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Divergent futures and structural change: Regional economic scenarios and resilience for trade shocks

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ABSTRACT

This paper develops quantitative regional economic scenarios for Dutch NUTS2 provinces, with varying global structural conditions, over 2020–2060 to assess regional economic resilience. Using panel econometric estimations combined with the EU-EMS recursive-dynamic spatial computable general equilibrium model, we translate scenario narratives, grounded in the SSP1 and SSP3 global pathways, into internally consistent projections of production value, employment, and sectoral specialization. The high-growth scenario assumes continued globalization and knowledge-intensive service expansion, whereas the low-growth scenario assumes deglobalization, reshoring of industrial production, and demographic stagnation. While the Dutch economy grows under both scenarios, growth falls substantially below the historical average and its spatial distribution diverges sharply. The high-growth scenario deepens the urban–peripheral divide by concentrating knowledge-intensive activity in the Randstad whereas the low-growth scenario revitalises industrial production in Noord-Brabant and Limburg through reshoring. The northern peripheral provinces face negative employment growth regardless of scenario, pointing to structural vulnerabilities that persist across both futures. The findings argue for adaptive, geographically differentiated resilience strategies rather than static policy commitments to a single structural future.

1. Introduction

Over the past three decades, high-income countries like the Netherlands have experienced significant transformations in industrial production patterns, notably characterized by the relocation of consumer product manufacturing to lower-wage countries and a concurrent specialization in high-value manufacturing and knowledge-intensive services. This structural shift is part of a broader pattern of deindustrialization observed across Western economies since the late twentieth century, driven by rising productivity in manufacturing, changing demand structures, and intensifying international competition (Rodrik, 2016). Globalization and technological advancements have accelerated the international fragmentation of production, with offshoring emerging as a dominant force in reshaping the industrial geography of advanced economies (Timmer et al., 2014). This has resulted in a fundamental restructuring of these economies. High-value manufacturing sectors, such as chemical products, pharmaceuticals, and high-end electrical equipment, have thrived alongside knowledge-intensive services like information and communication technologies (Friesenbichler and Kuegler, 2022).

The spatial concentration of knowledge-intensive business services has reinforced urban hierarchies, with metropolitan regions increasingly functioning as nodes for high-skill service activities (Meliciani and Savona, 2015). These developments have gone hand in hand with an expanding service economy and increasing regional differentiation in sectoral structures (Eurostat/European Commission, 2014). Meanwhile, current geopolitical tensions and shifts towards trade barriers and industrial policy have resulted in increasing uncertainty about long-term economic development and continuation of past trends in the future (IMF, 2026). As a result, regions are embedded in global value chains in markedly different ways, making them unevenly exposed to external economic shocks. This uneven exposure has been extensively documented in the literature: Autor et al. (2016) show how regional labor markets specializing in industries facing import competition suffer persistent employment and wage losses, while Timmer et al. (2014) demonstrate that value-added capture within global value chains is

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highly differentiated across countries and sectors.

Against this background, this paper aims to construct consistent regional economic scenarios for the Netherlands, based on coherent macro-economic storylines. These storylines describe alternative long-run development pathways that differ in terms of globalization, trade frictions, specialization patterns, and demographic dynamics. Rather than treating regional outcomes as simple downscaling of national trends, the scenarios explicitly account for structural change at the regional level, providing internally consistent baselines that can serve as reference points for policy analysis. The comparison of these scenarios are used to analyze the economic resilience of the Dutch regional economies.

To achieve this, the paper applies a novel methodology to model structural change at the regional economic level. Qualitative scenario narratives and macroeconomic projections are translated into quantitative regional and sector specific outcomes using a regional computable general equilibrium (CGE) model, EU-EMS. Econometric analysis is used to calibrate long-run regional sectoral composition, while demographic projections and global drivers are consistently coupled to regional dynamics. This approach allows structural transformation—across sectors, regions, and trade relations—to emerge endogenously over time, rather than being imposed exogenously. As a result, the paper offers two alternative future pathways that explicitly differ in trade frictions and specialization trends.

