

Table A.5: Definition of variables and data sources.

	N	Mean	Std. Dev.	Min.	Max.
		Dependent variables			
ln(CH4 pc), prod., agriculture	468	-4.10	1.82	-11.88	-0.52
ln(CH4 pc), prod., livestock	468	-1.11	1.23	-9.60	1.83
ln(CH4 pc), prod., energy	468	-2.63	1.92	-9.61	0.53
ln(CH4 pc), prod., manufacturing	468	-3.86	1.23	-8.64	-1.05
ln(CH4 pc), prod., services	468	-6.23	2.19	-22.13	-3.05
ln(CH4 pc), prod., transport	468	-3.62	1.61	-8.61	0.53
ln(CH4 pc), prod., public admin.	468	-1.37	0.61	-3.30	0.44
ln(CH4 pc), fin. prod., agriculture	468	-2.37	0.65	-4.50	-0.74
ln(CH4 pc), fin. prod., livestock	468	-1.34	1.00	-3.97	1.29
ln(CH4 pc), fin. prod., energy	468	-3.32	1.30	-6.72	-0.09
ln(CH4 pc), fin. prod., manufacturing	468	-1.97	0.86	-5.88	0.46
ln(CH4 pc), fin. prod., services	468	-1.98	1.01	-4.56	0.19
ln(CH4 pc), fin. prod., transport	468	-3.02	1.27	-7.02	0.08
ln(CH4 pc), fin. prod., public admin.	468	-1.20	0.61	-3.30	0.43
ln(CH4 pc), cons., agriculture	468	-2.27	0.58	-4.41	-0.76
ln(CH4 pc), cons., livestock	468	-1.25	0.77	-3.11	1.13
ln(CH4 pc), cons., energy	468	-3.28	1.34	-8.29	-0.08
ln(CH4 pc), cons., manufacturing	468	-1.82	0.92	-5.34	1.11
ln(CH4 pc), cons., services	468	-1.98	1.00	-4.57	0.06
ln(CH4 pc), cons., transport	468	-3.03	1.21	-6.71	0.01
ln(CH4 pc), cons., public admin.	468	-1.20	0.62	-3.30	0.42
ln(CH4 per VA), prod., agriculture	468	-2.77	2.13	-10.42	2.29
ln(CH4 per VA), prod., livestock	468	1.24	1.40	-9.40	4.40
ln(CH4 per VA), prod., energy	468	-0.98	1.93	-7.10	4.08
ln(CH4 per VA), prod., manufacturing	468	-3.39	2.07	-8.38	1.61
ln(CH4 per VA), prod., services	468	-6.84	2.90	-23.74	-0.59
ln(CH4 per VA), prod., transport	468	-2.05	1.74	-5.81	8.56
ln(CH4 per VA), prod., public admin.	468	-0.75	1.51	-5.16	4.46
ln(CH4 per VA), fin. prod., agriculture	468	-1.15	0.90	-2.83	2.12
ln(CH4 per VA), fin. prod., livestock	468	0.57	1.21	-2.84	4.09
ln(CH4 per VA), fin. prod., energy	468	-0.39	1.14	-4.40	2.65
ln(CH4 per VA), fin. prod., manufacturing	468	-1.64	0.93	-3.26	2.36
ln(CH4 per VA), fin. prod., services	468	-2.51	0.87	-4.14	-0.19
ln(CH4 per VA), fin. prod., transport	468	-1.22	0.80	-3.04	1.60
ln(CH4 per VA), fin. prod., public admin.	468	-0.90	1.30	-3.66	3.68
ln(CH4 per VA), cons., agriculture	468	-1.08	0.81	-2.72	2.09
ln(CH4 per VA), cons., livestock	468	0.66	1.05	-1.36	3.79
ln(CH4 per VA), cons., energy	468	-0.34	1.07	-4.20	2.64
ln(CH4 per VA), cons., manufacturing	468	-1.65	0.69	-2.69	1.28
ln(CH4 per VA), cons., services	468	-2.52	0.84	-4.11	-0.49
ln(CH4 per VA), cons., transport	468	-1.21	0.66	-2.56	1.26
ln(CH4 per VA), cons., public admin.	468	-0.91	1.26	-3.66	2.55

Table A.6: Descriptive statistics (continued on next page ...)

	N	Mean	Std. Dev.	Min.	Max.
Dependent variables					
ln(VA pc), prod., agriculture	468	-1.33	0.80	-3.51	0.60
ln(VA pc), prod., livestock	468	-2.35	1.19	-5.46	0.28
ln(VA pc), prod., energy	468	-1.65	1.37	-7.41	2.06
ln(VA pc), prod., manufacturing	468	-0.47	1.67	-5.34	2.29
ln(VA pc), prod., services	468	0.60	1.63	-3.01	3.48
ln(VA pc), prod., transport	468	-1.57	1.66	-11.44	1.91
ln(VA pc), prod., public admin.	468	-0.63	1.74	-5.82	2.40
ln(VA pc), fin. prod., agriculture	468	-1.21	0.81	-3.39	0.79
ln(VA pc), fin. prod., livestock	468	-1.91	1.18	-5.44	0.45
ln(VA pc), fin. prod., energy	468	-2.93	1.46	-7.87	-0.21
ln(VA pc), fin. prod., manufacturing	468	-0.33	1.56	-5.62	2.40
ln(VA pc), fin. prod., services	468	0.54	1.66	-3.64	3.64
ln(VA pc), fin. prod., transport	468	-1.79	1.56	-6.28	1.16
ln(VA pc), fin. prod., public admin.	468	-0.30	1.70	-5.31	2.78
ln(VA pc), cons., agriculture	468	-1.19	0.81	-3.42	0.77
ln(VA pc), cons., livestock	468	-1.91	1.12	-5.16	0.26
ln(VA pc), cons., energy	468	-2.94	1.49	-7.76	-0.21
ln(VA pc), cons., manufacturing	468	-0.16	1.45	-4.44	2.59
ln(VA pc), cons., services	468	0.54	1.63	-3.60	3.39
ln(VA pc), cons., transport	468	-1.82	1.44	-5.88	0.98
ln(VA pc), cons., public admin.	468	-0.29	1.69	-4.55	2.77
Baseline regressors and control variables					
ln(Income pc)	468	9.54	1.09	6.21	11.49
Annex I	468	0.31	0.46	0	1
Openness	468	0.82	0.47	0.18	3.27
Food exports (%)	468	0.12	0.13	0.00	0.76
Fuel exports (%)	468	0.14	0.20	0.00	0.94
ln(Pop. density)	468	-2.59	1.46	-6.03	2.04
Urbanization	468	0.63	0.22	0.12	1.00
Fossil rents	468	0.03	0.06	0.00	0.41
Polity IV	468	6.26	5.08	-7	10
HDI middle	468	0.21	0.40	0	1
HDI high	468	0.24	0.43	0	1
HDI very high	468	0.43	0.50	0	1
Instruments and threshold variable					
ICC ratification	468	0.33	0.47	0	1
ln(Income pc), lag 3	468	9.46	1.11	5.94	11.46
ln(Income pc), lag 5	468	9.40	1.11	5.87	11.43

Table A.6: Descriptive statistics (... continued from previous page.)

B Supplementary appendix tables

B.1 Detailed IV-FE results for CH_4 per capita

	Dependent variable: CH_4 per capita embodied in production in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
(% of total CH_4)	8.66%	34.98%	24.09%	5.03%	0.51%	5.57%	21.17%
ln(Income), reg.1	0.491 **	0.176	0.725 ***	-0.007	0.857	1.819 ***	0.297 **
	(0.205)	(0.158)	(0.187)	(0.406)	(0.819)	(0.639)	(0.123)
ln(Income), reg.2	0.424 **		0.762 ***		0.631	1.727 ***	0.275 **
	(0.192)		(0.183)		(0.747)	(0.612)	(0.128)
Annex I	-0.178	0.736	0.067	0.179	0.768	-0.424 *	-0.192 *
	(0.227)	(0.731)	(0.160)	(0.299)	(0.534)	(0.257)	(0.101)
Openness	0.303 ***	0.614	0.191 *	-0.109	0.269	0.151	0.011
	(0.078)	(0.451)	(0.105)	(0.161)	(0.355)	(0.245)	(0.077)
Food exports (%)	-0.026	0.400	-0.608	0.326	-0.968	-1.729 **	0.465
	(0.457)	(0.566)	(0.578)	(1.001)	(1.214)	(0.679)	(0.326)
Fuel exports (%)	-0.565 *	0.109	0.488	-0.524	-0.332	-0.770 *	-0.009
	(0.324)	(0.337)	(0.335)	(0.723)	(1.102)	(0.392)	(0.146)
ln(Pop. density)	-0.839	1.921	0.292	0.021	0.244	0.767	-0.353
	(0.547)	(1.627)	(0.523)	(1.273)	(1.280)	(1.144)	(0.253)
Urbanization	-0.377	2.018	0.299	-0.100	8.391 ***	-1.760	-1.263
	(0.785)	(1.843)	(0.986)	(0.978)	(2.762)	(2.012)	(0.814)
Fossil rents	-0.321	-0.372	-0.257	0.574	1.072	-4.965 ***	-0.874 **
	(0.753)	(0.638)	(0.962)	(1.341)	(2.311)	(0.929)	(0.421)
Polity IV	-0.002	0.001	-0.004	-0.009	-0.027	-0.037 ***	0.003
	(0.005)	(0.006)	(0.009)	(0.014)	(0.021)	(0.010)	(0.003)
HDI middle	-0.076	-0.036	-0.212	0.538	0.967	0.057	-0.020
	(0.141)	(0.098)	(0.250)	(0.463)	(0.666)	(0.176)	(0.043)
HDI high	-0.196	0.066	-0.222	0.683	1.356 **	-0.152	0.003
	(0.179)	(0.152)	(0.245)	(0.505)	(0.685)	(0.300)	(0.072)
HDI very high	-0.254	-0.013	-0.234	0.552	1.313 *	-0.319	0.090
	(0.208)	(0.159)	(0.266)	(0.526)	(0.699)	(0.395)	(0.112)
Threshold (value)	8.086		8.842		7.652	7.689	10.489
99% CI lower bound	8.047		8.803		7.652	7.652	10.487
99% CI upper bound	8.245		8.994		7.652	7.901	10.490
Bootstrap *p*-value	0.018		0.004		0.000	0.002	0.000
Wald equal. coeff. (p)	0.007		0.003		0.018	0.005	0.004
SSE without threshold	29.684	79.371	39.799	78.062	439.968	68.785	11.946
SSE with threshold	29.167		38.898		418.384	66.991	10.934
N regime 1	69	468	129	468	47	49	392
N regime 2	399		339		421	419	76

