Short version:

A perfect storm and the natural endowments of trade-enabling infrastructure

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Abstract

This paper examines the importance of trade-enabling infrastructure for regional development using a natural experiment. In 1825, a storm caused the Agger Isthmus in northwestern Denmark to flood and form a shallow channel, which gradually deepened and became navigable by 1834. This enabled large ships to access an otherwise isolated region. The timing of the storm was random and the formation of the channel was unexpected, making it a great natural experiment. The paper uses census and trade data to show that before 1834 there was no ship traffic to and from the region, but after 1834 trade to the region increased dramatically. This triggered a process of adaptation which eventually caused a 22 per cent population growth in affected parishes compared to unaffected parishes. The paper also uses a panel of archaeological findings and the occurrence of a similar natural experiment 700 years prior in the same location to support its central finding: Natural endowments of trade-enabling infrastructure determine the location of prosperity.

Keywords: First-nature, trade, geography, infrastructure, natural experiment, Denmark
JEL codes: N01, N73, O18, R1

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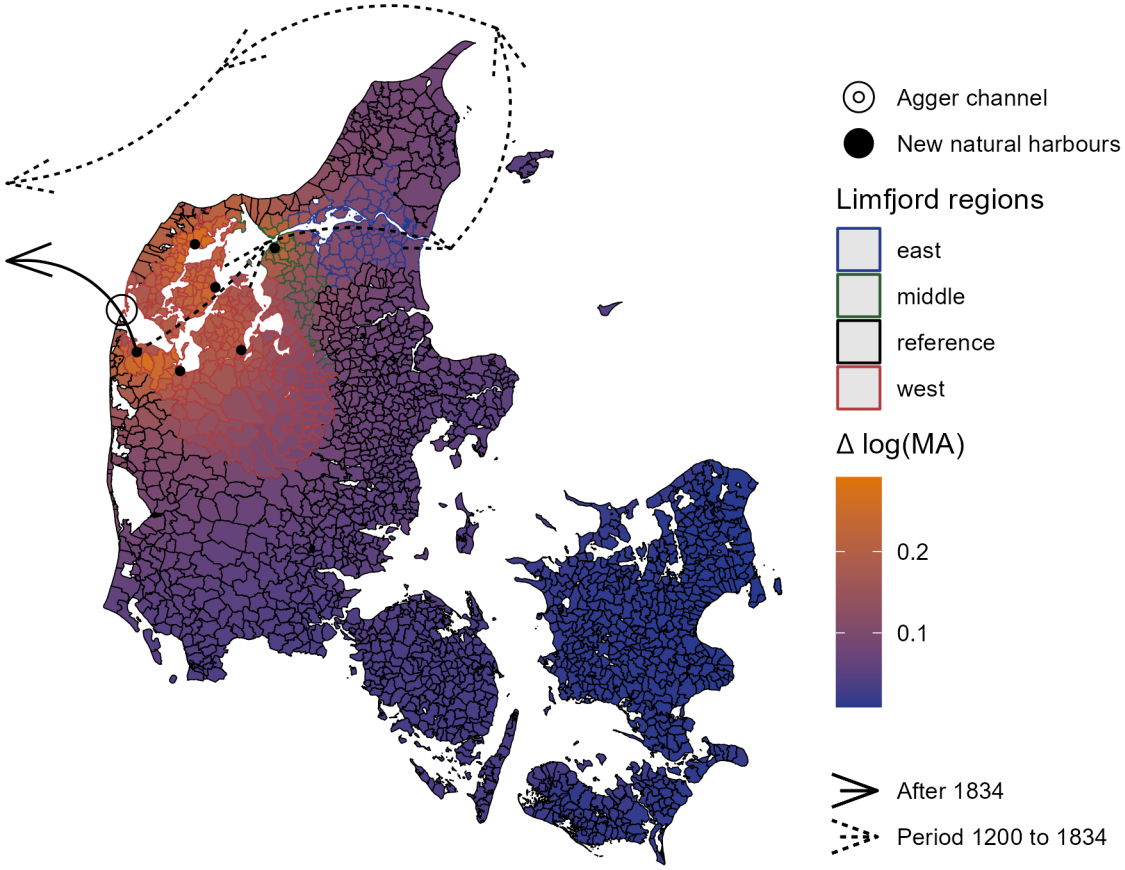
1 Introduction

This paper examines the importance of trade-enabling infrastructure for regional development using a natural experiment. In 1825, a storm caused the Agger Isthmus in northwestern Denmark to flood and form a shallow channel, which gradually deepened and became navigable by 1834. This enabled large ships to access an otherwise isolated region (see figure 1). The timing of the storm was random and the formation of the channel was unexpected, making it a great natural experiment. The paper uses census and trade data to show that before 1834 there was no ship traffic to and from the region, but after 1834 trade to the region increased dramatically. This triggered a process of adaptation which ultimately increased average population size by 22 per cent in affected parishes compared to unaffected parishes.