Comparing the two scenarios provides a framework for assessing regional economic resilience under contrasting structural conditions. The high-growth scenario, characterized by continued globalization and specialization in knowledge-intensive services, exposes peripheral and industrially-oriented provinces to sustained deindustrialization and slow employment growth, while creating growth management pressures in the most urbanized part of the Netherlands, the Randstad. The low-growth scenario, characterized by deglobalization, higher trade frictions, and a shift in trade preferences toward own-bloc supply chains, creates conditions for the reshoring of industrial production and revitalises Noord-Brabant and Limburg, but leaves northern peripheral provinces, namely Groningen, Friesland, and Drenthe, facing negative employment growth regardless of the global trajectory.

Rather than simulating discrete shock events, the scenarios represent alternative structural trajectories in which the cumulative effects of geopolitical reorientation, technological change, and demographic shifts manifest as divergent long-run growth paths. The resilience implications are therefore assessed comparatively, by examining which regional economies are better or worse positioned under each structural configuration, rather than by tracing short-run recovery dynamics following a discrete event.

These results carry concrete implications for regional resilience policy. Investments in housing, infrastructure, and labor market capacity in the Randstad metropolitan regions are warranted under both scenarios, as knowledge-intensive activity concentrates there irrespective of the global growth path. By contrast, investments in industrial retraining and manufacturing infrastructure in Noord-Brabant and Limburg are strongly scenario-contingent: highly valuable under low growth but carrying opportunity costs under high growth. For the northern peripheral provinces, neither scenario offers an automatic recovery path, pointing to the need for targeted structural interventions that do not depend on favorable global conditions materialising. These findings argue for adaptive policy frameworks, designed to be adjusted as global trade and technological conditions evolve, rather than static long-term commitments. The baseline scenarios developed in this paper provide the quantitative foundation for such frameworks, supporting strategic thinking on industrial policy, regional labor markets, and economic resilience in an increasingly uncertain global environment.

The article is structured as follows. Section 2 reviews the literature on long-term economic scenarios and regional CGE modeling, discussing the applicability of spatial CGE models and their relevance for regional economic analysis and resilience. Section 3 details the methodology, beginning with the conceptual framework and scenario storylines that define the qualitative drivers underlying the two WLO scenarios. It then describes the EU-EMS model structure and the data, calibration, and historical validation procedures, before presenting the quantitative operationalization of the scenarios. Section 4 presents the main results, covering both sectoral and regional developments under the WLO High and Low scenarios. Section 5 concludes with final remarks and policy implications.

2. Literature review

Long-term economic scenarios play a central role in policy analysis by providing coherent baseline pathways against which policy interventions can be evaluated. Such scenarios should not be seen as forecasts but as internally consistent representations of how economies might evolve in the absence of new policy measures. They define the structural, technological, demographic, and trade conditions under which counterfactual policy simulations can be conducted (Dellink et al., 2020). Because many policy challengessuch as climate transition, industrial restructuring, or strategic autonomy,unfold over decades, short-term projections are insufficient to capture their full economic implications. Long-term scenarios allow policymakers to assess how today's decisions interact with gradual structural change, accumulation of capital and skills, and evolving international economic conditions.

Moreover, long-term scenarios are particularly valuable when future developments are uncertain and cannot be extrapolated from historical trends alone. By explicitly articulating alternative macroeconomic storylines scenario analysis helps explore a range of plausible futures rather than a single expected outcome. This makes scenarios a key tool for stress-testing policies and for identifying robust strategies that perform well across different long-run developments.

While long-term scenarios are often constructed at the national or global level, there is increasing recognition that such aggregate perspectives mask substantial heterogeneity and dynamics within countries. The dynamics of international trade, regional wage disparities, and the availability of labor and capital lead to evolving patterns of regional specialization, making regional economies differently exposed to structural adjustment processes (Neffke, Henning, and Boschma, 2011). This and the way in which regional economies are positioned in global value chains in particular makes regions to a varying degree vulnerable to shocks in international trade or increased protectionism, as shown by McCann et al., (2026).