Table B.1: IV-FE results: CH_4 production per capita. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. The threshold estimate and the lower bound of the CI for services, and the lower bound of the CI for transport are truncated at 7.652 as a result of the 10% trimming. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: CH_4 per capita embodied in final production in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
(% of total CH_4)	13.25%	23.86%	5.11%	15.29%	13.10%	4.59%	24.80%
ln(Income), reg.1	0.297	0.079	0.027	0.376	0.241	1.174 ***	0.343 ***
	(0.231)	(0.137)	(0.231)	(0.260)	(0.318)	(0.334)	(0.080)
ln(Income), reg.2	0.253	0.058	0.061	0.437 **	0.293	1.147 ***	0.327 ***
	(0.231)	(0.141)	(0.232)	(0.221)	(0.305)	(0.331)	(0.081)
Annex I	0.320 *	0.088	-0.135	-0.110	0.234	0.576 **	-0.078
	(0.190)	(0.255)	(0.244)	(0.222)	(0.179)	(0.239)	(0.098)
Openness	-0.112	0.153 **	0.062	0.192 **	-0.019	0.244	0.103
	(0.107)	(0.072)	(0.196)	(0.084)	(0.144)	(0.163)	(0.081)
Food exports (%)	-0.592	-0.525	0.268	-1.275 *	0.694	-0.171	0.976 **
	(0.863)	(0.405)	(1.416)	(0.696)	(0.666)	(1.083)	(0.427)
Fuel exports (%)	-0.122	0.225	-0.502	-0.844	-0.408	-1.667 **	0.067
	(0.315)	(0.181)	(0.483)	(0.624)	(0.338)	(0.722)	(0.136)
ln(Pop. density)	-0.172	0.381	0.308	-0.253	0.535	0.261	-0.075
	(0.507)	(0.406)	(0.780)	(0.724)	(0.534)	(0.928)	(0.262)
Urbanization	0.157	-0.004	-2.246	-0.529	-0.230	-0.207	-0.202
	(0.923)	(0.904)	(1.405)	(0.985)	(0.886)	(1.636)	(0.687)
Fossil rents	-4.441 **	0.715	-2.195	1.165	-1.212	-3.557 *	-0.659
	(2.003)	(0.857)	(1.524)	(0.930)	(0.785)	(1.839)	(0.407)
Polity IV	-0.005	-0.005	-0.012	0.020 ***	0.002	-0.027 ***	0.006 *
	(0.009)	(0.008)	(0.014)	(0.007)	(0.009)	(0.011)	(0.003)
HDI middle	0.048	-0.033	0.044	0.313 ***	0.059	-0.112	-0.054
	(0.087)	(0.106)	(0.137)	(0.107)	(0.094)	(0.271)	(0.050)
HDI high	0.085	0.037	0.119	0.381 ***	0.216	-0.099	-0.036
	(0.157)	(0.129)	(0.201)	(0.140)	(0.142)	(0.326)	(0.079)
HDI very high	0.045	-0.040	0.169	0.357 **	0.204	-0.042	0.058
	(0.183)	(0.142)	(0.228)	(0.162)	(0.178)	(0.353)	(0.102)
Threshold (value)	9.952	10.415	10.222	8.055	7.963	9.669	10.443
99% CI lower bound	9.939	10.236	10.008	8.051	7.901	9.500	10.405
99% CI upper bound	9.955	10.604	10.314	8.055	8.137	9.828	10.526
Bootstrap *p*-value	0.000	0.014	0.010	0.000	0.010	0.040	0.000
Wald equal. coeff. (p)	0.001	0.043	0.002	0.290	0.002	0.027	0.005
SSE without threshold	27.711	19.482	46.150	28.299	23.423	46.092	8.816
SSE with threshold	26.280	19.055	45.167	26.697	22.918	44.760	8.266
N regime 1	293	370	329	68	63	249	377
N regime 2	175	98	139	400	405	219	91

Table B.2: IV-FE results: CH_4 final production per capita. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: CH_4 per capita embodied in consumption in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
(% of total CH_4)	13.25%	23.86%	5.11%	15.29%	13.10%	4.59%	24.80%
ln(Income), reg.1	0.413 **	0.150	0.154	0.509 **	0.246	1.546 ***	0.248 **
	(0.190)	(0.161)	(0.276)	(0.245)	(0.307)	(0.367)	(0.118)
ln(Income), reg.2	0.385 **	0.128	0.187	0.571 ***	0.297	1.498 ***	0.269 **
	(0.189)	(0.165)	(0.275)	(0.206)	(0.294)	(0.351)	(0.113)
Annex I	0.531 ***	-0.128	-0.081	0.155	0.184	0.687 ***	-0.191 *
	(0.183)	(0.224)	(0.284)	(0.141)	(0.162)	(0.206)	(0.110)
Openness	0.079	0.087	0.040	0.002	-0.043	0.193	0.109
	(0.092)	(0.105)	(0.202)	(0.096)	(0.162)	(0.169)	(0.086)
Food exports (%)	-0.839	-0.674	0.533	-0.198	0.720	0.245	0.888 **
	(0.690)	(0.430)	(1.903)	(0.600)	(0.657)	(1.054)	(0.362)
Fuel exports (%)	-0.108	0.093	-1.240	-0.089	-0.329	-0.907 *	0.070
	(0.302)	(0.194)	(1.020)	(0.312)	(0.310)	(0.470)	(0.132)
ln(Pop. density)	0.261	0.230	0.631	0.528	0.435	0.687	-0.010
	(0.488)	(0.465)	(0.937)	(0.508)	(0.501)	(0.789)	(0.261)
Urbanization	-0.140	-0.313	-1.286	-1.053	-0.109	0.617	0.044
	(0.952)	(0.815)	(1.395)	(0.902)	(0.858)	(1.633)	(0.681)
Fossil rents	-3.015	0.467	-1.599	0.475	-1.261	-3.411 **	-0.391
	(1.843)	(0.840)	(1.751)	(0.637)	(0.771)	(1.691)	(0.396)
Polity IV	0.005	-0.009	-0.003	0.016 **	0.002	-0.022 **	0.005 *
	(0.009)	(0.007)	(0.014)	(0.006)	(0.009)	(0.011)	(0.003)
HDI middle	0.055	-0.082	0.011	0.269 **	0.067	0.212	-0.017
	(0.093)	(0.105)	(0.123)	(0.117)	(0.093)	(0.214)	(0.048)
HDI high	0.205	-0.032	0.198	0.418 ***	0.225	0.264	0.015
	(0.154)	(0.121)	(0.207)	(0.149)	(0.138)	(0.270)	(0.074)
HDI very high	0.179	-0.014	0.221	0.447 **	0.211	0.152	0.133
	(0.169)	(0.130)	(0.248)	(0.174)	(0.168)	(0.289)	(0.093)
Threshold (value)	9.947	10.302	10.166	8.055	7.963	7.689	9.493
99% CI lower bound	9.929	10.241	7.652	8.055	7.901	7.652	9.493
99% CI upper bound	9.968	10.539	10.609	8.055	8.100	7.802	9.508
Bootstrap p-value	0.006	0.000	0.006	0.000	0.004	0.020	0.000
Wald equal. coeff. (p)	0.001	0.067	0.021	0.257	0.002	0.095	0.016
SSE without threshold	22.197	20.447	61.592	21.267	21.946	43.328	11.624
SSE with threshold	21.525	19.632	60.183	20.352	21.449	42.846	10.831
N regime 1	290	341	317	68	63	49	219
N regime 2	178	127	151	400	405	419	249

Table B.3: IV-FE results: CH_4 consumption per capita. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. The bounds of the threshold CI for energy, and the lower bound of the CI for transport are truncated at 7.652 and 10.609 as a result of the 10% trimming. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

B.2 Detailed IV-FE results for CH_4 per VA

	Dependent variable: CH_4 per unit of VA embodied in production in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
ln(Income), reg.1	-0.347	-0.468*	-0.503	-1.154 **	-0.257	11.745**	-0.800 **
	(0.217)	(0.257)	(0.315)	(0.487)	(0.813)	(5.252)	(0.343)
ln(Income), reg.2	-0.425 **			-1.181 **	-0.479		-0.776 **
	(0.209)			(0.462)	(0.736)		(0.346)
ln(Income), squared						-0.701**	
						(0.320)	
Annex I	0.099	1.125	-0.287	0.772 **	0.563	0.098	0.032
	(0.287)	(0.787)	(0.351)	(0.356)	(0.536)	(0.398)	(0.395)
Openness	0.452 ***	0.938*	-0.050	-0.060	0.555	0.207	0.180
	(0.104)	(0.536)	(0.234)	(0.274)	(0.402)	(0.209)	(0.164)
Food exports (%)	-0.271	-0.254	2.517	2.738 **	-0.915	-1.009	0.258
	(0.663)	(1.058)	(1.606)	(1.138)	(1.350)	(1.097)	(0.742)
Fuel exports (%)	0.274	0.879*	-2.245***	0.632	0.182	0.417	0.009
	(0.401)	(0.519)	(0.786)	(0.897)	(1.192)	(0.627)	(0.334)
ln(Pop. density)	-1.320 *	1.517	0.421	0.949	-0.131	-1.569	-0.580
	(0.689)	(1.869)	(0.896)	(1.324)	(1.328)	(1.710)	(0.786)
Urbanization	-1.612 *	0.299	0.677	0.135	7.866 ***	-1.246	-2.048
	(0.948)	(2.355)	(1.594)	(1.549)	(2.550)	(2.279)	(1.258)
Fossil rents	-1.250	-0.560	-2.145	1.781	1.464	-3.678	0.821
	(1.350)	(1.471)	(1.466)	(1.771)	(2.442)	(2.342)	(1.512)
Polity IV	0.008	0.021**	-0.008	-0.003	-0.026	-0.024*	0.014
	(0.007)	(0.009)	(0.018)	(0.016)	(0.020)	(0.012)	(0.009)
HDI middle	-0.236	-0.171	-0.154	0.553	0.916	-0.445	0.079
	(0.201)	(0.151)	(0.321)	(0.525)	(0.658)	(0.289)	(0.141)
HDI high	-0.342	-0.006	-0.030	0.766	1.258 *	-0.619	0.272
	(0.247)	(0.216)	(0.380)	(0.578)	(0.684)	(0.382)	(0.221)
HDI very high	-0.420	-0.275	0.163	0.685	1.170 *	-0.572	0.247
	(0.282)	(0.258)	(0.447)	(0.605)	(0.709)	(0.400)	(0.220)
Threshold (value)	8.055			8.086	7.652		9.777
99% CI lower bound	8.047			7.652	7.652		7.652
99% CI upper bound	8.086			10.609	7.652		10.609
Bootstrap p-value	0.002			0.034	0.002		0.014
Wald equal. coeff. (p)	0.008			0.556	0.030		0.068
Turning point						8.374	
Observations before TP (%)						83.5%	
U-Test (p)						0.025	
SSE without threshold	46.480	117.128	90.138	103.888	446.357	170.210	63.173
SSE with threshold	45.012			102.790	426.213		62.313
N regime 1	68	468	468	69	47	468	270
N regime 2	400			399	421		198

