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The complex regional effects of macro-institutional change: evidence from EU enlargement over three decades

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Abstract

The EU enlargement process has thrust EU internal border regions into the spotlight of the European single market. This study explores how this specific macro-institutional change has impacted their socio-economic development. Tracking outcomes across four EU enlargement waves from 1986 to 2007, we identify integration effects across EU NUTS3 regions. Pooled over all waves and border regions, positive integration effects emerge for per capita GDP, labor productivity, patents per capita, and night light emissions in border regions compared to non-border areas. These effects diminish with increasing spatial distance from the enlargement border. At a detailed level, structural heterogeneities become evident across enlargement waves and region types. Internal border regions in established EU member countries benefit relatively in terms of GDP per capita and labor productivity but experience relative declines in employment rates and population. In contrast, border regions in new member countries, particularly during the 2004 and 2007 eastern enlargements, gain from deepening economic integration in terms of population and employment growth. Sector-specific estimations indicate post-enlargement specialization of economic activities in border regions in line with standard trade theories.

Keywords Economic integration · EU enlargement · Internal border regions · Regional development · Treatment effect estimation

JEL Classification C23 · F15 · O47 · R11

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1 Introduction

Regions located along the border of economically integrating countries are highly exposed to this macro-institutional change and we address the question if this exposure translates into specific integration effects for the regions' socio-economic development path. As borders are a natural barrier to economic interaction (Capello et al., 2018a), the dismantling of border impediments through economic integration may, on the one hand, improve their market access by shifting border regions from the country's periphery to the heart of the newly formed economic block (e.g., Percoco, 2015). While this argument speaks in terms of positive EU integration effects in border vis-à-vis non-border regions, there are also arguments for a relative weaker performance of border regions: The 'path dependency' or 'lock in' argument, for instance, states that when borders have pertained for a long time, border regions may have suffered from a gradual process of marginalization that deprives them of the absorptive capacities and scale effects needed to benefit from economic integration more than their better endowed, agglomerated non-border counterparts (Floerkemeier et al., 2021; Petrakos & Topaloglou, 2008).

A significant growth premium in border regions would also be absent if trade costs were sufficiently low so that closer geographical proximity to new markets itself is not a decisive factor for reaping the benefits of open borders and economic integration as it is, for instance, predicted in Krugman (1991)-type core-periphery models. And finally, socio-economic development levels in countries on both sides of the integration border may differ in such a way that gains from economic integration in established (old) and new member states, i.e., effects stemming from widening and deepening EU integration, are unevenly distributed across border regions so that overall effects in border regions are difficult to measure. Thus, what seemed straightforward on a first glance, namely, to identify the treatment effects of economic integration for border regions along the integration border may, in fact, be quite complex and subject to structural, temporal, and spatial heterogeneities. In this paper, we take this 'complexity' perspective as starting point for an in-depth study of the integration effects associated with four consecutive enlargement waves of the European Union between 1986 and 2007. Essential research questions are:

1. Do we find evidence for common integration effects of EU enlargement for internal border regions in terms of key socio-economic outcomes such as GDP, employment, and population growth?
2. What types of structural, temporal, and spatial heterogeneity determine the direction, magnitude, and duration of integration effects across enlargement waves and sub-groups of border regions considered?

Providing answers to both research questions shall help policy makers to better assess the benefits and costs associated with EU economic integration in the context of regional commonalities but also heterogeneities.

When it comes to the selection of EU internal border regions as treatment group in our empirical investigation, we argue that this focus is well deserved out of

significance and relevance considerations. First, as stated by the EU Commission (2017), border regions account for approximately one third of EU population and a similar aggregate production share in the EU.¹ At the same time, border regions, on average, have a weaker economic performance, lower levels of labor market integration and public service provision compared to non-border regions in the EU Commission (2017), which is why EU regional policy supports the socio-economic development in border regions through different funding programmes (most notably through Interreg project funding and the b-solutions initiative, see EU Commission (2021)).

Second, beyond their status as being a specific (disadvantaged) regional group within the wider internal economic geography of the EU, the EU Commission sees border regions as important “living labs of European integration” (EU Commission, 2021). The idea of living labs is that they allow to study integration effects in border regions under the magnifying glass and that findings obtained here provide important general insights on the overall progress of EU integration and cooperation at large. Extending this logic, we argue that EU internal border regions are particularly well-suited to investigate the economic returns to EU economic integration at the regional level as they have been particularly exposed to associated shifts in the EU’s internal economic geography, while the enlargement process itself can be seen as an exogenous source of variation to their development path.

The exogeneity of the enlargement ‘shock’ at the small-scale regional level can be motivated by the fact that political decisions for EU enlargement were made at the national and supra-national level with goals not specifically tailored to the needs and economic conditions of border regions. The same logic applies to the allocation of the bulk of EU regional funding volumes, which focus on the regions’ development status irrespective of their geographical location within a country (Breidenbach et al., 2019), so that EU regional funding alone cannot explain a potential growth premium associated with economic integration in border regions. We accordingly argue that the focus on border regions enables us to study the effects of EU integration in a quasi-experimental manner.

Prior empirical evidence on a potential growth and development premium associated with EU accession and the economic freedoms associated with the European single market has remained inconclusive. While, e.g., Campos et al. (2019) report significant positive income growth effects of EU membership at the country level (with few exceptions), Andersen et al. (2019) generally do not find evidence for an EU membership growth premium. With respect to the focus of this study, there is also a knowledge gap on how the potential gains from economic integration are distributed across the different regions within integrating countries (Niebuhr & Stiller, 2004, Braakmann and Vogel, 2010, and Heider, 2019). It is generally supposed that regional ability to reap welfare gains from EU integration chiefly depend on a region’s relative competitiveness driven by industry composition and settlement structure, its institutional setup, trade intensity as well as size and geographical

¹ Based on a definition of internal border regions of the EU-28 (including the UK) and also including EU border regions to EEA countries (see EU Commission, 2017).

proximity to the enlargement border (e.g., Brakman et al., 2012; Brühlhart et al., 2012, 2018; McCallum, 1995).

While earlier studies have mainly focused on GDP growth as sole outcome variable, a novelty of our analysis is that we conduct a comprehensive empirical analysis of the complex border regional effects associated with the EU enlargement process during the 1980s, 1990s and 2000s. Specifically, we employ a broad set of outcome variables covering region-specific time patterns of per capita GDP, (sectoral) labor productivity, research and development (R&D) and innovation activity, employment, population development, night light emissions. As there is no information on the stock of public (and also private) infrastructure at the level of NUTS3 regions (the observational unit used in this paper), night light data fill an important gap. An increase in night light emissions reflects changes of the public infrastructure (such as streets or public buildings) but also changes of private activities such as housing stocks or firm density/activity.² It can thus be regarded as a general measure for agglomeration trends and has previously been used to map the development of population and firm density across regions (e.g., Mellander et al., 2015). Also, prior empirical analyses have used night light data to measure processes of economic integration, growth, and convergence, especially when other economic data are missing (see, e.g., Henderson et al., 2012; Galimberti, 2020). But even for geographical areas with fairly good data provision, Mellander et al. (2015) as well as Lessmann and Seidel (2017) have shown that night light data still delivers important insights on economic development trends and differences.

Four EU enlargement periods are covered in our analysis: First, the EU accession of Spain and Portugal in 1986 (third enlargement wave); second, the EU membership of Austria, Sweden, and Finland in 1995 (fourth enlargement wave); third, the so-far largest EU enlargement of mostly central and eastern European countries in 2004 (fifth enlargement wave); and fourth, the accession of Romania and Bulgaria to the EU in 2007 (sixth enlargement wave). To identify treatment effects of EU integration in border regions vis-à-vis non-border regions during these enlargement periods, we conduct an analysis for the 1289 NUTS3 regions of the EU-27 (including the UK but not Croatia) over the time period 1981–2014. We apply static and dynamic difference-in-difference (DiD) estimation to identify pooled and group-specific effects. The DiD approach has shown a high degree of flexibility and robustness when previously been applied to spatio-temporal analyses of border regional growth effects such as for the division and reunification of Germany (Redding & Sturm, 2008) and economic transformations after the fall of the iron curtain (Brühlhart et al., 2012, 2018) among other applications.

In the estimations we particularly account for the fact that the distribution of integration effects may be fuzzy with regard to spatial and temporal aspects. As such, we explicitly control for the circumstance that EU enlargement cannot be treated

² The NUTS classification (Nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the EU. The NUTS regulation mirrors the territorial administrative division of the EU member states and defines minimum and maximum population thresholds for the size of regions. At the NUTS Level 3 regions have a population size of between 150,000 and 800,000 inhabitants (for details see <https://ec.europa.eu/eurostat/web/nuts/principles>).

as precisely timed event. For example, in 2004, EU accession followed a process covering early agreements between old and new EU member states initiated in the aftermath of the collapse of the Soviet system (Dangerfield, 2006). This potentially results in ‘early anticipation’ effects that weaken the power of static DiD estimations, which rely on a precise classification of a single pre- and post-treatment period.³ To account for these methodical challenges, we apply a flexible DiD approach that estimates time-heterogeneous coefficients for the different stages around the timing of EU enlargement. In addition, we account other confounding factors, which may either affect all EU countries equally, such as the deepening of economic integration through the EU single market in 1992, or is confined to individual countries and country groups, such as the introduction of the Euro currency in 1999, by adding a multidimensional ‘fixed effects’ structure to our DiD specifications. We also run several robustness tests to see if the obtained results hold to variations in the data and regression specification.