Using archaeological data, it is demonstrated that a similar but reversed effect took place in the same location in the 12th century. The channel that existed at that time closed due to gradual land rises. The loss of the channel caused a decline in the region's prosperity compared to its neighbours. Denmark of the 12th century is very different from its 19th-century counterpart in terms of technology, institutions, religion and culture. But the geographical shock is almost identical. As such, the similar result corroborates the external validity across different societies.

The present work contributes to two strands of literature exploring the role of market access for trade (Bakker et al., 2021; Rauch & Maurer, 2022) and the role of infrastructure in the 19th century in shaping the emerging industrial revolution (Berger & Enflo, 2017; Bogart et al., 2019; Donaldson & Hornbeck, 2016). One approach to identify the effects of trade is to rely on distances as instruments (Frankel & Romer, 1999). However, this requires time variation in distances to be valid (Rodriguez & Rodrik, 2001). This motivates the seemingly paradoxical hunt for time variation in distances, which can be seen as the motivation for much of this work, including the present paper. This paper is the first to use an entirely *natural* natural experiment to understand this relationship between connectivity and economy.

Figure 1: Map of Denmark



Notes: 1834 Agger Isthmus breach effects on shipping routes. Shows improved market access (fill colour) and Limfjord regions (border colour). Arrows indicate shipping routes before (dashed) and after (solid) the breach. Source: Borders from www.digdag.dk

2 Historical background

A fjord is a navigable inlet of water - typically found in northern Europe and in particular Scandinavia. The fjords acted as the Scandinavian highways in a time before modern transportation systems. Looking at an atlas, it is noticeable that many Scandinavian towns and cities, even today, are located in key positions on a fjord. The Lim-fjord is a body of water located in Northern Jutland, Denmark, at the heart of Scandinavia. Historically, the Limfjord had both an eastern and western opening, making it a safe passage for ships avoiding the rough sea of Skagerak between Denmark and Norway.

During the Viking era, the Limfjord became a hub for trade and exploration (Rasmussen, 1966). The last historical evidence of the use of a western opening was in 1085. King Canute IV of Denmark gathered his fleet in the Limfjord, to sail west and uphold his 'claim' to the English throne after his great uncle Canute 'the Great' (Spejlborg, 2012). The sailors and soldiers rebelled against Canute IV, the fleet never left Denmark and he was killed when seeking refuge in a church in 1086. Soon after, the channel would close because of gradual land-rises - an ongoing process since the last ice age (Christensen et al., 2004). After this, the local economy would stagnate and fall behind its more geographically fortunate neighbours for the next 700 years.

This changed in 1825 when a storm breached the narrow strip of land called the Agger Isthmus, connecting the Limfjord with the North Sea once again. The newly formed channel would become navigable in 1834. The breach of the Agger Isthmus had two main effects on the Limfjord region. *First*, the channel facilitated an influx of trade, which logistically overwhelmed the small market towns of the region (Balle et al., 1974, p. 154). *Secondly*, the influx of trade caused institutions and secondary infrastructure to adapt and improve, further boosting local prosperity. In 1841, the Limfjord market towns were granted international trading rights and soon after they would invest in the construction of new ports. The Frederick VII canal opened in 1861 and improved connectivity within the Limfjord. In 1852 the first Danish steamship started trading with England leaving from the Agger channel (Schovelin, 1891, p. 62; Trap et al., 1906). This and similar projects would all carry a large combined effect of of the original breach.

3 Data and empirical strategy

The effect of the Agger Channel can be calculated as the change in an outcome in the areas affected by the channel compared to the areas that are not affected by it, while adjusting for the fixed effects of each parish and year. This leads to the following event-study specification, as shown in equation 1.

$$\log(y_{it}) = \alpha_t + \alpha_i + \sum_{j=1787, j\neq 1801}^{1901} 1[t = j] Affected_i \beta_j + \varepsilon_{it} \tag{1}$$

Here, y_{it} represents the outcome for parish i at time t (e.g. population size or rate of archaeological findings). The estimated parameters β_j represent the additional effect on the outcome (e.g. relative population for $\log(Population)$) in comparison to the reference year 1801 and non-affected parishes. For the archaeological evidence, the regression iterates over years 750, 800, ..., 1500 and the reference year used is 1000. This comparison provides a measure of the causal effect of the channel. That is, it represents the difference between what would have happened if the channel opened or closed versus a scenario in which it did not.