Whereas in the previous years *Smart Specialization Strategies* have been drawn up by the EU such that regions can become more specialized in knowledge-intensive, high value-added processes (see e.g., Balland et al., 2019, McCann and Ortega-Argilés, 2015), a new policy objective has gained attention: increasing regional resilience. This can be defined as the ability of regional economies to bounce back after a shock, for example caused by trade wars or supply chain disruptions (see Martin, 2012, Boschma, 2015). In recent years, various analyzes of regional economic resilience and trade disruptions have been studied, see e.g., He et al. (2024), den Nijs and Thissen (2026).

As a result, national-level scenarios may fail to capture region-specific vulnerabilities and opportunities. The combination of sectoral detail within regions is equally important: shifts in high-value manufacturing, energy-intensive industries, or knowledge-intensive services have distinct implications for regional employment, trade exposure, and resilience. Long-term scenarios that are both regional and sector-specific therefore provide a more realistic foundation for assessing policy trade-offs and distributional effects.

By comparing alternative scenarios, it is possible to assess how different structural configurations affect regional vulnerability and adaptive capacity. Regions with highly specialized, trade-exposed sectors may benefit from efficiency gains and globalization under some scenarios, while facing greater risks under others. Scenario-based

studies thus provide insights into the conditions under which regions are more or less resilient, and how policy can influence long-term adjustment paths. This paper provides a novel way to use such long-term scenarios to assess regional resilience for trade shocks.

For constructing such region-sector-specific long-term scenarios, in most cases Spatial Computable General Equilibrium models (CGE) are used. Examples of such models are the RHOMOLO model, the EU-EMS model (used in this study), and the TERM model, but various models exists for specific countries or regions. While all three models share the SCGE family's core Armington trade structure and market-clearing logic, they differ in important respects relevant to this study.

RHOMOLO (Christensen, 2022) is a static or comparative-static model covering EU NUTS2 regions, designed primarily for cohesion policy impact assessment; it does not simulate multi-decade structural change endogenously. TERM (Horridge, 2012) is a highly disaggregated bottom-up model that achieves spatial granularity through extensive input-output detail, but is typically applied in a single-period comparative-static framework for national economies rather than in recursive-dynamic long-run projections. EU-EMS, by contrast, is recursive-dynamic, integrating capital accumulation, endogenous TFP growth, skill-differentiated labor markets, and a Linear Expenditure System (LES) for household demand within a multi-regional structure explicitly calibrated to NUTS2 level. This recursive-dynamic architecture, combined with the econometric estimation of regional TFP trajectories described in Section 3, makes EU-EMS particularly suited for the long-run structural change analysis undertaken in this paper.

Recent applications of spatial CGEs to questions regarding regional infrastructure and trade illustrate the usefulness of the method: Ishikura and Yokoyama (2022) assess ring road impacts in the Greater Tokyo Area; Somé and Zidouemba (2025) trace how trade intermediaries shape the transmission of global shocks to regional economies in Burkina Faso; and Kim et al. (2024) apply a dynamic housing-CGE framework to South Korean housing markets. At the European level, Almström et al. (2024) use an SCGE model to assess regional sectoral effects of a Swedish carbon tax increase, while Almazán-Gómez et al. (2025) evaluate the regional economic impacts of the Next Generation EU recovery plan across Spanish regions.

Dellink et al. (2020) identifies several best practices and methodological approaches for constructing long-term baselines, where a robust baseline typically combines multiple core components: demographic and macroeconomic drivers, technological change, energy and environmental dynamics, and trade and policy assumptions. These are shortly discussed here.

Demographic and macroeconomic drivers form the backbone of long-run projections. Population growth, age structure, migration, and labor force participation shape labor supply, while macroeconomic growth assumptions anchor investment and capital accumulation paths (Fouré et al., 2020). These drivers are often taken from external projections and imposed through dynamic calibration.

Technological change is a second key element, particularly for capturing sectoral dynamics and structural transformation. Chateau et al. (2020) emphasize that productivity growth and technology adoption differ strongly across sectors, affecting substitution possibilities and input-output relationships over time. Without explicit modeling of such dynamics, long-run scenarios risk artificially locking economies into base-year structures.