The remainder of this paper is organized as follows: Sect. 2 outlines the underlying theory related to border regional growth effects of economic integration. This section also summarizes prior empirical findings for the economic effects of EU enlargement and identifies research gaps in the literature. Section 3 describes our empirical study design, which is followed by a description of the data and variables used in Sect. 4. Section 5 reports our empirical results for pooled and heterogeneous treatment effects of EU economic integration together with a series of robustness tests. Finally, Sect. 6 discusses policy implications and concludes the paper.

2 Border regional effects of economic integration: theory, evidence and gaps

2.1 A complexity perspective of economic integration

Models of regional growth, international trade, and economic geography stress the role of trade related to market size, market access and transport cost for regional development (e.g., Krugman & Venables, 1990; Percoco, 2015). It can be conjectured that border regions gain from EU enlargement due to their unique geographic location and the associated improvement of market access. These effects may, however, be partly or fully offset by sustaining border impediments, lacking absorptive capacities and this insufficient scale economies in border regions, which may lock regions in a peripheral position (Capello et al., 2018a; Petrakos & Topaloglou, 2008).

Our conceptual approach, which takes these opposing factors into account starts with a fairly general specification of a regional production function defined as $Y = A(K^\alpha L^\beta N^\varphi)$, where Y is a measure of regional output (typically GDP or GVA),

³ A similar problem would arise if effects only gradually ‘phase in’ over time because of institutional arrangements such as the 2+3+2 regulation, which allowed established member countries to temporarily protect their labor markets from free labor mobility associated with EU accession of new members. According to the 2+3+2 regulation the maximum protection period amounted to seven years (for details see <https://www.eurofound.europa.eu/en/european-industrial-relations-dictionary/mobility-workers>).

A is technology, K is capital, L denotes labor input and \mathbf{N} is a vector of further inputs; α , β and φ are the respective output elasticities. If we write this regional production function as growth specification in intensive form, we get

$$\Delta y_{it} = \Delta A_{it} + \alpha \Delta k_{it} + \sum_{r=1}^R \varphi_r \Delta n_{r,it} \quad (1)$$

where Δy_{it} is as measure for per worker (or per capita) output growth for region i at time t , $y = Y/L$, $k = K/L$ and similar for the remaining inputs ($n_r = N_r/L$). In an earlier analysis with national data for the EU-15, Badinger (2005) has focused on two potential channels how economic integration affects Δy_{it} as: i) a technology channel ($\Delta A_{it} = \gamma_{A0} + \gamma_{A1} \Delta INT_{it}$) and ii) a physical investment channel ($\Delta k_{it} = \gamma_{k0} + \gamma_{k1} \Delta INT_{it}$) with ΔINT being an indicator for changes in the level of integration at time t ; γ_{A0} and γ_{k0} are exogenous components of technological progress and capital formation, respectively. This logic can be straightforwardly extended to the integration effects of other inputs such as for input r as ($\Delta n_{r,it} = \gamma_{r,n0} + \gamma_{r,n1} \Delta INT_{it}$) and we can measure the relative performance of border regions for these inputs separately.

Alternatively, the input channels can be aggregated to an overall effect of economic integration on per capita income growth as

$$\Delta y_{it} = \delta_0 + \delta_1 \Delta INT_{it} \quad (2)$$

with $\delta_0 = (\gamma_{A0} + \alpha \gamma_{k0} + \sum_{r=1}^R \varphi_r \gamma_{r,n0})$ and $\delta_1 = (\gamma_{A1} + \alpha \gamma_{k1} + \sum_{r=1}^R \varphi_r \gamma_{r,n1})$.

Given our focus on border regions, Eq. (2) can be extended by incorporating a spatial component into the analysis of growth effects from economic integration as

$$\Delta y_{it} = \delta_0 + \left(\rho_1 + \rho_2 \left(\frac{1}{DIST_i^\theta} \right) \right) \Delta INT_{it} \quad (3)$$

where $\left(\frac{1}{DIST_i^\theta} \right)$ measures proximity for each region i to the newly integrated unit (with $DIST_i$ being some distance measure to the integration border or a specific point of interest across the border). Equation (3) thus splits the growth effects of integration δ_1 into a general non-spatial component ρ_1 and a growth premium for regions with closer proximity to the border (ρ_2) with $\delta_1 = \rho_1 + \rho_2$. While distance/proximity can be measured in different dimensions (Boschma, 2005), we refine to geographical distance as a catch-all term for other forms such as cultural, social, and historical proximity. This extension reflects that benefits from economic integration do not affect each region equally but predicts that regions closer to the integrated market receive larger benefits as typically found in gravity-type models of inter-regional trade such as in McCallum (1995).⁴ The parameter θ shown in Eq. (3) expresses the power of distance decay. For instance, for sufficiently high values of θ ,

⁴ Referring to the argument of intensified inter-regional trade after EU enlargement, Figure A1 in the Supplementary Online Materials provides an overview of trade flows between German NUTS1 regions and their two neighboring Eastern countries (Poland and Czechia). What can be seen is that those Ger-

we expect to only observe a spatial growth premium for regions directly adjacent to the enlargement border. Ways to empirically proxy the spatial proximity to the enlargement border will be presented below.

The role of distance decay as a factor determining trade cost and eventually output effects from economic integration is also stressed in models of the New Economic Geography (NEG). Krugman and Venables (1990), for instance, show for an NEG model application to the EU single market in 1992 that with reduced transport costs more firms may find it attractive to relocate to the periphery as a way take advantage of factor price differentials between countries. Other NEG models similarly predict that regions with a lower distance and thus transport cost to international markets reap the largest benefits from economic integration (Brühlhart et al., 2004; Crozet & Koenig, 2004).

Behrens et al. (2007) and Monfort and Nicolini (2000) show in NEG model settings that a country's internal economic geography constitutes a significant conditioning factor for the regional economic effects of international economic integration. For instance, Rauch (1991) presents a model in which coastal border regions are the main trade hub of a country. In this case, border regions can particularly benefit from trade integration. Overman and Winters (2006), study the impact of UK accession to the larger European market and find evidence for this setup indicating that coastal (border) regions hosting a port with better market access for exports and intermediate inputs experience higher employment compared to other similar regions.

If border regions suffer from locational disadvantages, model predictions may differ, though. Without scale effects emanating from locational advantages, consumers typically have to pay higher prices and firms can only supply goods to the market at higher cost when being located in a border region (Niebuhr & Stiller, 2004). Increased proximity to foreign markets of integrating countries then only allows border regions to grow faster than non-border regions if they possess specific territorial assets (Capello et al., 2018a). If such assets are missing, there is the risk of a 'tunnel effect', i.e., a bypassing of border regions after integration, which could further marginalize border regions if trade patterns after EU enlargement are dominated by central core regions (Petrakos & Topaloglou, 2008). In this case, ρ_2 can be expected to be zero or even negative.

2.2 Prior empirical evidence and remaining research gaps

Several empirical contributions have been concerned with the identification of growth effects of economic integration – predominately at the national level (e.g.,

Footnote 4 (continued)

man NUTS1 regions located in geographical vicinity to the enlargement border experienced a much stronger export growth to Poland and Czech Republic after 2004 than other German regions. In line with this stylized finding and with regard to the expected economic effects of EU integration for border regions, it can be hypothesized that improved cross-border exchange increases the regions' potential for economic development (see also EU commission, 2001; Brühlhart et al., 2004; Hanson, 2005; Brühlhart, 2011).

Andersen et al., 2019; Badinger, 2005; Campos et al., 2019; Henrekson et al., 1997). Bridging the gap between the available national and scarce regional-level evidence, Monastiriotis et al. (2017) analyze the spatial effects of EU integration for Central and Eastern European (CEE) regions. Using an event-study approach, the authors find that the process of EU accession has particularly strengthened agglomeration forces in CEE countries favoring regions with a high market potential, industry concentration and regional specialization in increasing returns sectors.⁵

Brühlhart et al. (2012) and Brühlhart et al. (2018) analyze the wage and employment effects of trade liberalization caused by the fall of the iron curtain for Austrian border towns. Their empirical results indicate that improved access to Eastern markets has a positive impact on employment and nominal wages in these regions vis-à-vis the rest of the country. The results in Brühlhart et al. (2018) additionally suggest that larger cities benefit more strongly from the border shock in terms of wages, whereas smaller cities experience larger employment effects with a peak for towns with a population of around 150,000. Taken together, their evidence suggests that residents of medium-sized towns gain the most from a given opening of cross-border trade.

Brakman et al. (2012) focus on the population effects of EU integration in EU border regions. Analyzing data for 1457 regions and 2410 cities since 1973, the authors find evidence for positive population growth effects in border regions vis-à-vis non-border regions. This effect is significant at the regional and urban level within a 70 km radius from national borders. It holds for both sides of the integration border. Relatedly, Heider (2019) focusses on the population growth effects of German and Polish border town in the course of the EU enlargement in 2004. The author finds evidence for positive population growth effects for German but not for Polish border towns.