Table B.4: IV-FE results: CH_4 production per value added. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. TP stands for turning point, and U-Test (p) is the p-value of the test for a polynomial relationship developed by Lind and Mehlum (2010). SSE is the sum of squared errors, and N is the number of observations. The threshold estimate and the lower bound of the CI for services, and the bounds of the CI for manufacturing and transport are truncated at 7.652 and 10.609 as a result of the 10% trimming. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: CH_4 per unit of VA embodied in final production in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
ln(Income), reg.1	-0.6107 ***	-0.550 ***	-0.673 **	-1.010 ***	-0.549 **	-0.120	-0.518
	(0.220)	(0.190)	(0.292)	(0.157)	(0.271)	(0.306)	(0.386)
ln(Income), reg.2	-0.5906 ***	-0.580 ***	-0.619 **	-0.951 ***	-0.522 *	-0.170	-0.539
	(0.223)	(0.183)	(0.292)	(0.149)	(0.274)	(0.295)	(0.373)
Annex I	0.4484 *	0.595 **	-0.241	0.229	-0.254	0.346 *	0.073
	(0.251)	(0.236)	(0.246)	(0.181)	(0.181)	(0.205)	(0.257)
Openness	-0.0553	0.398 ***	-0.130	-0.063	0.356 ***	0.353 ***	0.282 ***
	(0.140)	(0.118)	(0.192)	(0.105)	(0.088)	(0.132)	(0.098)
Food exports (%)	-0.6902	-0.736	2.099	1.178	0.215	0.204	0.131
	(1.044)	(0.512)	(1.630)	(1.069)	(0.717)	(0.751)	(0.671)
Fuel exports (%)	0.2966	0.259	-0.886	-0.271	-0.043	-0.494	0.070
	(0.391)	(0.213)	(0.662)	(0.313)	(0.378)	(0.451)	(0.263)
ln(Pop. density)	-0.1810	0.180	-0.378	-0.304	-0.098	0.494	-0.974 *
	(0.532)	(0.568)	(0.663)	(0.665)	(0.521)	(0.592)	(0.535)
Urbanization	-0.8890	0.285	-1.583	-0.266	-0.781	-0.827	-1.779 **
	(0.998)	(1.181)	(1.509)	(0.807)	(0.752)	(0.945)	(0.832)
Fossil rents	-4.3456 **	0.771	-4.636 ***	1.944 **	-0.972	-2.758 ***	0.459
	(2.018)	(1.223)	(1.614)	(0.827)	(0.728)	(0.903)	(1.316)
Polity IV	0.0009	0.023 ***	-0.014	0.009	0.004	-0.004	0.012 *
	(0.008)	(0.006)	(0.011)	(0.006)	(0.009)	(0.007)	(0.006)
HDI middle	-0.1712	-0.140	-0.193	0.240 **	0.004	-0.009	-0.020
	(0.122)	(0.105)	(0.175)	(0.095)	(0.100)	(0.111)	(0.094)
HDI high	-0.1270	-0.004	-0.052	0.388 ***	0.105	0.035	0.060
	(0.196)	(0.135)	(0.234)	(0.130)	(0.133)	(0.172)	(0.140)
HDI very high	-0.0854	-0.122	0.062	0.412 ***	0.082	-0.018	0.093
	(0.225)	(0.167)	(0.283)	(0.142)	(0.159)	(0.193)	(0.159)
Threshold (value)	10.470	8.055	10.131	8.217	10.455	8.055	9.559
99% CI lower bound	10.445	8.047	10.085	8.100	10.388	8.047	7.652
99% CI upper bound	10.489	8.086	10.184	8.257	10.489	8.086	10.609
Bootstrap *p*-value	0.016	0.004	0.040	0.000	0.070	0.006	0.044
Wald equal. coeff. (p)	0.070	0.176	0.002	0.008	0.006	0.021	0.248
Threshold at bound	0	0	0	0	0	0	0
min CI is at bound	0	0	0	0	0	0	1
max CI is at bound	0	0	0	0	0	0	1
SSE without threshold	34.171	28.113	73.302	24.305	19.606	30.415	38.681
SSE with threshold	33.239	27.338	72.403	23.125	19.476	29.488	38.157
N regime 1	385	68	314	74	384	68	231
N regime 2	83	400	154	394	84	400	237

Table B.5: IV-FE results: CH_4 final production per value added. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. The bounds of the threshold CI for public administration are truncated at 7.652 and 10.609 as a result of the 10% trimming. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: CH_4 per unit of VA embodied in consumption in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
ln(Income), reg.1	-0.489 *	-0.512 ***	-0.548 *	-0.670 ***	-0.547 **	0.036	-0.761 ***
	(0.258)	(0.182)	(0.288)	(0.101)	(0.262)	(0.259)	(0.267)
ln(Income), reg.2	-0.525 **	-0.547 ***	-0.498 *	-0.650 ***	-0.524 **	-0.010	-0.746 ***
	(0.248)	(0.174)	(0.288)	(0.101)	(0.264)	(0.247)	(0.266)
Annex I	0.491 ***	0.348 *	-0.074	-0.018	-0.214	0.195	0.054
	(0.176)	(0.200)	(0.278)	(0.145)	(0.168)	(0.162)	(0.211)
Openness	0.121	0.186 *	-0.046	0.017	0.371 ***	0.309 ***	0.245 **
	(0.112)	(0.107)	(0.204)	(0.083)	(0.085)	(0.089)	(0.096)
Food exports (%)	-0.906	-0.775	1.513	0.746	0.290	0.461	0.034
	(0.878)	(0.488)	(1.675)	(0.739)	(0.705)	(0.628)	(0.614)
Fuel exports (%)	-0.095	0.105	-0.642	-0.399	-0.044	-0.425	-0.011
	(0.337)	(0.214)	(0.698)	(0.270)	(0.360)	(0.341)	(0.220)
ln(Pop. density)	-0.072	-0.046	-0.241	-0.165	-0.006	0.325	-0.717
	(0.422)	(0.486)	(0.833)	(0.491)	(0.494)	(0.532)	(0.533)
Urbanization	-0.159	0.066	-0.500	0.014	-0.753	-0.855	-1.538 *
	(0.887)	(1.053)	(1.630)	(0.616)	(0.727)	(0.868)	(0.850)
Fossil rents	-3.426 **	0.350	-4.760 ***	0.634	-1.074	-3.095 ***	1.161
	(1.680)	(1.130)	(1.580)	(0.696)	(0.698)	(0.784)	(1.139)
Polity IV	0.004	0.016 ***	-0.011	0.012 *	0.004	-0.005	0.009
	(0.008)	(0.006)	(0.012)	(0.007)	(0.009)	(0.006)	(0.006)
HDI middle	-0.208	-0.174 *	-0.269	0.234 **	-0.009	0.025	0.023
	(0.130)	(0.100)	(0.188)	(0.093)	(0.099)	(0.091)	(0.103)
HDI high	-0.131	-0.102	-0.075	0.303 **	0.083	0.059	0.121
	(0.192)	(0.130)	(0.240)	(0.118)	(0.131)	(0.147)	(0.152)
HDI very high	-0.113	-0.170	-0.020	0.397 ***	0.068	-0.038	0.118
	(0.214)	(0.152)	(0.283)	(0.128)	(0.156)	(0.162)	(0.156)
Threshold (value)	8.051	8.055	10.101	10.377	10.455	8.055	9.459
99% CI lower bound	8.047	8.047	10.013	10.241	10.369	8.047	7.652
99% CI upper bound	8.086	8.086	10.184	10.380	10.513	8.086	10.609
Bootstrap p-value	0.016	0.004	0.010	0.032	0.068	0.002	0.028
Wald equal. coeff. (p)	0.061	0.102	0.004	0.000	0.012	0.030	0.161
SSE without threshold	23.981	22.182	73.073	15.982	18.446	20.781	22.099
SSE with threshold	23.414	21.520	71.181	15.729	18.330	20.144	21.819
N regime 1	67	68	312	358	384	68	212
N regime 2	401	400	156	110	84	400	256

Table B.6: IV-FE results: CH_4 consumption per value added. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. The bounds of the threshold CI for public administration are truncated at 7.652 and 10.609 as a result of the 10% trimming. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