The population size at the parish level is obtained from the digitised version of the Danish censuses. The data also contains 3.7 million manually-labelled HISCO occupations for some observations (Clausen, 2015). I used these labels to train a machine learning algorithm to label the remaining observations, which yields individual level occupational categories for all 12.4 million census records 1787-1901. The top 100 most frequent occupations were manually classified as belonging to the fishing or manufacturing industries.

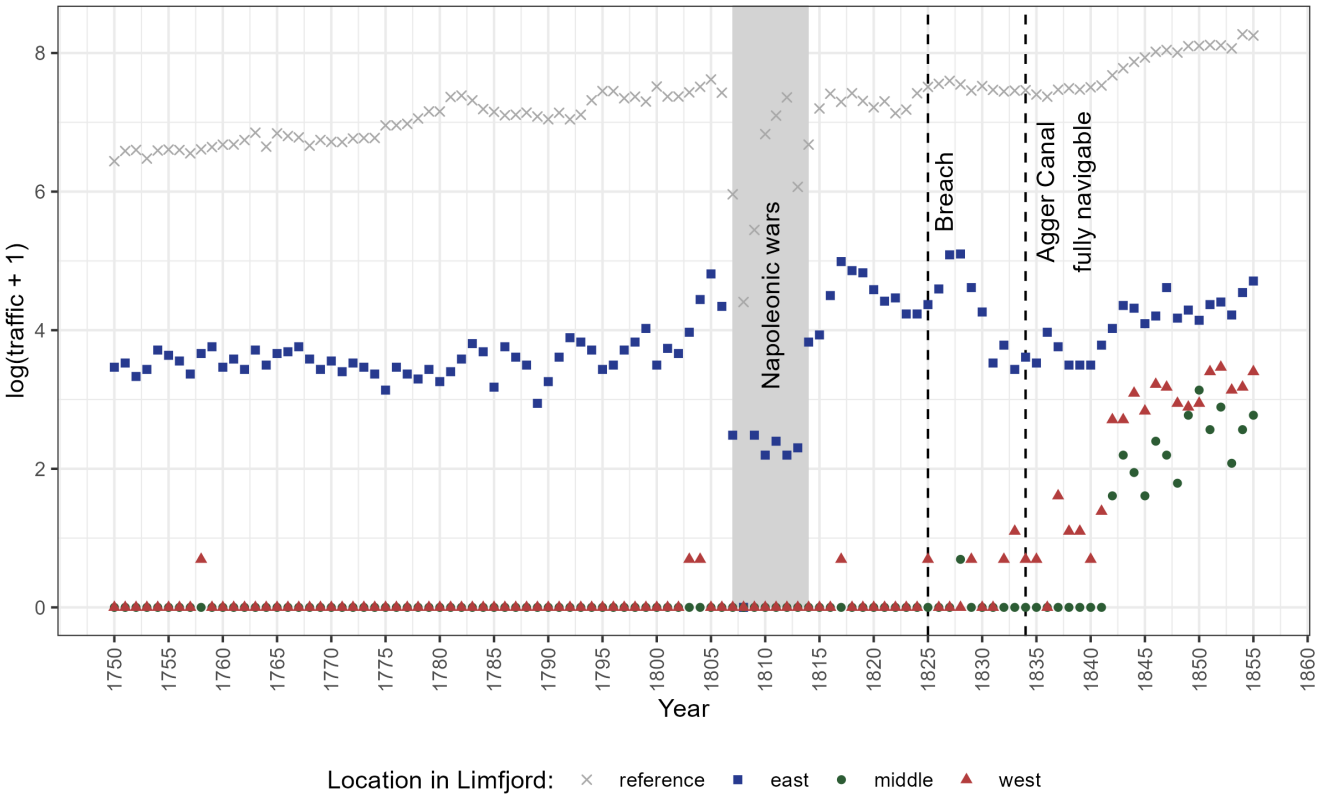
Two approaches are used to measure the regions affected by the channel. First, parishes located in the Western Limfjord are assumed to be affected by the shock. This aligns with the historical background, as these locations were endowed with a convenient western channel after 1834 and before 1086. Secondly, a theoretically motivated measure based on market access is derived in the spirit of Harris (1954), which is a standard approach in the economic geography literature (Donaldson & Hornbeck, 2016; Redding & Sturm, 2008).[1] Both measures are illustrated in Figure 1.