While the majority of studies thus reports positive population and economic effects of trade liberalization and economic integration in border regions of the EU (particularly in the EU15), there is also empirical evidence for insignificant or negative effects as, for instance, reported in Braakmann and Vogel (2011) or Marin (2011). Using data for firms located in East Germany close to Germany's eastern border, Braakmann and Vogel (2011) find no short-run employment effects of the EU enlargement in 2004 except for firms active in wholesale and retail trade, hotels, and restaurants. Negative wage effects are found for skilled workers in consulting, research, and related activities. This points to sector-specific effects in border regions subject to EU enlargement. Studying employment growth from the perspective of firms in Central and Eastern European Countries (CEECs), Serwicka et al. (2022) find a significant increase in foreign investment and employment growth after the 2004 EU enlargement.

While the prior literature has started to shed light on regional effects of EU integration for selected outcomes, mainly income levels and individual enlargement

⁵ Niebuhr (2008) adds to this finding by studying the income effects of EU enlargement in 2004 using a three-region economic geography model calibrated with pre-accession data for 1995–2000. The simulation results indicate that border regions realize higher integration benefits than non-border regions with the strongest effects found for Central and Eastern European (CEE) regions along the former external EU15 border.

waves, a comprehensive analysis of the complex spatial effects of EU integration over the last decades is still missing. This is what we are aiming for in the following.

3 Estimation setup

We use flexible DiD estimation and apply different specifications to robustly identify potential common (pooled) effects of EU enlargement together with structural heterogeneities related to i) differences across enlargement waves, ii) the timing of expected effects from EU enlargement (pooled and for individual waves) and iii) the spatial extent of effects. An overview of our estimation setup is outlined in Fig. 1. Our main treatment group are direct border regions defined as regions adjected to territorial border lines for one of the four different enlargement waves considered (1986, 1995, 2004 and 2007). To estimate the role of spatial spreading effects of EU enlargement, we then extend the treatment group to include indirect border regions defined as higher-order neighbors of direct border regions adjacent to the enlargement borders.

As shown in Fig. 1, we start estimating a panel specification that measures common average treatment effects across all enlargement waves and direct border regions in a pooled manner. In the light of institutional differences across regions and enlargement waves considered, we additionally run several regressions that test for effect differences between the individual enlargement waves to account for institutional differences associated with the enlargement and to distinguish between border regions in established and new member states and associated effects from widening and deepening integration, respectively. This type of heterogeneity is classified as structural heterogeneity in Fig. 1.

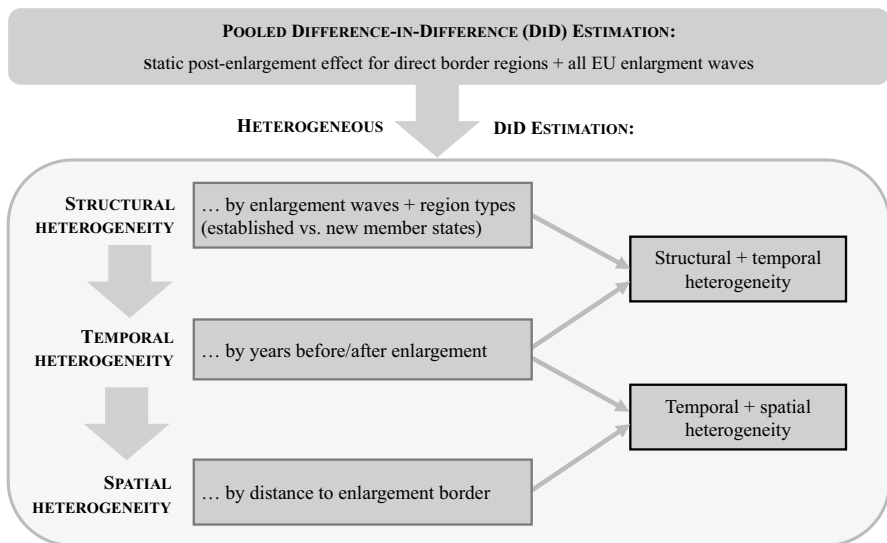


Fig. 1 Estimation setup for identification of integration effects from EU enlargement. Authors' figure

Similarly, the path towards integration and, according, the timing of integration effects before and after EU enlargement, may differ across enlargement waves. We classify this as temporal heterogeneity shown in Fig. 1. We capture temporal heterogeneity in treatment effects by switching from static DiD estimation, which identifies treatment effects on the basis of a strict definition of a pre- and a post-treatment period around the formal accession of new EU member countries, to dynamic DiD regressions. This allows us to account for leads and lags in the transmission process from EU enlargement to regional economic effects together with a staggered treatment start (in our case, the four different enlargement waves covered). The dynamic DiD approach is also referred to as ‘panel event study’ (see, e.g., Schmidheiny & Siegloch, 2019; Callaway & Sant’Anna, 2021; Goodman-Bacon, 2021; Sun & Abraham, 2021). As outlined in Borusyak & Javarel (2020) dynamic DiD estimates may particularly be helpful to overcome a potential estimation bias in the static baseline approach that arises if treatment effects have a significant temporal pattern. As shown in Fig. 1, we further account for spatial heterogeneity in effects and combinations of heterogeneity dimensions.

A common challenge to the different specifications shown in Fig. 1 relates to the potential problem of treatment endogeneity as the event of EU accession cannot be seen as a source of exogenous variation to the national economic performance, especially for new member states. The two-way link between national development and EU accession mainly stems from the fact that a good economic performance partly reflects a successful transition policy and the adoption of certain institutions linked to democratic governance and a functioning market economy, which in turn are a prerequisite for signing accession agreements. Here, we follow the argumentation in Brakman et al. (2012) referring to the fact that EU enlargement did not primarily target the economic development in border regions and, hence, that this macroeconomic enlargement ‘shock’ can still be seen as an exogenous source of variation for border regions.

To comprehensively capture the integration effects of EU enlargement, we use different outcomes such as the growth rate of GDP per capita, labor productivity, R&D and innovation (proxied through the number of patent applications per local population), employment and population growth, as well as night light emissions. These different measures shall capture the potential transmissions channels described in Sect. 2. In terms of model specification, we adapt a standard approach of regional growth models extended by the integration effect shown in Eq. (3). Formally, our baseline static DiD approach, which pools treatment effects across EU enlargement waves and region types, takes the following form

$$outcome_{it} = \beta' \mathbf{x}_{it} + \underbrace{\delta \left(d_i^{border} \times d_t^{EU} \right)}_{\left[\left(\frac{1}{DIST_i^\theta} \right) \times \Delta INT_t \right]} + \mu_i + (\xi_{c(i)} \times \lambda_t) + \varepsilon_{it}, \quad (4)$$

where $outcome_{it}$ denotes the (log-transformed) outcome level in region i at time t , which is specified as a function of (log-transformed) regional covariates (\mathbf{x}_{it}), region fixed effects (μ_i) and country-year fixed effects ($\xi_{c(i)} \times \lambda_t$), where $\xi_{c(i)}$ denote country fixed effects, with regions grouped to countries, and λ_t are time fixed effects. This multidimensional ‘fixed effects’ structure shall account for common and country-specific time trends such the creation of the Single market in 1992, the introduction

of the Euro currency in 1999, national business cycle movements or national policy interventions (Ahrend et al., 2017). In addition, we lean on the empirical identification approach used in Monastiriotis et al. (2017) and control for observable regional time-varying characteristics \mathbf{x}_{it} that are assumed to influence regional economic growth besides the pure enlargement effect. This likely increases the homogeneity of border and non-border regions in the light of structural differences across countries and thus works in favor of the parallel trend assumption of DiD models (Lechner, 2011).⁶

Our main regression parameter of interest is δ . It measures the relative border regional outcome effect of EU enlargement for the included DiD term ($d_i^{border} \times d_t^{EU}$), which is constructed as interaction term of a treatment group dummy for border regions (d_i^{border}) and a time dummy that measures the associated timing of EU enlargement (d_t^{EU}). Specifically, the interaction term takes a value of one from 1986 onwards for internal border regions affected by the second EU enlargement wave (and similarly for 1995, 2004 and 2007, respectively) and is zero before that year. If δ is found to be statistically significant and positive, this indicates that border regions along the internal territorial border between established and new member states have grown faster than other EU regions in the post-enlargement period. As shown in Eq. (4), the focus on border regions along the integration border as default treatment group (measured as those NUTS3 regions with territorial overlap to the integration border) implicitly uses a very high distance decay parameter θ as baseline specification.

While δ in Eq. (4) measures the integration effects of EU enlargement in border regions in a pooled fashion, results may be biased if underlying structural heterogeneity prevails. To capture heterogeneity across enlargement waves and region types, we can decompose the treatment dummies from Eq. (4) as

$$outcome_{it} = \beta' \mathbf{x}_{it} + \sum_{w=1}^4 \sum_{r=1}^2 \delta_{w,r} \left(d_i^{border_type(r)} \times d_t^{EU_wave(w)} \right) + \mu_i + (\xi_{c(i)} \times \lambda_t) + \varepsilon_{it} \quad (5)$$

which estimates individual treatment effects $\delta_{w,r}$ for each of the $w=1, \dots, 4$ EU enlargement waves and $r=1, 2$ border region types as being located in established or new EU member states.