B.3 Detailed IV-FE results for VA per capita

	Dependent variable: VA per capita embodied in production in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
ln(Income), reg.1	1.003 ***	0.738 ***	1.335***	1.231 ***	1.097***	1.817 ***	0.900 **
	(0.209)	(0.166)	(0.327)	(0.194)	(0.108)	(0.640)	(0.389)
ln(Income), reg.2	0.982 ***	0.719 ***		1.217 ***		1.735 ***	0.933 **
	(0.207)	(0.163)		(0.192)		(0.573)	(0.375)
Annex I	-0.340 **	-0.422 **	0.338	-0.566 ***	0.205	-0.035	-0.154
	(0.167)	(0.191)	(0.303)	(0.161)	(0.127)	(0.256)	(0.321)
Openness	-0.132	-0.320 ***	0.219	-0.018	-0.287**	-0.273	-0.170
	(0.091)	(0.116)	(0.221)	(0.163)	(0.115)	(0.176)	(0.126)
Food exports (%)	0.351	0.767	-3.111**	-2.442 ***	-0.044	0.198	0.138
	(0.409)	(0.827)	(1.261)	(0.491)	(0.486)	(0.997)	(0.732)
Fuel exports (%)	-0.852 ***	-0.744 **	2.760***	-1.300 ***	-0.510***	-1.447 **	-0.070
	(0.223)	(0.296)	(0.633)	(0.474)	(0.165)	(0.676)	(0.300)
ln(Pop. density)	0.266	0.250	-0.197	-0.909 *	0.373	0.890	0.869
	(0.430)	(0.552)	(0.748)	(0.475)	(0.321)	(1.349)	(0.557)
Urbanization	1.078	1.521	-0.079	-0.047	0.489	-3.411	1.370
	(0.872)	(1.144)	(1.450)	(0.990)	(0.650)	(2.616)	(0.971)
Fossil rents	0.630	-0.041	1.980	-1.211	-0.389	-0.598	-1.298
	(1.145)	(1.332)	(1.333)	(1.333)	(0.706)	(1.663)	(1.406)
Polity IV	-0.007	-0.020 ***	0.006	-0.005	-0.001	-0.014 *	-0.012
	(0.007)	(0.006)	(0.021)	(0.007)	(0.005)	(0.008)	(0.008)
HDI middle	0.108	0.103	-0.106	-0.001	0.045	-0.075	0.010
	(0.117)	(0.115)	(0.225)	(0.158)	(0.088)	(0.201)	(0.107)
HDI high	0.068	0.033	-0.180	-0.079	0.095	-0.036	-0.056
	(0.152)	(0.153)	(0.310)	(0.193)	(0.103)	(0.253)	(0.161)
HDI very high	0.118	0.258	-0.401	-0.139	0.140	-0.211	-0.021
	(0.181)	(0.192)	(0.382)	(0.221)	(0.131)	(0.356)	(0.174)
Threshold (value)	9.509	9.493		10.173		10.222	9.508
99% CI lower bound	9.433	7.652		10.101		10.192	9.493
99% CI upper bound	9.556	10.609		10.452		10.314	9.684
Bootstrap p-value	0.036	0.044		0.002		0.000	0.018
Wald equal. coeff. (p)	0.001	0.045		0.117		0.299	0.103
SSE without threshold	18.866	25.930	56.721	22.968	10.546	125.618	53.259
SSE with threshold	18.617	25.705		21.964		117.623	52.002
N regime 1	222	219	468	318	468	329	221
N regime 2	246	249		150		139	247

Table B.7: IV-FE results: sectoral VA per capita in production. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. The bounds of the threshold CI for livestock are truncated at 7.652 and 10.609 as a result of the 10% trimming. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: VA per capita embodied in final production in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
ln(Income), reg.1	0.934 ***	0.779***	0.775 ***	1.398 ***	1.031***	1.160 ***	0.835 **
	(0.189)	(0.184)	(0.207)	(0.177)	(0.146)	(0.237)	(0.403)
ln(Income), reg.2	0.912 ***		0.725 ***	1.374 ***		1.212 ***	0.869 **
	(0.189)		(0.204)	(0.177)		(0.225)	(0.389)
Annex I	-0.189	-0.668***	0.003	-0.253 *	0.372**	0.290	-0.189
	(0.118)	(0.165)	(0.222)	(0.154)	(0.154)	(0.193)	(0.276)
Openness	-0.071	-0.210**	0.132	0.238	-0.319**	-0.121	-0.169
	(0.118)	(0.103)	(0.149)	(0.157)	(0.144)	(0.128)	(0.138)
Food exports (%)	0.172	0.177	-1.858 ***	-2.470 **	0.511	-0.380	0.843
	(0.414)	(0.646)	(0.660)	(1.003)	(0.486)	(0.890)	(0.770)
Fuel exports (%)	-0.430 **	-0.117	0.452	-0.697	-0.454*	-1.191 ***	0.012
	(0.184)	(0.253)	(0.433)	(0.665)	(0.276)	(0.374)	(0.282)
ln(Pop. density)	0.128	0.055	0.397	0.178	0.694*	0.003	1.004 *
	(0.375)	(0.462)	(0.547)	(0.498)	(0.412)	(0.668)	(0.551)
Urbanization	1.365	-0.173	-0.545	-0.363	0.897	0.862	1.780 **
	(0.864)	(1.293)	(1.149)	(0.716)	(0.866)	(1.066)	(0.723)
Fossil rents	0.038	-0.106	2.872 *	-0.489	-0.226	-0.401	-0.896
	(0.907)	(1.150)	(1.658)	(0.930)	(0.706)	(1.748)	(1.529)
Polity IV	-0.004	-0.025***	0.004	0.010	-0.000	-0.019 **	-0.005
	(0.007)	(0.009)	(0.016)	(0.007)	(0.006)	(0.007)	(0.007)
HDI middle	0.231 *	0.120	0.199	0.100	0.114	-0.045	-0.010
	(0.121)	(0.139)	(0.175)	(0.122)	(0.096)	(0.202)	(0.093)
HDI high	0.258 *	0.062	0.165	0.001	0.188	-0.044	-0.042
	(0.147)	(0.172)	(0.208)	(0.157)	(0.124)	(0.231)	(0.142)
HDI very high	0.188	0.148	0.041	-0.081	0.264*	-0.029	0.032
	(0.164)	(0.192)	(0.237)	(0.177)	(0.159)	(0.256)	(0.146)
Threshold (value)	10.008		9.079	10.258		8.047	9.559
99% CI lower bound	9.927		9.019	10.233		8.026	9.493
99% CI upper bound	10.101		9.139	10.359		8.137	9.684
Bootstrap *p*-value	0.000		0.000	0.000		0.050	0.010
Wald equal. coeff. (p)	0.008		0.001	0.009		0.011	0.083
SSE without threshold	14.770	25.389	45.519	21.262	17.378	34.557	44.421
SSE with threshold	14.150		43.805	19.908		34.170	42.804
N regime 1	301	468	157	336	468	66	231
N regime 2	167		311	132		402	237

Table B.8: IV-FE results: sectoral VA per capita in final production. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: VA per capita embodied in consumption in:						
	agr.	liv.	egy.	mfc.	ser.	trn.	pub.
ln(Income), reg.1	0.972 ***	0.777 ***	0.743 ***	1.340 ***	1.022***	1.254 ***	0.880 **
	(0.158)	(0.181)	(0.180)	(0.147)	(0.136)	(0.214)	(0.374)
ln(Income), reg.2	0.951 ***	0.755 ***	0.703 ***	1.311 ***		1.309 ***	0.910 **
	(0.159)	(0.185)	(0.180)	(0.148)		(0.202)	(0.363)
Annex I	0.070	-0.503 ***	-0.060	0.190	0.296**	0.516 ***	-0.187
	(0.150)	(0.183)	(0.210)	(0.170)	(0.142)	(0.188)	(0.252)
Openness	-0.029	-0.079	0.062	0.002	-0.362***	-0.142	-0.155
	(0.127)	(0.114)	(0.151)	(0.116)	(0.139)	(0.129)	(0.134)
Food exports (%)	0.054	0.073	-0.980	-1.021 *	0.452	-0.153	0.823
	(0.417)	(0.701)	(0.603)	(0.603)	(0.450)	(0.807)	(0.767)
Fuel exports (%)	-0.127	-0.113	-0.529	0.110	-0.372	-0.420	0.033
	(0.166)	(0.247)	(0.500)	(0.183)	(0.248)	(0.263)	(0.269)
ln(Pop. density)	0.428	0.206	0.666	0.560	0.493	0.324	0.938 *
	(0.397)	(0.492)	(0.585)	(0.375)	(0.382)	(0.604)	(0.530)
Urbanization	0.730	-0.099	-0.520	-0.385	0.982	1.021	1.860 ***
	(0.811)	(1.117)	(1.072)	(0.647)	(0.803)	(1.126)	(0.695)
Fossil rents	0.403	0.075	3.482 **	-0.266	-0.179	-0.134	-1.107
	(1.000)	(1.120)	(1.648)	(0.721)	(0.657)	(1.494)	(1.375)
Polity IV	0.001	-0.023 **	0.009	0.007	-0.000	-0.010	-0.005
	(0.007)	(0.009)	(0.018)	(0.006)	(0.006)	(0.008)	(0.006)
HDI middle	0.293 **	0.114	0.250	0.073	0.134	0.081	0.002
	(0.132)	(0.137)	(0.160)	(0.100)	(0.093)	(0.211)	(0.093)
HDI high	0.372 **	0.082	0.269	0.120	0.215*	0.137	-0.023
	(0.156)	(0.162)	(0.198)	(0.126)	(0.116)	(0.236)	(0.139)
HDI very high	0.292 *	0.149	0.213	-0.018	0.271*	0.137	0.032
	(0.164)	(0.175)	(0.224)	(0.154)	(0.140)	(0.262)	(0.144)
Threshold (value)	10.023	10.306	9.079	10.421		8.047	9.559
99% CI lower bound	9.988	10.251	8.762	10.382		7.963	9.493
99% CI upper bound	10.101	10.377	9.139	10.431		8.100	9.690
Bootstrap p-value	0.004	0.000	0.012	0.042		0.090	0.006
Wald equal. coeff. (p)	0.001	0.063	0.017	0.000		0.005	0.072
SSE without threshold	15.293	24.135	42.552	14.920	14.474	34.658	37.123
SSE with threshold	14.975	22.676	41.438	14.674		34.415	35.777
N regime 1	304	343	157	371	468	66	231
N regime 2	164	125	311	97		402	237

Table B.9: IV-FE results: sectoral VA per capita in consumption. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