Archaeological data is obtained from the Danish registry of archaeological sites.[2] The data is geo-referenced with an exact coordinate, categorized by type and dated to a certain interval of years. The archaeological dating of the site is then used to construct a panel of the probability at which coin findings were likely generated in each parish in the period 750 CE to 1500 CE. The presented results are robust to using various other types of archaeological findings as the outcome, such as buildings, bricks, trade sites, etc.

[1] The presented results are robust to different control groups and theoretically feasible parameters (α, θ) of the Market Access function $MA_i = \sum_{\forall j} CostDistance(\alpha, i, j)^{-\theta}$. More details are available upon request.

[2] Available at www.kulturarv.dk

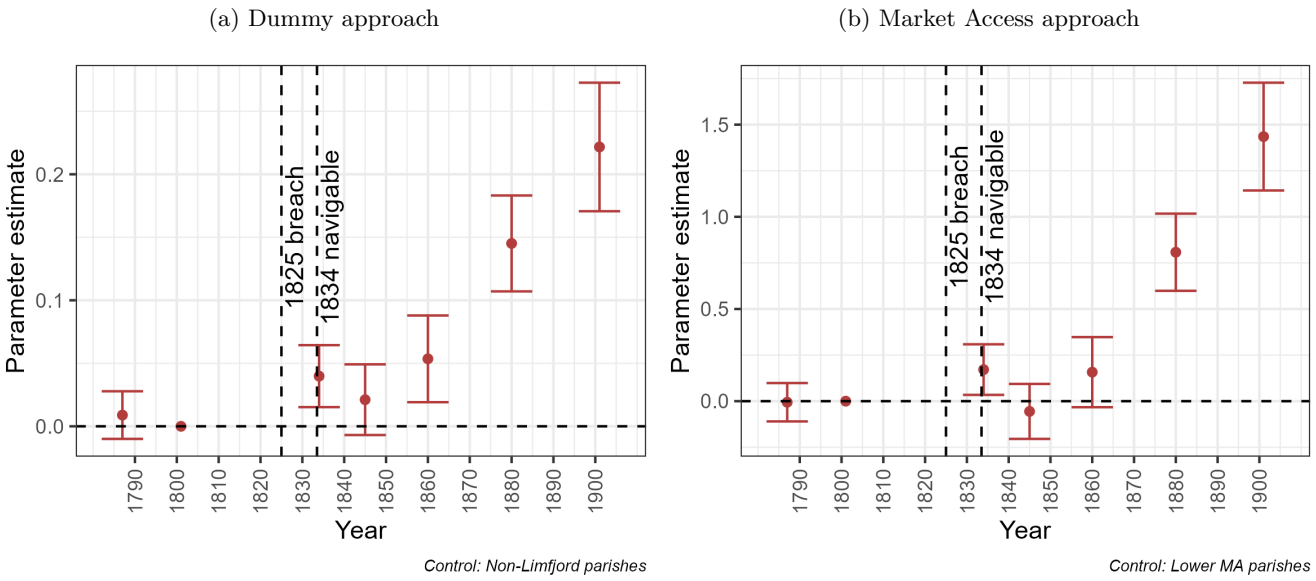
Figure 2: Limfjord Ship Traffic



Notes: Plot of log of sum of ships passing Elsinor to Limfjord regions. This shows a sudden increase in trade to West and Middle Limfjord after 1834.

Source: Sound Toll Register Online (Veluwenkamp and Woude, 2009).

Figure 3: Results for population



Notes: These plots display the impact of the 1834 Agger Channel breach on population growth. Panel (a): The estimated causal effect shows a 4 per cent increase in affected parishes in 1834, growing to 22 per cent in 1901. Panel (b): Measured in terms of market access improvement this corresponds to 0.17 and 1.44.
Source: Danish Demographic Database.

4 Results, mechanisms and external validity

After the channel became navigable there was suddenly a flow of traffic to the West and Middle Limfjord region as recorded in the Sound Toll Register. There was none before. This is documented in figure 2. Figure 3 shows the effect of being affected by the Agger channel on population. The first panel uses a dummy for being in the western Limfjord as a measure of being affected. The second panel defines being affected as the change in market access caused by the channel. Already by 1834, the Agger channel had caused moderate population growth. The affected West Limfjord region had a 4% larger population as compared to what would be expected without the channel. This corresponds to an elasticity of Market Access of 0.17, meaning that a 1% increase in market access would lead to an increase in population of 0.17%. However, the effect intensifies dramatically between 1845 and 1860. By 1901 those parishes that were affected by the channel had seen 22% more population growth than the rest of the country. This corresponds to an elasticity of market access of 1.44.