As outlined in Fig. 1, we also consider two other sources of parameter heterogeneity: The first one relates to the dynamic nature of EU integration effects, and we move from static DiD estimations to the estimation of time-specific treatment effects in line with the literature on dynamic DiD or panel event studies. The specification of a flexible dynamic DiD estimator has the advantage that it accounts for potential lead and lag structures in the distribution of the economic

⁶ Further assumptions needed to ensure the consistency of the DiD estimator are i) exogeneity of the included control variables with regard the treatment and outcome, ii) common support implying that no other systematic factors are varying across geography and over time and iii) the absence of relevant interactions between the members of the population, which is also referred to as the stable unit treatment value assumption (SUTVA, see Rubin 1977). We use alternatively composed treatment groups to account for spatial spillovers that may affect the SUTVA.

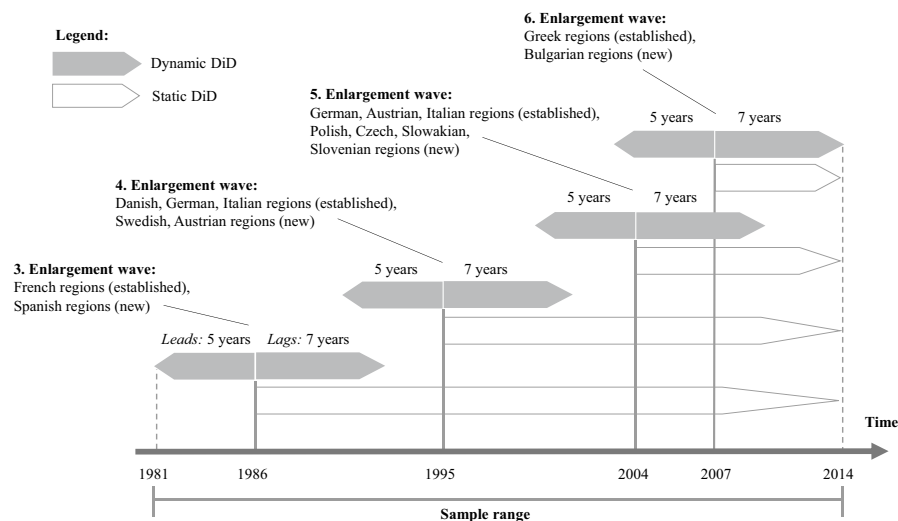


Fig. 2 Identification of treatment effects in static and dynamic DiD estimation. Authors' figure

integration effect on regional growth processes over time. The underlying assumption is that economic integration effects captured by the coefficient of the DiD term (δ) in Eq. (4) are not uniformly distributed over time. We capture temporal lead and lag effects as

$$outcome_{it} = \beta' x_{it} + \sum_{s=-N}^M \delta_s (d_i^{border} \times d_{t-s}^{EU}) + \mu_i + (\xi_{c(i)} \times \lambda_t) + \varepsilon_{it} \quad (6)$$

where d_{t-s}^{EU} is an indicator for event time s (time-since-event), meaning that the event date E_i^w , i.e., wave w of EU enlargement, took place s periods before period t measured in absolute calendar years, that is, $s = t - E_i^w$. For example, $s=2$ would mean that outcome in t is measured two years after EU enlargement. A separate term is included for each event time with $s \in \{-N, \dots, 0, \dots, M\}$ defining the maximum number of leads ($-N$) prior to treatment and lags (M) after treatment considered. The difference in data organization between the static and dynamic DiD estimation is summarized in Fig. 2.

Importantly, the dynamic DiD specification measure effects relative to treatment start E_i^w for each enlargement wave. The advantage of considering temporal heterogeneity is that all treated border regions receive an equal sample weight for the estimation of treatment effects even if they some regions are treated later than others (in absolute time). In addition, quantifying annual treatment effects around the timing of EU enlargement allows to test for the presence of Ashenfelter's (1978) dip, i.e., early anticipation effects. Borusyak & Javarel (2020) provide a discussion of consistency problems associated with static approaches when time dynamics in treatment effects is present. Beyond pooled dynamic estimation,

we also combine estimates accounting for structural and temporal heterogeneity as shown in Fig. 1.

We also account for the fact that economic integration may not only have an impact on direct border regions but also the broader geographical neighborhood of the enlargement border. Clarke (2017) has recently pointed out that the stable unit treatment value assumption (SUTVA) underlying DiD estimation may be too strong when dealing with regional data to estimate treatment effects. The reason is that territorial borders are porous and may give rise to spatial spillovers. In order to estimate unbiased treatment effects in the presence of spatial spreading effects, Clarke (2017) proposes the use of a weaker condition than SUTVA, which relies on the assumption that there exists at least some subset of units which are not affected by the treatment status of others. As it can be assumed that those economic actors living in regions close to treated (border) regions are able to either partially or fully access treatment, the subset of regions unaffected by the treatment can be determined by their (geographic, economic etc.) distance to treated units.

We can capture this spatial heterogeneity mechanism by including an extended set of treatment group dummies (d_i^k), where the index $k = g, \dots, G$ indicates the total number of treatment group dummies included in the empirical specification. Each of the K treatment groups thereby represents a slice of space, for instance, defined by a specific maximum geographical distance g relative to the enlargement border. This process can be seen as testing for incremental changes in economic integration effects over space, where the hypothesis from standard inter-country and inter-regional trade models is that a potential growth effect of economic integration decreases with further distance to the border (e.g., Eaton & Kortum, 2002). While the spatial disaggregation of the treatment group can be used for static estimations as in Eq. (5), we also combine spatial and temporal heterogeneity to identify incremental growth effects of EU integration over space and time as

$$outcome_{it} = \beta' \mathbf{x}_{it} + \sum_{s=-N}^M \sum_{k=g}^G \delta_{s,k} (d_i^k \times d_{t-s}) + \mu_i + (\xi_{c(i)} \times \lambda_t) + \varepsilon_{it} \quad (7)$$

Equation (7) shows a general (space-time) flexible DiD estimator that allows us to conduct a grid search for significant coefficients over slices of time and space to provide a comprehensive assessment of the border regional growth effects of EU enlargement.

4 Data and variables

We use 1289 NUTS3 regions (based on the NUTS2010 classification) for the EU-27 (including the UK but without Croatia) as units of observation and set the estimation period to 1981–2014. These data settings allow us to work on a finely granulated spatial level with a sufficiently long observation period to include a common set of leads and lags for all covered EU enlargement waves (except for night light emissions, which are only available from 1992 onwards). The data set is unbalanced since observations for East German regions and Central and Eastern European

regions are only recorded from 1991 onwards. However, this does not affect the maximum number of lag- and lead-terms used for the identification of treatment effects in the dynamic DiD specifications since those regions are only subject to later, i.e., the 2004 and 2007, EU enlargement waves.

We apply a comprehensive testing approach for different outcome variables to capture the potentially complex effects of EU integration on internal border regions. The set of outcome variables includes:⁷

$outcome_{it} = \{\text{GDP per capita, (sectoral) labor productivity, patents per capita, (sectoral) employment rates, regional population levels, night light emissions}\}.$

In all cases, we test for differences in (log-transformed) levels in these variables between the respective treatment and comparison groups. To give an example, in the case of per capita GDP we test for static and dynamic treatment effects by comparing per capita GDP levels across groups before and after EU enlargement. If we find significant differences in GDP levels, these can be interpreted as temporary short- to mid-run growth effects in the light of our fixed effects specifications and the theoretical arguments outlined in Sect. 2. We also provide sector-specific evidence for the development of productivity and the employment rate. The ERD data allow us to analyze effects separately for Agriculture (NACE Code: A), construction (C), industry (excl. construction (B-E), wholesale, retail, transport, accommodation & food services, information, and communication (G-J), financial & business services (K-N) and non-market services (O-U). Variable definitions and summary statistics are given in Table 1.

Geographical information on the EU's internal territorial borders is extracted from a shapefile on administrative units in the EU obtained from Eurostat. Direct border regions for the enlargement waves 1986, 1995, 2004 and 2007 are defined as those regions whose administrative boundaries intersect with a corresponding NUTS3 region from a new member state (and vice versa).^{8,9} By this definition, the enlargement in 2004 marks the biggest enlargement wave with 4.6% of all observed regions defined as direct border regions (Table 1), which corresponds to 2.9% of the population in the EU-27 in 2004. The 1995 enlargement wave covers 2.6% of the regions and 1.6% of the EU-27 population with the treatment groups of direct border regions being significantly smaller in 1986 (0.8%) and 2007 (0.7%).

⁷ While data for the variable night light emissions are collected as raw DMSP (Defense Meteorological Program) data from the Radiance Light Trends Application (lighttrends.lightpollutionmap.info) for 1992 onwards, data for all other variables are taken from the European Regional Database (ERD) provided by Cambridge Econometrics. The database provides a long time series of data for a fixed territorial status of the NUTS regions in Europe.

⁸ See Capello et al. (2018b) for a discussion of alternative methods to define border regions.

⁹ While almost all direct border regions can be uniquely assigned to a specific EU enlargement wave, in a total of four cases, i.e., two Austrian NUTS3 regions (at211, at313), one German region (de225) and one Italian region (it42), we observe that regions receive multiple treatments as being direct border regions in both 1995 and 2004. In these few cases, we assign treatment start to the first period in which the region has been exposed to the macro-institutional change of EU enlargement.