B.4 Detailed FE results for CH_4 per capita

	Dependent variable: CH_4 per capita embodied in production in:						
	agr.	ctl.	egy.	mfc.	ser.	trn.	wab.
ln(Income), reg.1	0.1649	0.326	0.9032 ***	0.378*	1.036	1.242***	0.306 ***
	(0.129)	(0.236)	(0.238)	(0.225)	(0.652)	(0.418)	(0.104)
ln(Income), reg.2	0.1141		0.8504 ***		0.772		0.282 ***
	(0.123)		(0.206)		(0.579)		(0.108)
Annex I	-0.0405	0.160	-0.0173	0.009	0.077	-0.037	-0.081
	(0.064)	(0.167)	(0.070)	(0.092)	(0.378)	(0.092)	(0.059)
Openness	0.2716 ***	0.592	0.1912 *	-0.076	0.188	0.117	0.018
	(0.065)	(0.483)	(0.109)	(0.154)	(0.299)	(0.237)	(0.087)
Food exports (%)	0.0008	0.072	-0.6699	0.319	-1.400	-1.493**	0.519
	(0.390)	(0.320)	(0.574)	(0.997)	(1.234)	(0.724)	(0.359)
Fuel exports (%)	-0.4578 *	-0.139	0.3442	-0.603	-0.549	-0.529	0.032
	(0.268)	(0.158)	(0.334)	(0.763)	(1.175)	(0.340)	(0.142)
ln(Pop. density)	-0.6877 **	0.961	0.0614	-0.135	-0.948	1.212	-0.177
	(0.322)	(0.769)	(0.458)	(0.993)	(1.211)	(1.026)	(0.211)
Urbanization	-0.1334	1.084	0.8270	-0.622	7.536 ***	-1.822	-1.134
	(0.755)	(0.900)	(1.122)	(1.110)	(2.285)	(1.867)	(0.796)
Fossil rents	-0.0290	-1.351	-0.5116	0.199	-0.215	-4.089***	-0.711
	(0.725)	(1.409)	(0.676)	(1.080)	(1.747)	(0.879)	(0.445)
Polity IV	-0.0027	-0.001	-0.0007	-0.009	-0.033	-0.031***	0.003
	(0.006)	(0.004)	(0.009)	(0.014)	(0.020)	(0.010)	(0.003)
HDI middle	-0.0077	-0.165	-0.2685	0.423	0.990	-0.068	-0.008
	(0.128)	(0.175)	(0.232)	(0.457)	(0.707)	(0.256)	(0.044)
HDI high	-0.0693	-0.182	-0.1994	0.494	1.246 *	-0.135	0.027
	(0.151)	(0.211)	(0.230)	(0.475)	(0.734)	(0.351)	(0.069)
HDI very high	-0.0982	-0.250	-0.2495	0.332	1.233	-0.278	0.100
	(0.175)	(0.253)	(0.262)	(0.494)	(0.769)	(0.402)	(0.118)
Threshold (value)	8.086		8.306		7.648		10.490
99% CI lower bound	8.026		8.284		7.648		10.484
99% CI upper bound	8.442		8.371		7.652		10.492
Bootstrap *p*-value	0.042		0.080		0.004		0.000
Wald equal. coeff. (p)	0.013		0.311		0.008		0.002
SSE without threshold	29.104	72.229	39.744	76.669	427.452	65.716	11.652
SSE with threshold	28.321		38.608		404.296		10.676
N regime 1	69	468	81	468	46	468	393
N regime 2	399		387		422		75

Table B.10: FE results: CH_4 production per capita. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. The lower bound of the threshold CI for services is truncated at 7.648 as a result of the 10% trimming. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: CH_4 per capita embodied in final production in:						
	agr.	ctl.	egy.	mfc.	ser.	trn.	wab.
ln(Income), reg.1	0.141	0.4142 **	0.030	0.407 *	0.445*	0.808***	0.348 ***
	(0.188)	(0.171)	(0.223)	(0.239)	(0.229)	(0.277)	(0.081)
ln(Income), reg.2	0.096	0.3688 **		0.472 **			0.332 ***
	(0.188)	(0.159)		(0.199)			(0.083)
Annex I	0.259 ***	-0.0285	-0.041	0.088	0.108	0.278***	-0.026
	(0.080)	(0.063)	(0.101)	(0.061)	(0.071)	(0.084)	(0.046)
Openness	-0.133	0.2161 ***	0.074	0.208 **	0.004	0.180	0.110
	(0.100)	(0.077)	(0.194)	(0.087)	(0.148)	(0.173)	(0.078)
Food exports (%)	-0.672	-0.5022	0.243	-1.135 *	0.578	-0.495	0.976 **
	(0.860)	(0.402)	(1.438)	(0.685)	(0.674)	(1.138)	(0.450)
Fuel exports (%)	-0.145	0.1155	-0.656	-0.749	-0.544	-1.827**	0.129
	(0.295)	(0.179)	(0.534)	(0.658)	(0.362)	(0.818)	(0.140)
ln(Pop. density)	-0.339	0.3564	0.450	0.114	0.340	-0.234	-0.031
	(0.355)	(0.265)	(0.673)	(0.502)	(0.448)	(0.766)	(0.211)
Urbanization	0.178	0.2271	-2.539*	-0.316	-0.106	-0.265	-0.035
	(0.854)	(0.842)	(1.379)	(1.085)	(0.845)	(1.458)	(0.643)
Fossil rents	-4.504 **	0.7057	-2.094	1.478 *	-1.442*	-3.718**	-0.596
	(1.929)	(0.883)	(1.384)	(0.814)	(0.747)	(1.689)	(0.380)
Polity IV	-0.005	-0.0007	-0.012	0.021 ***	0.001	-0.029***	0.006 **
	(0.009)	(0.006)	(0.013)	(0.008)	(0.010)	(0.010)	(0.003)
HDI middle	0.073	-0.0306	0.025	0.333 ***	0.091	-0.070	-0.048
	(0.078)	(0.086)	(0.141)	(0.100)	(0.115)	(0.260)	(0.051)
HDI high	0.118	0.0368	0.094	0.431 ***	0.210	-0.062	-0.028
	(0.143)	(0.126)	(0.207)	(0.123)	(0.160)	(0.312)	(0.076)
HDI very high	0.096	-0.0197	0.105	0.396 ***	0.183	-0.058	0.057
	(0.163)	(0.147)	(0.234)	(0.150)	(0.191)	(0.338)	(0.106)
Threshold (value)	9.952	8.055		8.055			10.489
99% CI lower bound	9.939	8.051		8.051			10.405
99% CI upper bound	9.955	8.100		8.055			10.539
Bootstrap p-value	0.000	0.026		0.004			0.000
Wald equal. coeff. (p)	0.001	0.047		0.248			0.005
SSE without threshold	27.635	19.381	46.137	27.196	23.143	43.426	8.653
SSE with threshold	26.104	18.731		25.893			8.212
N regime 1	293	68	468	68	468	468	392
N regime 2	175	400		400			76

Table B.11: FE results: CH_4 final production per capita. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: CH_4 per capita embodied in consumption in:						
	agr.	ctl.	egy.	mfc.	ser.	trn.	wab.
ln(Income), reg.1	0.303 *	0.212	0.106	0.616 ***	0.469**	1.079***	0.309 ***
	(0.177)	(0.134)	(0.244)	(0.221)	(0.226)	(0.261)	(0.109)
ln(Income), reg.2	0.273	0.190		0.672 ***			0.330 ***
	(0.177)	(0.136)		(0.180)			(0.105)
Annex I	0.317 ***	-0.012	-0.026	0.097 *	0.107	0.337***	-0.086 *
	(0.071)	(0.069)	(0.102)	(0.057)	(0.068)	(0.090)	(0.049)
Openness	0.053	0.099	0.077	0.012	-0.014	0.119	0.123
	(0.104)	(0.091)	(0.200)	(0.098)	(0.160)	(0.188)	(0.079)
Food exports (%)	-1.007	-0.569	0.494	-0.215	0.641	-0.028	0.969 **
	(0.692)	(0.422)	(1.909)	(0.585)	(0.674)	(1.017)	(0.385)
Fuel exports (%)	-0.197	0.153	-1.396	-0.132	-0.444	-1.014**	0.113
	(0.301)	(0.190)	(1.104)	(0.301)	(0.328)	(0.482)	(0.133)
ln(Pop. density)	-0.163	0.447	0.677	0.454	0.334	-0.116	0.200
	(0.327)	(0.292)	(0.781)	(0.427)	(0.437)	(0.692)	(0.206)
Urbanization	-0.381	-0.290	-1.397	-1.145	0.065	-0.081	0.152
	(0.796)	(0.701)	(1.330)	(0.885)	(0.828)	(1.454)	(0.665)
Fossil rents	-3.340 *	0.581	-1.629	0.357	-1.417*	-3.814**	-0.232
	(1.762)	(0.821)	(1.600)	(0.623)	(0.737)	(1.585)	(0.425)
Polity IV	0.004	-0.009	-0.004	0.017 **	0.002	-0.021*	0.006 **
	(0.010)	(0.007)	(0.014)	(0.006)	(0.009)	(0.011)	(0.003)
HDI middle	0.044	-0.080	-0.009	0.244 **	0.101	0.094	-0.014
	(0.078)	(0.114)	(0.127)	(0.115)	(0.113)	(0.253)	(0.053)
HDI high	0.169	-0.023	0.166	0.371 ***	0.228	0.143	0.030
	(0.137)	(0.140)	(0.205)	(0.139)	(0.156)	(0.301)	(0.073)
HDI very high	0.165	-0.029	0.204	0.391 **	0.195	0.085	0.137
	(0.151)	(0.156)	(0.237)	(0.165)	(0.182)	(0.317)	(0.098)
Threshold (value)	9.947	10.356		8.055			9.493
99% CI lower bound	9.929	10.241		8.055			9.493
99% CI upper bound	9.986	10.539		8.055			9.514
Bootstrap *p*-value	0.002	0.022		0.004			0.000
Wald equal. coeff. (p)	0.000	0.045		0.308			0.019
SSE without threshold	21.330	20.021	61.459	21.220	21.837	40.542	11.261
SSE with threshold	20.555	19.351		20.231			10.594
N regime 1	290	351	468	68	468	468	219
N regime 2	178	117		400			249

Table B.12: FE results: CH_4 consumption per capita. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