But what carried this effect from ship access to population growth? There are two principal uses of ships: fishing and market access (trade). Using the newly available occupational information in the censuses, it is possible to test these mechanisms. Today, Thyborøn, located just at the opening of the channel, is one of Denmark's main fishing ports, accounting for 25% of the Danish catch in 2021.[3] If an emerging fishing industry was the carrier of the effect, then the effect on population would disappear when this mediator is controlled for.[4] If in contrast, the effect is primarily carried by market access, then there should be a corresponding increase in the production of goods, which would imply an increase in manufacturing jobs. Figure 4 shows the results of this. Note that the rise of manufacturing jobs does indeed almost fully account for the population growth experienced by this region (panel b), while this is not the case for fishing. The increase in manufacturing carried the effect of the channel.

Two classical concerns remain: Growth or reallocation and external validity. Did the channel really cause population growth or was it simply prosperity moving to this region from elsewhere? Furthermore, is this effect replicable outside the limited scope of 19th-century north-western Denmark? The first can also be addressed with census data. This contains a string which describes the birthplace of any person in the census years 1845 and forward. The share of people born in a different county is then used as the outcome instead of the log of population. This is a measure of the net in-migration. Figure 5 (panel a) shows that for the west Limfjord parishes, the amount of people born in a different county grew more than other parishes - at least from 1845 and forward. This shows that a growing share of the population growth of the west Limfjord came from internal migration.

For the case of external validity the optimal setup would be if it was possible to repeat the exact same shock to geography but in an entirely different country and time. Denmark of the 12th century is in all

[3] Data extracted from Minsistry of Food & Fisheries (2022).

[4] Specifically a control of the form $\sum_{j=1787, j\neq 1801}^{1901} 1[t=j] Affected_i \times \log(Occupation_{it}+1)\delta_j$ is included in equation 1.

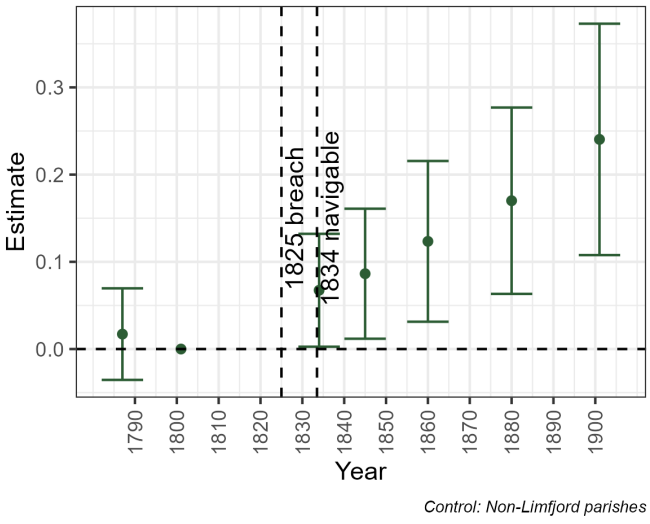
important ways that comparison. Figure 5 (panel b) shows a large drop in coin findings associated with western Limfjord parishes, which are attributable to the years after the previous channel closed. The effect peaks at around 8% fewer coins being generated than otherwise expected. This indicates that the deteriorated market access after the 12th century caused lower economic activity of the western Limfjord of a significant magnitude.