Table 1 Definitions and summary statistics for variables used in the empirical analysis for 1289 NUTS3 periods during 1981–2014

Variable	Description	Mean	S.D	Min	Max
GDPpc	Per capita GDP (in 1000 Euro, in 2005 prices)	20.114	11.070	1.083	188.679
Yprod	Labor productivity defined as gross value added (GVA) per employee (in 1000 Euro)	40.974	17.292	1.238	310.492
Yprod (agriculture)	> Agriculture (NACE Rev. 2, Sector code A)	22.777	35.174	0.002	2048.154
Yprod (construction)	> Construction sector (F)	37.553	18.350	0.209	420.587
Yprod (industry excl. construction)	> Industry excl. construction (B-E)	50.004	37.242	0.538	1157.735
Yprod (WR services, I&C)	> Wholesale, retail, transport, accommodation & food services, information, and communication (G-J)	35.210	15.872	1.044	299.409
Yprod (financial & business services)	> Financial & business services (K-N)	94.973	62.386	1.094	2028.800
Yprod (non-market services)	> Non-market services (O-U)	33.515	14.325	0.485	287.712
Patent	Patent applications per 1000 inhabitants in region	0.081	0.225	0	5.729
Emprate	Employment per population in region (1 = 100%)	0.433	0.108	0.121	1.224
Emprate (agriculture)	> Agriculture (NACE rev. 2, sector code A)	0.037	0.054	0	0.816
Emprate (construction)	> Construction sector (F)	0.033	0.013	0	0.188
Emprate (industry w/o. Construction)	> Industry excl. construction (B-E)	0.092	0.052	0.001	0.539
Emprate (WR services, I&C)	> Wholesale, retail, transport, accommodation & food services, information, and communication (G-J)	0.108	0.042	0.007	0.362
Emprate (financial & business services)	> Financial & business services (K-N)	0.046	0.033	0.000	0.397
Emprate (non-market services)	> Non-market services (O-U)	0.118	0.048	0.006	0.417
Empshare (agriculture)	Sectoral employment share for agriculture in total regional employment (1 = 100%)	0.090	0.116	0	0.920
Empshare (construction)	Sectoral employment share for construction in total regional employment (1 = 100%)	0.077	0.032	0	0.442
Empshare (industry excl. Construction)	Sectoral employment share for industry excl. construction (manufacturing sectors) in total regional employment (1 = 100%)	0.212	0.100	0.002	0.799
Empshare (WR services, I&C)	Sectoral employment share for wholesale and retail services, information, and communication in total regional employment (1 = 100%)	0.249	0.063	0.017	0.610
Empshare (financial & business services)	Sectoral employment share for financial and business services in total regional employment (1 = 100%)	0.101	0.054	0.000	0.726

Table 1 (continued)

Variable	Description	Mean	S.D	Min	Max
Empshare (non-market services)	Sectoral employment share for non-market services in total regional employment (1 = 100%)	0.272	0.081	0.022	0.644
Pop	Population level of NUTS3 region (in 1000 persons)	370.476	428.355	6.748	6418.41
Nlight	Night light emission level per NUTS3 region	17.251	15.536	0	63
Border regions (EU enlargement 1986)	Binary dummy for direct border regions of EU enlargement in 1986 (see Fig. 1)	0.008	0.088	0	1
Border regions (EU enlargement 1995)	Binary dummy for direct border regions of EU enlargement in 1995 (see Fig. 1)	0.026	0.160	0	1
Border regions (EU enlargement 2004)	Binary dummy for direct border regions of EU enlargement in 2004 (see Fig. 1)	0.046	0.209	0	1
Border regions (EU enlargement 2007)	Binary dummy for direct border regions of EU enlargement in 2007 (see Fig. 1)	0.007	0.083	0	1

Data at the level of NUTS3 regions; all data (except for night light emissions and patent applications) have been gathered from the European regional database (ERD) of Cambridge Econometrics (version 2017). Night light emissions have been extracted from: <https://lighttrends.lighthousemap.info>; patents extracted from the OECD RegPat database, see Maraut et al. (2008)

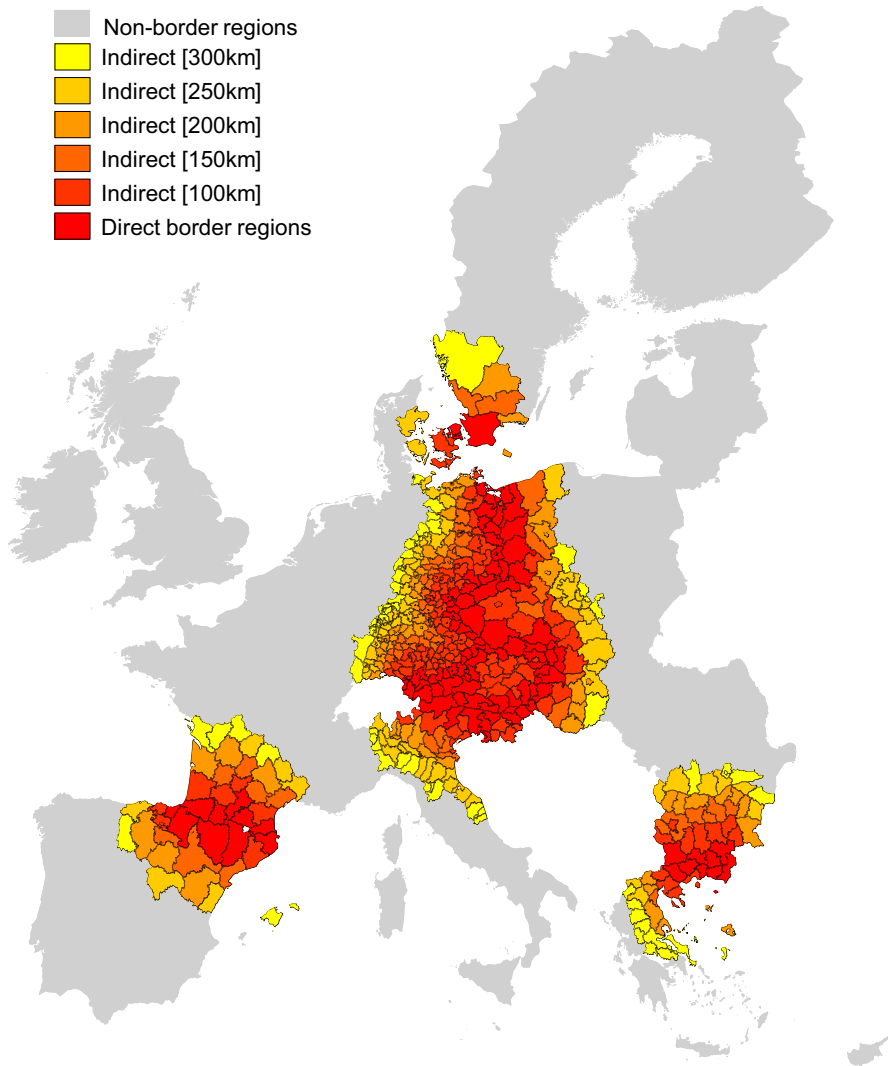


Fig. 3 Direct and indirect border regions for EU enlargement 1986, 1995, 2004 and 2007. Information on the territorial borders of EU-27 (including UK, without Croatia) NUTS3 regions has been obtained from the GISCO statistical unit dataset available at: <https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts>. Maps for border regions by EU enlargement wave and region type (established vs new) are provided in Figure A2 in the appendix

Given the temporal distribution of EU enlargement events throughout our sample period 1981–2014, we can estimate dynamic treatment effects for a maximum of five years prior to and seven years after the institutional changes for all four EU accession waves (except for night light emissions, which is only available from 1992

onwards).¹⁰ While it would be preferable to extend the data to periods beyond 2014 and also include Croatia's EU accession, there are also reasons to restrict the sample to 2014. Particularly, the EU migration crisis of 2015 and 2016 with substantial migration flows to border regions of several EU countries may bias at least all outcomes on "per capita" levels.

To measure the degree of spatial heterogeneity and neighborhood effects, we define indirect border regions based on their geographical distance from the border. To do so, we calculate for all regions not classified as direct border regions the geographical distance from the region's centroid to the closest location at the border. Using 50 km threshold distances g with $k = \{100 \text{ km}, 150 \text{ km}, \dots, 300 \text{ km}\}$, we then build additional treatment group dummies for regions within these 50 km distance belts from the border and test for spatially distributed integration effects (with $k=0$ km being direct border regions along the integration border).¹¹ A graphical overview of direct and indirect border regions for our sample of 1289 NUTS3 regions for all four EU enlargement waves is given in Fig. 3.

5 Empirical results

5.1 Baseline estimates

Table 2 reports the estimation output for our pooled static DiD specification according to Eq. (4). Accounting for the multidimensional 'fixed effects' structure including country-specific time trends as most general specification to account for latent time-varying confounding factors, three significant findings emerge: First, border regions relatively increase their labor productivity relative to non-border regions after treatment (Panel A) and have higher levels of night light emissions (Panel E) as a general measure for agglomeration effects (Mellander et al., 2015). While the specifications shown in columns (I) and (II) thereby use the average development of non-border regions in the sample as benchmark, the inclusion of country-specific time trends tightens the benchmark to non-border regions in the respective country of border regions considered. Effect size points to a roughly 4–5% relative increase in the levels of labor productivity and night light emissions. In terms of labor productivity, this corresponds to an approx. increase of 1500–2000 Euro per worker increase evaluated at the sample average for labor productivity of 40,800 Euro per worker in non-treated regions. Since night light emissions levels are measured on a relative scale between 0 and 63, the above reported percentage increase is difficult to interpret. However, we can illustrate its magnitude with the help of an example. Evaluated against the sample average of night light emissions in non-treated regions of about 20, a 4–5% increase means an additional night

¹⁰ For this reason, we also exclude the 1981 EU accession of Greece as additional treatment. Besides, by the time of EU accession, Greece did not share any territorial border with an established EU country so that no treatment group can be identified here.