B.5 Detailed FE results for CH_4 per VA

	Dependent variable: CH_4 per unit of VA embodied in production in:						
	agr.	ctl.	egy.	mfc.	ser.	trn.	wab.
ln(Income), reg.1	-0.646 ***	-0.430	-0.180	-0.860***	-0.113	11.060*	-0.746**
	(0.236)	(0.317)	(0.280)	(0.260)	(0.656)	(5.633)	(0.349)
ln(Income), reg.2	-0.715 ***		-0.224		-0.374		
	(0.229)		(0.278)		(0.580)		
ln(Income), squared						-0.680*	
						(0.352)	
Annex I	0.092	0.350*	0.038	0.251**	0.065	0.081	0.082
	(0.103)	(0.209)	(0.126)	(0.121)	(0.387)	(0.139)	(0.139)
Openness	0.414 ***	0.890	-0.013	-0.067	0.484	0.177	0.200
	(0.105)	(0.592)	(0.259)	(0.244)	(0.342)	(0.248)	(0.164)
Food exports (%)	-0.341	-0.738	3.008 *	2.527**	-1.237	-1.126	0.297
	(0.618)	(0.866)	(1.604)	(1.157)	(1.378)	(1.113)	(0.757)
Fuel exports (%)	0.304	0.548	-1.939 ***	0.478	0.045	0.418	0.066
	(0.357)	(0.409)	(0.706)	(0.898)	(1.238)	(0.633)	(0.283)
ln(Pop. density)	-1.426 ***	0.165	0.794	0.189	-0.998	-1.649	-0.621
	(0.505)	(1.018)	(0.691)	(1.065)	(1.267)	(2.108)	(0.591)
Urbanization	-1.529	-0.838	1.002	-1.141	7.320 ***	-0.989	-2.108*
	(0.958)	(1.482)	(1.583)	(1.349)	(2.258)	(2.058)	(1.067)
Fossil rents	-1.195	-1.835	-2.028	0.829	0.503	-3.621*	1.133
	(1.338)	(2.086)	(1.394)	(1.615)	(1.978)	(2.174)	(1.672)
Polity IV	0.007	0.019**	-0.004	-0.005	-0.031	-0.024*	0.015*
	(0.007)	(0.007)	(0.015)	(0.014)	(0.020)	(0.012)	(0.009)
HDI middle	-0.186	-0.307	-0.177	0.355	0.979	-0.367	0.063
	(0.202)	(0.227)	(0.290)	(0.528)	(0.710)	(0.303)	(0.120)
HDI high	-0.260	-0.283	-0.007	0.435	1.225	-0.508	0.238
	(0.241)	(0.271)	(0.339)	(0.554)	(0.743)	(0.405)	(0.174)
HDI very high	-0.306	-0.522	0.203	0.353	1.162	-0.433	0.296
	(0.285)	(0.330)	(0.398)	(0.584)	(0.799)	(0.409)	(0.246)
Threshold (value)	8.055		9.291		7.648		
99% CI lower bound	8.047		9.215		7.648		
99% CI upper bound	8.137		9.480		7.652		
Bootstrap p-value	0.016		0.128		0.004		
Wald equal. coeff. (p)	0.020		0.009		0.013		
Turning point						8.137	
Observations before TP (%)						86.8%	
U-Test (p)						0.041	
SSE without threshold	46.115	104.604	87.703	96.707	439.291	169.750	62.956
SSE with threshold	44.652		85.660		416.730		
N regime 1	68	468	186	468	46	468	468
N regime 2	400		282		422		

Table B.13: FE results: CH_4 production per unit of value added. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. TP stands for turning point, and U-Test (p) is the p-value of the test for a polynomial relationship developed by Lind and Mehlum (2010). SSE is the sum of squared errors, and N is the number of observations. The lower bound of the threshold CI for services is truncated at 7.648 as a result of the 10% trimming. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: CH_4 per unit of VA embodied in final production in:						
	agr.	ctl.	egy.	mfc.	ser.	trn.	wab.
ln(Income), reg.1	-0.810***	-0.685***	-0.448 *	-1.015 ***	-0.669 ***	-0.257	-0.631**
	(0.196)	(0.165)	(0.260)	(0.152)	(0.212)	(0.277)	(0.297)
ln(Income), reg.2			-0.395	-0.957 ***	-0.698 ***	-0.306	
			(0.260)	(0.143)	(0.213)	(0.265)	
Annex I	0.372***	0.217***	0.104	0.192 ***	0.026	0.205 ***	0.119
	(0.098)	(0.073)	(0.126)	(0.061)	(0.064)	(0.071)	(0.111)
Openness	-0.104	0.350**	-0.083	-0.065	0.375 ***	0.328 **	0.269**
	(0.134)	(0.147)	(0.184)	(0.104)	(0.100)	(0.138)	(0.103)
Food exports (%)	-0.894	-0.973*	2.365	1.152	0.203	0.080	0.072
	(1.027)	(0.489)	(1.639)	(1.037)	(0.710)	(0.734)	(0.656)
Fuel exports (%)	0.235	0.180	-0.754	-0.290	0.021	-0.548	0.039
	(0.376)	(0.176)	(0.610)	(0.315)	(0.312)	(0.475)	(0.218)
ln(Pop. density)	-0.559	-0.488	0.304	-0.374	0.026	0.196	-0.789*
	(0.387)	(0.433)	(0.637)	(0.516)	(0.401)	(0.505)	(0.402)
Urbanization	-1.031	-0.510	-1.306	-0.299	-0.579	-0.945	-1.532*
	(0.934)	(0.943)	(1.499)	(0.796)	(0.721)	(0.896)	(0.792)
Fossil rents	-4.587**	0.160	-4.139 ***	1.881 **	-0.879	-2.955 ***	0.810
	(1.961)	(1.290)	(1.587)	(0.737)	(0.684)	(0.862)	(1.277)
Polity IV	-0.001	0.020***	-0.012	0.009	0.002	-0.005	0.011
	(0.009)	(0.006)	(0.010)	(0.006)	(0.009)	(0.007)	(0.007)
HDI middle	-0.164	-0.215**	-0.190	0.236 **	0.028	-0.003	0.019
	(0.118)	(0.096)	(0.188)	(0.099)	(0.096)	(0.103)	(0.090)
HDI high	-0.155	-0.138	-0.018	0.379 ***	0.112	0.032	0.123
	(0.186)	(0.118)	(0.245)	(0.126)	(0.126)	(0.153)	(0.130)
HDI very high	-0.153	-0.219	0.042	0.405 ***	0.044	-0.002	0.102
	(0.218)	(0.159)	(0.286)	(0.138)	(0.151)	(0.180)	(0.167)
Threshold (value)			10.101	8.217	10.004	8.055	
99% CI lower bound			10.059	8.100	9.951	7.998	
99% CI upper bound			10.184	8.245	10.012	8.137	
Bootstrap *p*-value			0.002	0.000	0.002	0.094	
Wald equal. coeff. (p)			0.004	0.012	0.002	0.029	
SSE without threshold	33.643	24.679	72.863	24.302	18.904	29.766	38.680
SSE with threshold			69.922	23.097	18.105	29.017	
N regime 1	468	468	312	74	299	68	468
N regime 2			156	394	169	400	

Table B.14: FE results: CH_4 final production per unit of value added. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

	Dependent variable: CH_4 per unit of VA embodied in consumption in:						
	agr.	ctl.	egy.	mfc.	ser.	trn.	wab.
ln(Income), reg.1	-0.762***	-0.704***	-0.355	-0.924 ***	-0.646 ***	-0.242	-0.680***
	(0.205)	(0.151)	(0.265)	(0.111)	(0.207)	(0.198)	(0.252)
ln(Income), reg.2			-0.304	-0.889 ***	-0.673 ***	-0.218	
			(0.265)	(0.104)	(0.209)	(0.199)	
Annex I	0.337***	0.139**	0.105	0.111 ***	0.028	0.097 *	0.073
	(0.078)	(0.067)	(0.127)	(0.042)	(0.060)	(0.056)	(0.079)
Openness	0.069	0.141	-0.012	-0.035	0.391 ***	0.265 ***	0.253***
	(0.116)	(0.118)	(0.189)	(0.068)	(0.082)	(0.094)	(0.095)
Food exports (%)	-1.021	-0.913*	1.679	0.736	0.277	0.415	0.145
	(0.906)	(0.496)	(1.665)	(0.687)	(0.697)	(0.627)	(0.621)
Fuel exports (%)	-0.057	0.113	-0.568	-0.327	0.009	-0.218	0.043
	(0.357)	(0.180)	(0.655)	(0.274)	(0.301)	(0.301)	(0.201)
ln(Pop. density)	-0.390	-0.429	0.147	-0.057	0.093	0.115	-0.774**
	(0.323)	(0.392)	(0.709)	(0.383)	(0.391)	(0.457)	(0.378)
Urbanization	-0.613	-0.505	-0.382	-0.224	-0.589	-1.116	-1.623**
	(0.743)	(0.912)	(1.637)	(0.626)	(0.707)	(0.773)	(0.737)
Fossil rents	-3.626**	0.025	-4.515 ***	0.841	-1.009	-3.159 ***	1.032
	(1.626)	(1.168)	(1.571)	(0.644)	(0.654)	(0.758)	(1.107)
Polity IV	0.003	0.013**	-0.010	0.007	0.002	-0.008	0.010*
	(0.009)	(0.005)	(0.011)	(0.007)	(0.009)	(0.006)	(0.006)
HDI middle	-0.220*	-0.217**	-0.283	0.261 ***	0.008	0.030	0.007
	(0.116)	(0.090)	(0.197)	(0.083)	(0.094)	(0.102)	(0.091)
HDI high	-0.146	-0.167	-0.080	0.335 ***	0.084	0.087	0.098
	(0.173)	(0.111)	(0.253)	(0.106)	(0.125)	(0.146)	(0.127)
HDI very high	-0.087	-0.199	-0.052	0.413 ***	0.031	0.057	0.120
	(0.191)	(0.144)	(0.291)	(0.120)	(0.151)	(0.159)	(0.154)
Threshold (value)			10.101	8.217	10.004	10.263	
99% CI lower bound			10.013	8.051	9.951	10.166	
99% CI upper bound			10.184	8.257	10.086	10.356	
Bootstrap *p*-value			0.010	0.056	0.006	0.044	
Wald equal. coeff. (p)			0.004	0.059	0.004	0.023	
SSE without threshold	23.126	20.949	72.989	15.907	17.930	20.380	22.064
SSE with threshold			70.393	15.472	17.234	19.825	
N regime 1	468	468	312	74	299	338	468
N regime 2			156	394	169	130	

Table B.15: FE results: CH_4 consumption per unit of value added. Note: agr. stands for agriculture, liv. for livestock, egy. for energy, mfc. for manufacturing, ser. for services, trn. for transport, and pub. for public administration (see Table A.2 in the Appendix). min CI and max CI stand for the lower- and the upper-bound of the confidence interval. SSE is the sum of squared errors, and N is the number of observations. Cluster robust standard errors (Stock and Watson, 2008) in parentheses.