5 Conclusion

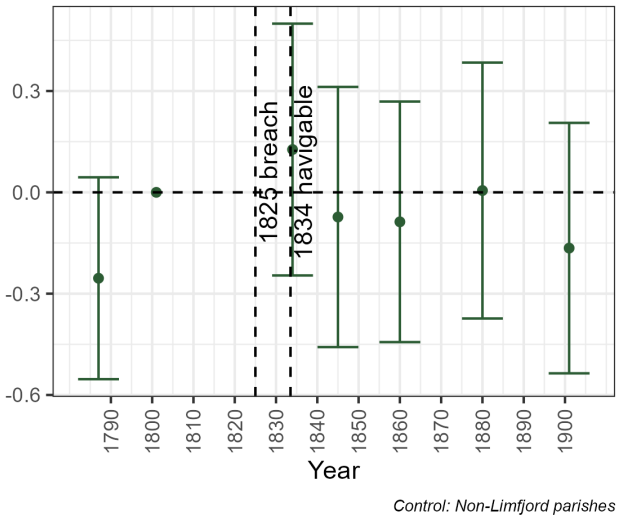
Waterways, by determining market access, have a key role in determining the location of economic activity. We are all prisoners of geography, but what happens when the shackles are loosened? The unexpected emergence of the Agger channel in Denmark's western Limfjord region in the early 19th century serves as a useful example of this phenomenon. The channel brought new trade opportunities and revitalized a region that had been lagging behind its neighbours for centuries. However, the full benefits of the channel's improved connectivity were not realized until the local region adapted to the new opportunities. To fully grasp the regional distribution of prosperity, it is crucial to understand both geography and institutions, and how their interplay shapes economic outcomes. By studying events like the one described in this paper, we can gain new and deeper insights into the complex relationship between geography, market access, and society.

Figure 4: Mediation results

(a) Effect to population controlled for increase in fishermen

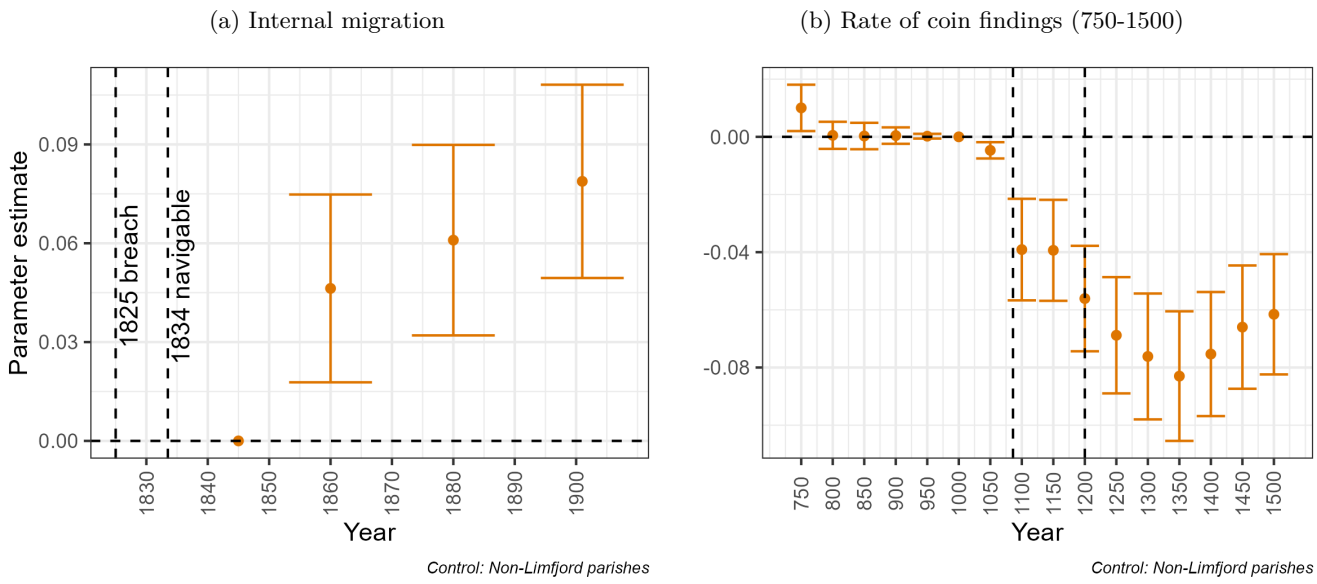


(b) Effect to population controlled for increase in manufacturing occupations



Notes: These plots show the results of controlling for the impact of the Agger channel on population growth. In panel (a), when controlling for the increase in fishermen, the population growth remains similar. Panel (b) shows that when controlling for the effect on manufacturing, there is little remaining effect of the channel on population. Source: Danish Demographic Database and own AI-labelling of occupation.

Figure 5: Migration and archaeological evidence



Notes: Panel (a) shows the effect increase in internal migration in the west Limfjord region after the Agger channel was introduced. This is measured as the share of people born in a different county than their current residency. Data only available from 1845 and forward. Panel (b) shows the effect on the rate of coin findings after the previous channel closed between 1086 and 1208 (as indicated by the dotted vertical lines).
Source: Danish Demographic Database, 'Fund of Fortidsminder' database

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