¹¹ All distances are calculated based on the regions' centroids. We merge the first two slices of 50 km and 100 km distances as there are few indirect border regions with a maximum distance of 50 km to the enlargement border.

Table 2 Baseline treatment effects of EU enlargement for direct border regions

Specification	(I)	(II)	(III)
<i>Panel A: GDP per capita</i>			
EU enlargement	0.0475*** (0.01215)	0.0313** (0.01274)	0.0258** (0.01280)
R ²	0.65	0.78	0.79
Obs	42,012	42,012	41,974
<i>Panel B: labor productivity</i>			
EU enlargement	0.0719*** (0.01330)	0.0530*** (0.01350)	0.0492*** (0.01256)
R ²	0.52	0.72	0.74
Obs	42,012	42,012	41,974
<i>Panel C: patents per capita</i>			
EU enlargement	0.0281*** (0.00552)	0.0115** (0.00537)	0.0108** (0.00539)
R ²	0.32	0.37	0.37
Obs	42,012	42,012	41,974
<i>Panel D: employment rate</i>			
EU enlargement	−0.0252** (0.00998)	−0.0268*** (0.00979)	−0.0277*** (0.00948)
R ²	0.15	0.38	0.46
Obs	42,012	42,012	41,974
<i>Panel E: population</i>			
EU enlargement	−0.0086 (0.00822)	−0.0012 (0.00845)	−0.0064 (0.00784)
R ²	0.18	0.41	0.43
Obs	42,012	42,012	41,974
<i>Panel F: night light emissions</i>			
EU enlargement	0.0804*** (0.01620)	0.0474*** (0.01247)	0.0427*** (0.01203)
R ²	0.51	0.80	0.81
Obs	27,065	27,065	27,041
Region FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Time × Ctry FE	No	Yes	Yes
Regional controls	No	No	Yes

***, **, * = denote significance at the 1%, 5% and 10% critical level; robust standard errors clustered at the regional level are given in brackets. Sample period 1981–2014; 1289 NUTS3 regions. See Table 1 for details on outcome variable definitions. Variables are log transformed; in the case of patents per capita a box-cox transformation has been applied as log transformation did not meet the normality assumption. The difference in observations between columns (I), (II) and column (III) is due to missing values for regional controls (sectoral employment shares)

light emission level of 0.8–1. The latter corresponds to an accumulation of night light intensities for growing metropolitan regions such as Madrid and Hamburg of about

5–7 years. Panel C also reports an increase in regional patent applications per capita following EU enlargement, which points to the working of the technology channel ΔA_{it} of economic integration as outlined in Eq. (1). However, the development of the employment rate falls behind the overall EU-trend during the sample period by around 3%-points (for an average employment rate of approx. 43% in our data sample). No significant effects are observed for regional population development.

5.2 Structural heterogeneity

Differences in treatment effects may be driven by structural heterogeneity across the group of border regions and underlying compositional effects associated with region-sector combinations, which may not be fully captured by our set of regional controls (sectoral employment shares). To gain a deeper understanding of the underlying mechanisms at play, we disaggregate effects by enlargement waves (Panel A of Table 3) and country groups, that is, we distinguish between effects for border regions in old (established) and new member states for each EU enlargement wave (Panel B of Table 3) as outlined in Fig. 1. Especially the enlargement waves in 2004 and 2007 saw larger structural differences between established EU member countries and CEECs in their transition from planned to market economies after the fall of the iron curtain. This meant that per capita income levels, labor productivity and labor market parameters were significantly different in established EU member countries and newly joining CEECs in 2004 and 2007.

As Panel A shows, the estimated positive treatment effects for labor productivity and night light emissions are mainly driven by the 1995 and 2004 enlargement waves. Negative effects on the employment rate are similarly found for the 1995 and 2004 enlargement waves in particular. The latter also show a decline in population development and regional innovativeness in border regions. A positive development in terms of regional innovativeness measured through patents per capita is found for the 1986 enlargement wave. Panel B of Table 3 further indicates that estimated treatment effects not only differ across enlargement waves but are also determined by the regions' development level and, hence, the region's absorptive capacity at the timing of integration. Positive productivity effects of the 1995 and 2004 enlargement wave are captured by border regions in established EU countries. For these regions the 1995 enlargement also induced general agglomeration effects measured in terms of a positive population development and increases in night light emissions relative to non-border regions.

This effect is less significant for border regions in established EU member countries during the fifth enlargement wave in 2004. Relative population levels are observed to decline in the process of EU integration. On the other hand, border regions in new EU member states grow in terms of innovativeness (1986) and general agglomeration effects (night light emissions) in 2004 together with a strong increase in the employment rate by approximately 17% in 2007. The latter effect is likely driven by persistent wage differences between established EU countries (Greece) and the new member states Bulgaria and Romania who joint in 2007. Only during the 1986 EU enlargement do border regions in new member countries see a relative productivity increase and a improvements in innovativeness.

Table 3 Treatment effects for different EU enlargement waves and country groups

Specification	(I)	(II)	(III)	(IV)	(V)	(VI)
Outcome	GDP per capita	Labor productivity	Patents per capita	Employment rate	Population	Night light emissions
<i>Panel A: symmetric effects across border regions in established and new EU member states</i>						
Border region ×	0.0298	0.0326	0.0515***	0.0030	0.0091	n.a
Enlargement 1986	(0.01856)	(0.02164)	(0.01585)	(0.01378)	(0.03198)	
Border region ×	0.0324	0.0532**	0.0079	-0.0309**	0.0371***	0.0867***
Enlargement 1995	(0.02370)	(0.02201)	(0.0092)	(0.01235)	(0.00950)	(0.02896)
Border region ×	0.0207	0.0469***	0.0112	-0.0274***	-0.0409***	0.0326**
Enlargement 2004	(0.01593)	(0.01300)	(0.00825)	(0.01046)	(0.00956)	(0.01344)
Border region ×	-0.0319	-0.0049	-0.0215**	-0.0331	-0.0084	0.0250
Enlargement 2007	(0.03533)	(0.01310)	(0.01033)	(0.07558)	(0.02406)	(0.03904)
R ²	0.79	0.74	0.37	0.46	0.44	0.81
Obs	41,974	41,974	41,974	41,974	41,974	27,041
<i>Panel B: asymmetric effects across border regions in established and new EU member states</i>						
Border region (old) ×	0.0379	0.0031	0.0140	0.0134	0.0344	n.a
Enlargement 1986	(0.03066)	(0.02905)	(0.01384)	(0.01176)	(0.04181)	
Border region (old) ×	0.0764**	0.0978***	0.0109	-0.0268*	0.0308**	0.0969***
Enlargement 1995	(0.03176)	(0.02774)	(0.01045)	(0.01538)	(0.01248)	(0.03437)
Border region (old) ×	0.0370*	0.0543***	0.0166*	-0.0175	-0.0582***	0.0216
Enlargement 2004	(0.01944)	(0.01612)	(0.01002)	(0.01142)	(0.01218)	(0.01592)
Border region (old) ×	-0.0451	0.1085	-0.0229	-0.1778**	-0.0049	-0.0216
Enlargement 2007	(0.05206)	(0.10202)	(0.01648)	(0.08244)	(0.02981)	(0.04854)
Border region (new) ×	0.0214	0.0633***	0.0904***	-0.0078	-0.0171	n.a
Enlargement 1986	(0.01993)	(0.02683)	(0.01737)	(0.02473)	(0.04609)	
Border region (new) ×	-0.0526***	-0.0345	0.0023	-0.0371*	0.0487***	0.0666
Enlargement 1995	(0.02037)	(0.02488)	(0.01754)	(0.01998)	(0.01268)	(0.05150)

Table 3 (continued)

Specification	(I)	(II)	(III)	(IV)	(V)	(VI)
Outcome	GDP per capita	Labor productivity	Patents per capita	Employment rate	Population	Night light emissions
Border region (new) ×	−0.0341	0.0141	−0.0033	−0.0533**	0.0038	0.0558**
Enlargement 2004	(0.02425)	(0.02179)	(0.01275)	(0.02082)	(0.00735)	(0.02381)
Border region (new) ×	−0.013	−0.1738***	−0.0193**	0.1816***	−0.014	0.0865
Enlargement 2007	(0.04175)	(0.06490)	(0.00792)	(0.05834)	(0.03987)	(0.05343)
R ²	0.79	0.74	0.37	0.46	0.44	0.81
Obs	41,974	41,974	41,974	41,974	41,974	27,041
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE × Cry FE	Yes	Yes	Yes	Yes	Yes	Yes
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes

***, **, * = denote significance at the 1%, 5% and 10% critical level; robust standard errors clustered at the regional level are given in brackets. Sample period 1981–2014; 1289 NUTS3 regions. See Tables 1, 2 for further details on the definition of outcome variables. The terms (old) and (new) refer to border regions in established and new EU states, respectively

5.3 Temporal heterogeneity

Static treatment regressions may be biased if estimated effects show significant patterns of early anticipation or gradual phasing-in. Figure 4 therefore plots the results of a flexible DiD approach, which estimates yearly treatment effects relative to the timing of EU enlargement. The pre-enlargement year ($t - 1$) is used as a reference year against which pre- and post-enlargement effects are evaluated. The results largely confirm the static treatment effect estimates in terms of positive and significant effects for labor productivity and night light emissions. In addition, Panel A of Fig. 4 also reports a positive and significant relative GDP per capita development in EU internal border vis-à-vis non-border regions. Maximum effect size for the 7-year lag period considered is an GDP per capita increase of about 2% (compared to 2.6% in the baseline static estimation approach). Annual treatment effects for labor productivity levels are found to range between 2 and 4% during the first seven years after EU enlargement. The temporal distribution of GDP and productivity effects point at a levelling out of additional growth effects after approximately 5–7 years, which supports the view of a medium-term growth bonus associated with EU integration (Baldwin & Wyplosz, 2015; in't Veld, 2019).