C Complementary analysis of agricultural sectors

This section reports the results of a complementary, more detailed analysis of the agriculture and livestock sectors. In this analysis we split the agriculture sector into two more narrowly defined subsectors—crops, and forestry and fishing—and the livestock sector into three subsectors—red meat, other livestock, and dairy. Table C.1 provides details on the sectoral breakdown.

Agricultural Sector	**subsectors**
Agriculture	
Crops	Paddy Rice (pdr); Wheat (wht); Cereal grains nec (gro); Vegetables, fruit, nuts (v_f); Oil seeds (osd); Sugar cane, sugar beet (c_b); Plant-based fibers (pfb); Crops nec (ocr); Sugar (sgr); Food products nec (ofd); Beverages and tobacco products (b_t); Vegetable oils and fats (vol); Processed Rice (pcr);
Forestry and Fishing	Forestry (frs); Fishing (fsh);
Livestock	
Red Meat	Cattle, sheep, goats, horses (ctl); Meat: cattle, sheep, goats, horse (cmt); Wool, silk-worm cocoons (wol);
Other Livestock	Animal products nec (oap); Meat products nec (omt);
Dairy	Raw milk (rmk); Dairy products (mil);

Table C.1: subsectors of the five agricultural sectors.

We repeated the econometric analysis as detailed in the main text for these five alternative subsectors in order to evaluate how the relationships in these subsectors affect the results for the broader agriculture and livestock sectors. Therefore, we estimated polynomial and threshold models for each of the subsectors and inventories. If both specifications provided evidence for non-linearities, we report the results of both models and the sum of squared errors for each model. If none of the two specifications provided evidence for non-linearities, we report the results of a linear model. All estimations included the full list of control variables and country and time fixed effects. We instrumented income per capita and the ratification of the Kyoto Protocol by Annex I members following the instrumentation strategy described in the main text. The detailed results for the specifications reported in this appendix are available upon request.

Table C.2 reports the results using methane emissions per capita as dependent variable. In line with the results for the agriculture and livestock sectors in the main text, we detected evidence for a piecewise-linear relationship between income per capita and emissions per capita in most subsector-inventory combinations. An exception to this were production inventories in the red meat, other livestock and dairy subsectors, for which we did not detect non-linearities (in line with the results for the livestock sector in the main text). The

	Crops	Forestry, Fishing	Red Meat		Other Livestock	Dairy
	Panel 1: CH_4 per capita embodied in production in:					
ln(Income), reg.1	0.617 ***	-0.631	0.235		0.117	0.256
	(0.211)	(0.956)	(0.178)		(0.210)	(0.191)
ln(Income), reg.2	0.542 ***	-0.072				
	(0.197)	(0.906)				
Annex I	-0.188	1.703	0.865		0.487	0.587
	(0.222)	(1.118)	(0.806)		(0.643)	(0.686)
Openness	0.262 ***	0.306	0.775*		0.405	0.583
	(0.086)	(0.664)	(0.470)		(0.429)	(0.430)
Additional controls	yes	yes	yes		yes	yes
Threshold (value)	8.086	8.629				
99% CI lower bound	8.047	8.629				
99% CI upper bound	8.143	8.633				
Bootstrap *p*-value	0.012	0.000				
Wald equal. coeff. (p)	0.004	0.027				
N regime 1/2	69/399	106/362	468		468	468
	Panel 2: CH_4 per capita embodied in final production in:					
ln(Income), reg.1	0.295	-0.383	0.286		-0.179	-0.223
	(0.262)	(0.391)	(0.254)		(0.502)	(0.530)
ln(Income), reg.2	0.256	-0.472	0.202		-0.131	-0.088
	(0.263)	(0.389)	(0.240)		(0.493)	(0.512)
Annex I	0.423 *	0.326	-0.696		-0.161	-0.061
	(0.228)	(0.443)	(0.444)		(0.549)	(0.368)
Openness	-0.127	0.038	0.291		0.080	-0.324
	(0.120)	(0.294)	(0.300)		(0.184)	(0.330)
Additional controls	yes	yes	yes		yes	yes
Threshold (value)	9.952	9.988	8.055		9.315	8.345
99% CI lower bound	9.939	9.988	7.652		7.652	8.345
99% CI upper bound	9.955	10.004	10.609		10.609	8.345
Bootstrap *p*-value	0.004	0.000	0.056		0.034	0.000
Wald equal. coeff. (p)	0.011	0.003	0.016		0.058	0.021
N regime 1/2	293/175	297/171	69/400		190/278	86/382
	Panel 3: CH_4 per capita embodied in consumption in:					
ln(Income), reg.1	0.403 *	0.119	-4.030**	0.224	-0.008	-0.078
	(0.223)	(0.439)	(2.042)	(0.247)	(0.472)	(0.463)
ln(Income), reg.2	0.377 *	0.039		0.136	0.043	0.014
	(0.222)	(0.436)		(0.242)	(0.462)	(0.459)
ln(Income), squared			0.229*			
			(0.119)			
Annex I	0.624 ***	0.282	-0.624*	-0.649 *	0.074	0.117
	(0.216)	(0.472)	(0.330)	(0.350)	(0.531)	(0.348)
Openness	0.071	0.215	0.026	0.006	0.242	0.132
	(0.094)	(0.249)	(0.162)	(0.187)	(0.173)	(0.303)
Additional controls	yes	yes	yes	yes	yes	yes
Threshold (value); [TP]	9.947	9.988	[8.809]	8.055	9.315	8.345
99% CI lower bound	9.929	9.988		8.051	7.652	8.345
99% CI upper bound	9.955	10.008		8.100	10.609	8.345
Bootstrap *p*-value	0.024	0.000		0.044	0.004	0.000
Wald equal. coeff. (p)	0.005	0.007		0.009	0.059	0.021
U-Test (p)			0.053			
SSE			50.753	50.866		
N regime 1/2 [%N<TP]	290/178	297/171	468 [24%]	68/400	190/278	86/382

Table C.2: IV-FE results: CH_4 per capita. Note: TP stands for the value of the turning point. CI stands for confidence interval. U-Test (p) is the *p*-value of the test for a polynomial relationship developed by Lind and Mehlum (2010). SSE is the sum of squared errors, N is the number of observations and %N<TP refers to the share of observations before the TP. Cluster robust standard errors (Stock and Watson, 2008) in parentheses. All regressions include additional control variables.

sign and statistical significance of the estimated income elasticities for the five subsectors correspond to the patterns detected for the agriculture and livestock sectors in the main text: The significant effect of income on emissions in the agriculture sector was largely driven by the crops subsector, where income significantly affected emissions embodied in production and consumption; the income elasticities in the other four subsectors were statistically insignificant. Interestingly, for the consumption inventory in the red meat subsector our estimates also provide evidence for a polynomial relationship between income and emissions, which suggests that the effect of income on emissions followed a U-shape. Yet, a detailed analysis across the range of values of income per capita showed that this effect was statistically insignificant for most of the income-range observed in our sample (only the negative effect at very low income levels was marginally statistically significant).

The findings concerning Kyoto ratification by Annex I countries and trade openness are also in line with the results described in the main text: The significant and positive (emission increasing) effect of Kyoto ratification detected for footprint inventories in Annex I countries in the agriculture sector was largely driven by the crops subsector, while in most of the other subsectors Annex I membership was insignificant; the only exception was the consumption-inventory of the red meat subsector, in which the Kyoto Protocol had a negative (emission reducing) and marginally significant effect on emissions in Annex I members—this effect was too weak, however, to show up in the aggregate livestock sector on account of the positive (but insignificant) point estimates for Annex I membership in the other livestock and the dairy subsectors. Trade openness had a significant and positive effect on production-based emission inventories in the crops and the red meat subsectors only.

Moving on to the results using value added per capita as the dependent variable, Table C.3 shows that increases in income per capita led to sectoral expansions of the crops, forestry and fishing, and red meat subsectors. Income per capita did not significantly affect value added per capita in the other livestock and the dairy subsectors, however. The ratification of the Kyoto Protocol by Annex I members, when statistically significant, led to a contraction of sectoral activity. Notably, it appears that the crops and the red meat subsectors were responsible for the findings for the agriculture and the livestock sectors, respectively, documented in the main text. Trade openness had a statistically significant and negative effect on sectoral activity in the production of the red meat subsector and in production and final production in the dairy subsector.

The results for methane per unit of value added (methane intensity) as the dependent variable are summarized in Table C.4. Again, most subsector-inventory combinations were characterized by a threshold relationship, with the exceptions of the production-inventories in the red meat and the other livestock subsectors, where, in line with the results for the aggregate livestock sector in the main text, we did not find evidence for non-linearities between income and emission intensities. The estimated income-elasticities were negative whenever they were statistically significant, indicating that economic growth led to a reduction of methane intensities. For the footprint inventories, the effects were significant in the majority of subsectors, while for the production inventories they were significant only in the forestry and fishing and the red meat subsector. Noteworthy, for the consumption inventory in the forestry and fishing subsector we also found evidence for a polynomial relationship between income and emission intensity, which followed a U-shape. A detailed analysis over the range of income per capita showed that the negative part of this relationship at lower levels of income per capita was statistically significant for a large part of the countries in our sample, while the positive part of this relationship at higher income levels remained insignificant.

The ratification of the Kyoto Protocol by Annex I countries led to an increase in methane intensity in all subsectors where it was statistically significant, what coincides with the effects found in the analysis reported in the main text. For production-based inventories, Annex I membership was marginally significant in the forestry and fishing and the red meat subsectors, but these effects were too weak to show up in the aggregate agriculture and livestock sectors analyzed in the main text. Again in line with the main analysis, the effect of trade openness was positive (emission increasing) whenever it was statistically significant.