Annual treatment effects prior to EU enlargement are statistically insignificant and do not point to early anticipation effects associated with potential confounding factors around treatment start. Effects turn significant with a time lag of 4–5 years after the enlargement event. This indicates that positive economic effects from economic integration need to unfold until they are fully visible in the regional economy. Likely reasons for this gradual phasing-in process are that associated private and public investment effects typically only show up over time (Breidenbach et al., 2019; Eberle et al., 2019). The difference between the statistically significant static estimation results for the development of patents per capita and the insignificant annual dynamic effects in the first seven years after enlargement underline the role of gradual phasing in effects and the time needed to transform regional innovation systems in treated regions (Isaksen & Tripl, 2016).

But not only did technology transformation and the adaption of production systems takes time, also labor market opening after EU enlargement followed a gradual pattern, particularly for the EU eastern enlargement waves in 2004 and 2007, determined, for instance, by the 2+3+2 regulation that restricted employment access in (some) incumbent EU member states by citizens of new EU member after an up to seven years transition period.¹² Also, the Schengen entry of new member countries followed EU accession with a temporal lag of about three years. Compared to the static baseline case, the flexible DiD estimates show negative, albeit marginally statistically insignificant effects of EU enlargement on the employment rate in internal border regions (Panel C, evaluated at 95% confidence intervals). Finally, the dynamic estimates confirm positive and statistically significant increases in night light activity as general agglomeration effect in border regions.

¹² For the case of the largest enlargement wave in 2004, only two states (Germany and Austria) have utilized the full 7-year duration of the 2+3+2 rule.

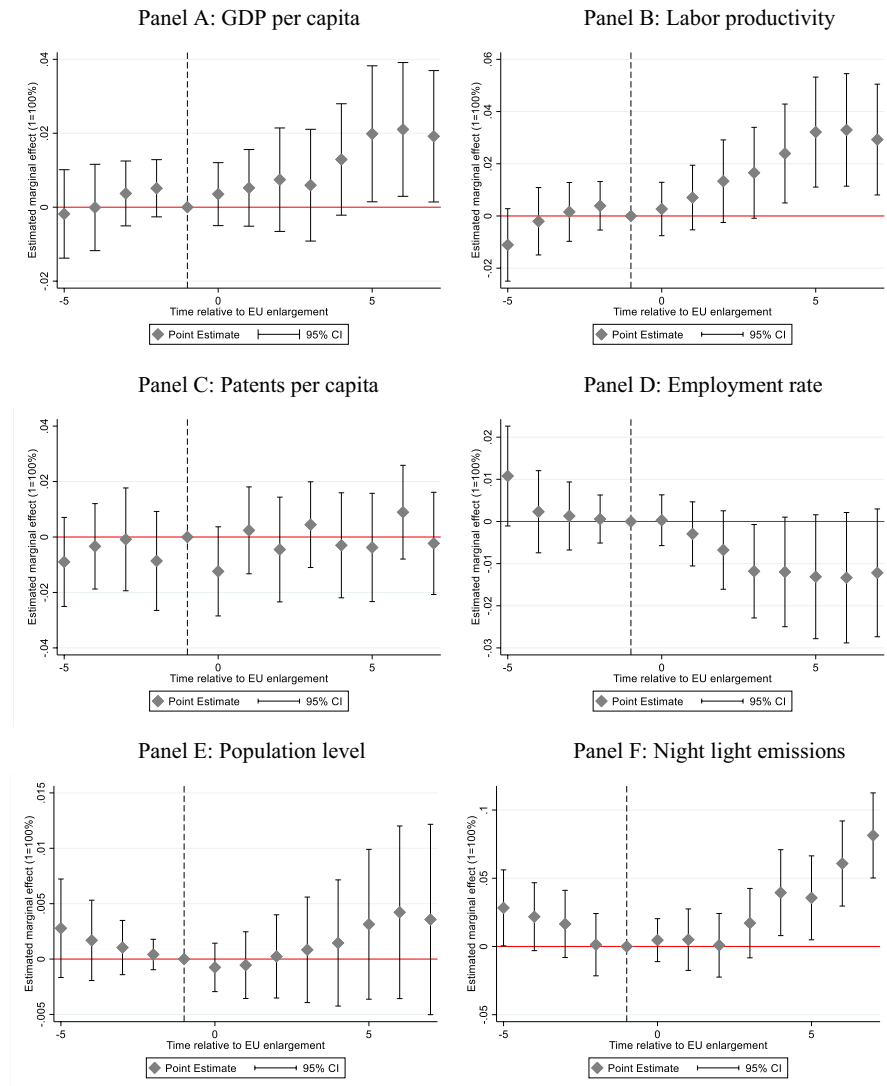


Fig. 4 Dynamic treatment effects of EU enlargement on border regions. Diamonds show point estimates for annual treatment effects of EU enlargement in border regions together with 95% confidence intervals (vertical lines; based on robust standard errors clustered at the regional level). The vertical dashed line indicates the pre-enlargement year ($t-1$) used a reference year against which pre- and post-enlargement effects are evaluated. Underlying flexible DiD estimates include region FE, year FE, country-year FE and regional controls. For further details see main text. Sample period 1981–2014; 1289 NUTS3 regions

5.4 Spatial heterogeneity

Table 4 reports the results from baseline DiD regressions, which add indirect border regions based on their geographical distance (in 50 km slices) to the enlargement border to the default treatment group as visualized in Fig. 1. Given that very few indirect border regions have a distance of 50 km to the enlargement border (while to not belong to the group of direct border regions), those regions have been merged with the 100 km slice of indirect border regions.

As the results show in Table 4 show, the inclusion of additional treatment dummies for indirect border regions does not alter the effect size found direct border regions (as reported in Table 2 and Fig. 4). In addition, we observe that indirect border regions experience treatment effects of the same direction but with diminishing size as the distance to the border increases. These spatial spreading effects are especially observed for GDP per capita, labor productivity, patents per capita and night light emissions. From 300 km onwards effects are absent except of the development in patents per capita. This observed decay in effects is in line with previous findings such as Brakman et al. (2012) and Brühlhart et al. (2018). The results thus point to the theoretical argument that increased market access in the process of EU integration is a major development factor for EU internal border regions. The negative effect on the employment rate is limited to direct border regions.

5.5 Extensions

As robustness tests, we run regressions combining heterogeneity dimensions. Table 5 summarizes dynamic DiD estimations by enlargement wave and region types. Underlying individual regressions can be found in the appendix. Border regions in established EU member countries benefit mostly in terms of GDP per capita and labor productivity increases but experience a relative decline in employment rates. A common result from Table 5 is that border regions both across enlargement waves and country groups gain through increase in agglomeration economies (night light emissions) and, with the exception of the 2004 enlargement in terms of population. The latter finding is in line with a border population effect of EU integration identified in Brakman et al. (2012).

Table 6 summarizes the main effects from dynamic DiD estimates for the spatial extent of integration effects. Effects enter as being positive or negative in the table if at least one yearly post-treatment effect is estimated to be statistically significant (evaluated at 95% confidence intervals). Brackets in Table 6 indicate that significant post-treatment effects are found but also that pre-treatment trends were present. The latter limit the validity of estimated treatment effects. Detailed visualizations of dynamic treatment effects by treatment group and outcome variable are given in the appendix.

The results summarized in Table 6 underline the presence of spatial spreading effects up to a maximum distance of 250 km to the integration border, which are mostly positive. One exception is the relative development of night light emissions point to negative spatial correlation between direct border regions and their

Table 4 Treatment effects of EU enlargement by spatial distance to enlargement border

Specification	(I)	(II)	(III)	(IV)	(V)	(VI)
Outcome	GDP per capita	Labor productivity	Patents per capita	Employment rate	Population	Night light emissions
Direct border	0.0543*** (0.01449)	0.0870*** (0.01413)	0.0241*** (0.00592)	-0.0318*** (0.01076)	-0.0043 (0.00868)	0.0746*** (0.01450)
Indirect (100 km)	0.0581*** (0.01329)	0.0735*** (0.01217)	0.0283*** (0.00551)	-0.0092 (0.00798)	0.0058 (0.00753)	0.0460*** (0.01142)
Indirect (150 km)	0.0512*** (0.01653)	0.0693*** (0.01596)	0.0200*** (0.00645)	-0.0102 (0.00937)	0.0013 (0.00877)	0.0670*** (0.01193)
Indirect (200 km)	0.0471*** (0.01220)	0.0631*** (0.01195)	0.0126** (0.00506)	-0.0057 (0.00886)	-0.0082 (0.00781)	0.0314*** (0.01199)
Indirect (250 km)	0.0266** (0.01039)	0.0401*** (0.01041)	0.0111** (0.00457)	-0.0038 (0.00730)	0.0031 (0.00680)	0.0385*** (0.01197)
Indirect (300 km)	0.0007 (0.01279)	0.0024 (0.01173)	0.0088* (0.00478)	0.0040 (0.00952)	0.0053 (0.00649)	0.0027 (0.01013)
R ²	0.79	0.74	0.38	0.46	0.43	0.81
Obs	41,974	41,974	41,974	41,974	41,974	27,041
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Time × Ctry FE	Yes	Yes	Yes	Yes	Yes	Yes
Regional controls	Yes	Yes	Yes	Yes	Yes	Yes

***, **, * = denote significance at the 1%, 5% and 10% critical level; robust standard errors clustered at the regional level are given in brackets. Sample period 1981–2014; 1289 NUTS3 regions. For a definition of indirect border regions based on kilometer distance to EU enlargement border, see main text. Tables 1, 2 provide for further details on the definition of outcome variables

Table 5 Summary of dynamic treatment effects by country group and enlargement wave

Dynamic treatment effects (By enlargement wave and border region type)	Positive		Negative	
	Established	New	Established	New
GDP per capita	1995, 2004			1995, 2004
Labor productivity	1995, 2004, 2007			
Patents per capita	1995	1986	2007	1995, 2007
Employment rate	1986	2007	(1995), 2007	1995
Population	1986, 1995	(1995), (2004)	(2004)	
Night light emissions	1995, 2004	1995, 2004, 2007	2007	

Reported are treatment groups by enlargement wave with a significant positive/negative treatment effect for at least one post-treatment period. Brackets indicate significant pre-treatment effects. Detailed regression results are plotted in the appendix. Underlying flexible DiD estimates include region FE, year FE, country-year FE and regional controls. For further details see main text. Sample period 1981–2014; 1289 NUTS3 regions

immediate hinterlands [100 km]. The latter pattern may point to some relocation effects taking place with economic activity moving out of the hinterlands closer to the enlargement border. Further, different from the development in direct border regions, the dynamic DiD estimates report some evidence for positive employment rate effects in the hinterlands of border regions.

Finally, we check for sector-specific patterns associated with positive (or negative) integration effects in border regions. These effects are summarized in Table 7 for labor productivity (Panel A) and employment rates (Panel B); underlying estimation results can be found in the appendix. Regarding labor productivity, we can see a clear differences in effects between border regions in established and new EU members.¹³ For the enlargement waves 1995 and 2004, for which we already observed an overall increase in labor productivity, we see that the aggregate effect is mainly driven by productivity growth in 1) industrial production (sector B-E; effect up to +12%) and 2) financial and business services (sector K-N; effect between +6 to +9%). Given the large share of these two sectors in the gross value added of most European countries, these two particular sector-specific effects largely determine the effect of the overall economy. At the same time, for these sectors we observe overall negative treatment effects on productivity in border regions of new member state (particularly for the 2007 enlargement wave).

While negative productivity developments in regions of new member states may point to business relocations among the most productive firms, a closer look at sector-specific employment rate shows that the effect is also driven by employment increases in border regions of new member states after the enlargement. Again, this effect is particularly significant for the 2007 enlargement wave and for the industrial

¹³ The comprehensive results including the coefficients and standard errors for the overview in Table 7 are shown in Table A1.

Table 6 Summary of dynamic treatment effects by distance to internal enlargement border

Dynamic treatment effects	Positive	Negative
<i>(By spatial distance to border)</i>		
GDP per capita	Direct border regions (Indirect border [100 km]) Indirect border [200 km] Indirect border [250 km]	
Labor productivity	Direct border regions (Indirect border [100 km]) Indirect border [200 km]	
Patents per capita	Indirect border [100 km] (Indirect border [150 km])	Indirect border [200 km]
Employment rate	(Indirect border [250 km])	Direct border regions
Population		Indirect border [200 km] (Indirect border [250 km]) (Indirect border [300 km])
Night light emissions	Direct border regions Indirect border [200 km] Indirect border [250 km]	(Indirect border [100 km])

Reported are treatment groups with a significant positive/negative treatment effect for at least one post-treatment period. Brackets indicate significant pre-treatment effects. Detailed regression results are plotted in the appendix. Underlying dynamic DiD estimates include region FE, year FE, country-year FE and regional controls. For further details see main text. Sample period 1981–2014; 1289 NUTS3 regions

sector together with wholesale & retail activity, transport, accommodation & food services, information and communication (sector G-J; effect up to + 20%).

Border regions in new EU member states associated with EU enlargement 1995 see a shift in employment towards industrial production and construction and away from service sector employment. Similarly, service sector employment declines in the aftermath of the 2004 EU enlargement in new member states. In line with standard trade theories, this specialization pattern indicates that sectors sensitive to spatial wage differences and changes in transport costs such as industrial production and the construction sector increase employment in border regions of new EU member states. Competition on local labor market may thereby reduce service sector employment. Apart from these significant effects, the results in Table 7 show a less clear sectoral picture for the development of the employment rate in border regions after EU enlargement.

Table 7 Disaggregated treatment effects for labor productivity and employment rate by sectors

Treatment effects	Positive		Negative	
(By enlargement wave and region type)	Established	New	Established	New
Labor productivity				
Sector A			1995	2007
Sector C	1995, 2004		2007	
Sector B-E	1995, 2004, 2007			2007
Sector G-J	1995			
Sector K-N	1995, 2004, 2007	1986	1986	2007
Sector O-U	1986, 1995, 2004			2007
Employment rate				
Sector A		2007	1986	1995
Sector C		1995	2004, 2007	
Sector B-E		1995, 2007		
Sector G-J		2007		2004
Sector K-N				1995, 2004
Sector O-U				1995, 2004, 2007

Reported are treatment groups with a significant positive/negative treatment effect at the 90% critical level. Detailed regression results are plotted in the appendix (Table A1). Underlying static DiD estimates by sectors include region FE, year FE, country-year FE and regional controls. For further details see main text. Sample period 1981–2014; 1289 NUTS3 regions. Sector codes (NACE, Rev. 2) are: A=agriculture; C=construction; B-E=industry excl. Construction; G-J=wholesale, retail, transport, accommodation & food services, information, and communication; K-N=financial & business services; O-U=non-market Services

6 Discussion and conclusion

This paper has studied the local economic effects of four EU enlargement waves in 1986, 1995, 2004 and 2007 using a comprehensive empirical evaluation design. Our particular emphasis on border regions as treated units is, on the one hand, motivated by theoretical considerations indicating that border regions are particularly exposed to EU enlargement and can be expected to significantly respond to this exogenous macro-institutional change. On the other hand, border regions are closely monitored by EU policy makers associated with the specific challenges of border regions. Border regions typically experience lower development levels than non-border regions in the light of their remoteness related to limited market access, public service provision etc. (European Commission). Estimating the integration effects of EU enlargement in border regions is thus challenging due to the complexity of forces at work. Here, we have taken up this ‘complexity’ challenge in our empirical identification approach by using multiple outcome variables and by applying flexible difference-in-difference estimation for EU-27 NUTS3 regions over the period 1981–2014. This allowed us to comprehensively and to robustly identify the treatment effects of EU enlargement.

Several distinct effects emerge: Overall, we find evidence for positive productivity and agglomeration effects in border regions subject to EU enlargement. However, effects vary by enlargement wave and country groups considered. While increases in overall socio-economic activity measured in terms of light night emissions are estimated as an overarching positive development trend for EU internal border regions, productivity gains are mostly experienced by border regions in established member states. This is contrasted by increases in employment rates in border regions of new member states particularly after the 2004 and 2007 enlargements. Our results hold across different methodological setups such as static and the dynamic DiD estimation.

In new member states, positive employment effects cover different sectors, most notably agriculture and industrial production. EU enlargement is found to exhibit positive spatial spreading effects to the hinterlands for direct border regions and is estimated to gradually phase in over time. The temporal distribution of treatment effects is likely due to the gradual change of institutions after EU accession (particularly in 2004 and 2007), which temporarily protected labor markets in established EU member countries from wage competition through the labor force of EU accession countries. Similarly, border impediments such as passport-free border crossing associated with the Schengen area were fully implemented some years after EU accession of CEECs.

The complexity of estimated regional effects poses some challenges to the working of regional policy support schemes to boost growth and cohesion in EU border regions as a means to reduce the prevailing structural differences in border regions compared to non-border regions. Beside the specific support of firms in border regions to access larger markets and transnational networks (Schäffler et al., 2017) or the adoption of proper institutions (Pinkovskiy, 2017), our results suggest that ongoing integration and a consequent facilitation of cross-border trade and mobility should be supported to accelerate economic development in border regions. Existing literature (see, e.g., Bosker et al., 2010; Kashiha et al., 2017; Capello et al., 2018a) shows that national borders still have strong impacts on trade and economic prosperity within the European Union and that border regions may be particularly affected by exogenous shocks such as the recent COVID-19 pandemic limiting international economic exchange (Capello et al., 2022). This leaves space for future integration efforts targeting the support to economic cooperation and development in border regions.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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