Finally, the results of the analysis for the five subsectors can be described as a combination of scale, composition, and technique effects of economic growth. The scale effect is studied through the effects of economic growth on value added per capita, while the composition and technique effects are analyzed through the effects of economic growth on methane per value added (methane intensity). Our analysis suggests that the scale effect of economic growth was especially pronounced in the red meat subsector and in production of value added in the forestry and fishing subsector (i.e. these sectors expanded considerably as a result of increasing income per capita). In these sectors, economic growth also led to strong reductions in methane intensity, pointing to relatively large composition and technique effects. As a result, the overall effect of income on emissions per capita in these subsectors was statistically insignificant and we could not reject absolute decoupling. By contrast, in the crops subsector we detected a positive and statistically significant overall effect of economic growth on emissions per capita embodied in production in and consumption. In this subsector, production and consumption expanded with economic growth; however, in the production-based inventory this expansion was not accompanied by significant gains in methane intensity while in the consumption-based inventory the expansion was associated with slight declines in methane intensity. Consequently, in this subsector the reductions in methane intensity could not outweigh the scale-effects of economic growth. In the other livestock and the dairy subsectors, economic growth did not lead to significant expansions of these subsectors; its effect on methane intensity was also statistically insignificant. Accordingly, economic growth did not affect these subsectors.

	Crops	Forestry, Fishing		Red Meat	Other Livestock	Dairy
		Panel 1: Value added per capita embodied in production in:				
ln(Income), reg.1	0.775 ***	1.290 ***		1.272 ***	0.014	0.568
	(0.174)	(0.191)		(0.336)	(0.220)	(0.586)
ln(Income), reg.2	0.755 ***	1.253 ***		1.223 ***	0.045	0.667
	(0.172)	(0.193)		(0.334)	(0.216)	(0.539)
Annex I	-0.292 *	0.038		-0.594 *	-0.322	-0.523
	(0.169)	(0.329)		(0.331)	(0.220)	(0.364)
Openness	-0.125	0.220		-0.375 **	-0.298	-0.814 ***
	(0.104)	(0.170)		(0.188)	(0.193)	(0.296)
Additional controls	yes	yes		yes	yes	yes
Threshold (value)	9.509	10.222		9.183	8.749	8.327
99% CI lower bound	9.426	10.192		9.049	7.652	8.318
99% CI upper bound	9.579	10.304		9.247	10.609	8.327
Bootstrap *p*-value	0.024	0.000		0.000	0.002	0.002
Wald equal. coeff. (p)	0.001	0.008		0.001	0.025	0.354
N regime 1/2	222/246	329/139		169/299	117/351	83/385
		Panel 2: Value added per capita embodied in final production in:				
ln(Income), reg.1	0.838 ***	0.711 ***	6.864***	1.294 ***	0.120	1.017
	(0.154)	(0.269)	(2.162)	(0.339)	(0.281)	(0.701)
ln(Income), reg.2	0.813 ***	0.650 **		1.234 ***	0.157	1.092
	(0.152)	(0.260)		(0.334)	(0.275)	(0.681)
ln(Income), squared			-0.355***			
			(0.131)			
Annex I	-0.073	0.054	0.056	-1.348 ***	-0.674 ***	-0.601 **
	(0.126)	(0.421)	(0.493)	(0.406)	(0.224)	(0.301)
Openness	-0.027	0.023	-0.162	-0.243	-0.163	-0.439 *
	(0.102)	(0.220)	(0.152)	(0.203)	(0.167)	(0.253)
Additional controls	yes	yes	yes	yes	yes	yes
Threshold (value); [TP]	9.950	9.988	[9.665]	9.085	8.713	8.327
99% CI lower bound	9.924	9.988		8.940	7.652	8.318
99% CI upper bound	9.968	10.008		9.291	10.609	8.345
Bootstrap *p*-value	0.000	0.000		0.000	0.008	0.000
SSE with threshold		58.325	59.544			
Wald equal. coeff. (p)	0.002	0.073		0.005	0.042	0.295
U-Test (p)			0.075			
N regime 1/2 [%N<TP]	291/177	297/171	468 [47%]	158/310	111/357	83/385
		Panel 3: Value added per capita embodied in consumption in:				
ln(Income), reg.1	0.872 ***	1.055 ***		1.128 ***	0.3970	1.032
	(0.154)	(0.285)		(0.339)	(0.243)	(0.711)
ln(Income), reg.2	0.850 ***	0.988 ***		1.071 ***	0.3723	1.011
	(0.153)	(0.274)		(0.334)	(0.247)	(0.717)
Annex I	0.123	0.160		-1.245 ***	-0.3267	-0.424
	(0.174)	(0.451)		(0.387)	(0.264)	(0.327)
Openness	-0.014	0.102		-0.214	-0.0311	-0.017
	(0.122)	(0.172)		(0.177)	(0.131)	(0.250)
Additional controls	yes	yes		yes	yes	yes
Threshold (value)	9.947	9.988		9.085	10.358	10.452
99% CI lower bound	9.909	9.988		8.940	10.241	10.241
99% CI upper bound	9.986	10.013		9.236	10.502	10.501
Bootstrap *p*-value	0.000	0.000		0.002	0.006	0.014
Wald equal. coeff. (p)	0.000	0.060		0.013	0.024	0.108
N regime 1/2	290/178	297/171		158/310	353/115	382/86

Table C.3: IV-FE results: Value added per capita. Note: TP stands for the value of the turning point. CI stands for confidence interval. U-Test (p) is the *p*-value of the test for a polynomial relationship developed by Lind and Mehlum (2010). SSE is the sum of squared errors, N is the number of observations and %N<TP refers to the share of observations before the TP. Cluster robust standard errors (Stock and Watson, 2008) in parentheses. All regressions include additional control variables.

	Crops	Forestry, Fishing	Red Meat	Other Livestock	Dairy
	Panel 1: CH_4 per unit of VA embodied in production in:				
ln(Income), reg.1	0.002	-2.087 *	-0.950**	0.011	-0.405
	(0.229)	(1.136)	(0.451)	(0.302)	(0.624)
ln(Income), reg.2	-0.086	-1.400			-0.475
	(0.217)	(1.070)			(0.585)
Annex I	0.043	2.361 *	1.574*	0.835	1.164
	(0.283)	(1.417)	(0.886)	(0.731)	(0.820)
Openness	0.404 ***	0.159	1.135**	0.726	1.387 ***
	(0.121)	(0.812)	(0.556)	(0.591)	(0.531)
Additional controls	yes	yes	yes	yes	yes
Threshold (value)	8.055	8.629			8.327
99% CI lower bound	8.047	8.629			8.245
99% CI upper bound	8.086	8.633			8.370
Bootstrap *p*-value	0.006	0.000			0.004
Wald equal. coeff. (p)	0.006	0.031			0.466
N regime 1/2	68/400	106/362	468	468	83/385
	Panel 2: CH_4 per unit of VA embodied in final production in:				
ln(Income), reg.1	-0.467 *	-1.109 ***	-1.278 ***	-0.393	-1.241
	(0.247)	(0.324)	(0.279)	(0.423)	(0.806)
ln(Income), reg.2	-0.446 *	-1.070 ***	-1.224 ***	-0.350	-1.172
	(0.250)	(0.327)	(0.278)	(0.415)	(0.789)
Annex I	0.401	0.087	0.743 **	0.571	0.549
	(0.250)	(0.261)	(0.343)	(0.503)	(0.388)
Openness	-0.104	-0.024	0.491 **	0.278	0.088
	(0.165)	(0.165)	(0.209)	(0.211)	(0.329)
Additional controls	yes	yes	yes	yes	yes
Threshold (value)	10.470	10.258	9.079	9.315	8.375
99% CI lower bound	10.445	10.202	8.940	7.652	7.652
99% CI upper bound	10.489	10.359	9.269	10.609	10.609
Bootstrap *p*-value	0.028	0.002	0.002	0.006	0.052
Wald equal. coeff. (p)	0.032	0.015	0.002	0.077	0.019
N regime 1/2	385/83	336/132	157/311	190/278	89/379

	Crops	Forestry, Fishing		Red Meat	Other Livestock	Dairy
	Panel 3: CH_4 per unit of VA embodied in consumption in:					
ln(Income), reg.1	-0.453 *	-6.431***	-0.9466 ***	-1.240 ***	-0.391	-1.125 *
	(0.248)	(1.721)	(0.354)	(0.304)	(0.420)	(0.663)
ln(Income), reg.2	-0.444 *		-0.9195 **	-1.188 ***	-0.350	-1.072 *
	(0.251)		(0.358)	(0.301)	(0.412)	(0.642)
ln(Income), squared		0.317***				
		(0.091)				
Annex I	0.470 **	0.015	0.0030	0.711 **	0.512	0.448
	(0.188)	(0.235)	(0.250)	(0.280)	(0.475)	(0.307)
Openness	0.089	0.192	0.0937	0.172	0.267	0.092
	(0.118)	(0.158)	(0.202)	(0.125)	(0.206)	(0.254)
Additional controls	yes	yes	yes	yes	yes	yes
Threshold (value); [TP]	10.470	[10.130]	10.258	9.012	9.315	7.756
99% CI lower bound	10.405		10.103	8.952	7.652	7.652
99% CI upper bound	10.540		10.609	9.046	10.609	10.609
Bootstrap *p*-value	0.100		0.044	0.020	0.004	0.064
Wald equal. coeff. (p)	0.281		0.064	0.010	0.104	0.174
U-Test (p)		0.041				
SSE		53.664	54.799			
N regime 1/2 [%N<TP]	385/83	468 [63%]	336/132	146/322	190/278	51/417

Table C.4: IV-FE results: CH_4 per value added. Note: TP stands for the value of the turning point. CI stands for confidence interval. U-Test (p) is the *p*-value of the test for a polynomial relationship developed by Lind and Mehlum (2010). SSE is the sum of squared errors, N is the number of observations and %N<TP refers to the share of observations before the TP. Cluster robust standard errors (Stock and Watson, 2008) in parentheses. All regressions include additional control variables.