Energy and environmental dimensions are also critical in contemporary baseline construction. Fæhn et al. (2020) show that assumptions about energy technologies, efficiency improvements, and emissions trajectories can materially affect long-term economic outcomes. These elements can be incorporated endogenously within CGE models, imposed exogenously, or introduced through links with detailed energy system models.

Trade and policy assumptions further shape long-term baselines. Bekkers et al. (2020) document large differences across CGE models in the treatment of trade growth, Armington elasticities, and trade balance closures. Assumptions about tariffs, non-tariff barriers, and trade frictions are particularly important when scenarios aim to explore alternative globalization pathways.

Methodologically, the literature distinguishes between bottom-up endogenization approaches, exogenous parameterization, and model-linking strategies. Bottom-up approaches embed sufficient technological and sectoral detail to generate structural change endogenously (Fouré et al., 2020). Exogenous parameterization relies on external projections for key variables, combined with dynamic recalibration of model parameters. Model-linking strategies connect CGE models with sector-specific or biophysical models to enrich baseline detail (Delzeit et al., 2020). Dynamic calibration procedures then ensure consistency between base-year data, historical trends, and long-run targets (Wojtowicz et al., 2019).

While the methodological best practices described above have been well developed for national and global CGE analyzes, their translation to the regional level introduces a distinct set of challenges that the literature has only partially addressed. Regional CGE models must simultaneously capture the internal economic dynamics of individual regions, including inter-regional trade flows, factor mobility, and localized productivity growth, and remain consistent with national and global macroeconomic constraints. This multi-level consistency requirement makes regional baseline construction considerably more demanding than its national-level counterpart.

A first challenge concerns the modeling of structural change at the regional level. At the national level, structural transformation is typically driven by sectoral productivity differentials, factor reallocation, and shifting demand patterns, all of which can be estimated from reasonably dense time-series data. At the regional level, however, the same processes interact with geography, agglomeration economies, and regional institutional contexts in ways that are difficult to parameterize from historical data alone. Regions do not simply replicate the national structural change trajectory at a smaller scale: the pace and direction of deindustrialization, service sector expansion, or knowledge-economy upgrading varies significantly across regions depending on their initial specialization, connectivity to global value chains, and access to human capital (Neffke et al., 2011; Boschma, 2015). Capturing these dynamics requires explicit modeling of regional path dependencies and relatedness structures, rather than uniform scaling of national sectoral growth rates.

A second and closely related challenge concerns the estimation of regional-level total factor productivity (TFP) growth and its sectoral decomposition. In national CGE baselines, TFP trajectories are often calibrated to match historical productivity growth and then projected forward using sector-specific assumptions. At the regional level, this approach is complicated by data limitations, as regional productivity accounts are less complete than their national equivalents, and by the conceptual difficulty of separating genuine regional productivity differences from compositional effects arising from the mix of firms and activities within a region (Chateau et al., 2020). Moreover, regional TFP growth is partly endogenous to agglomeration and knowledge spillovers, meaning that the choice of scenario trajectory can itself influence the regional productivity path in ways that a purely exogenous calibration approach fails to capture.

A third challenge lies in the translation from macro-level qualitative storylines to quantitative regional growth drivers. National and global scenarios such as the WLO framework used in this paper are typically articulated in terms of high-level narratives such as degrees of globalization, geopolitical orientation, and technological optimism, that do not map directly onto the parameters of a regional CGE model. Bridging this gap requires an intermediate translation step in which qualitative scenario dimensions are converted into region- and sector-specific assumptions about demand growth, trade exposure, and labor productivity. The literature offers several approaches to this problem. Some studies use expert elicitation or Delphi methods to disaggregate national scenario assumptions to the regional level (Wardekker et al., 2012).

Others apply shift-share decompositions or regional input-output analysis to estimate how national sectoral growth translates into regional employment and output change under different structural assumptions (Flegg & Tohmo, 2013). A more integrated approach, applied in a growing number of studies, links a national or global CGE model with a regional satellite model, using the former to generate consistent macro-economic boundary conditions and the latter to resolve the spatial distribution of economic activity (Delzeit et al., 2020).

This paper follows and extends this integrated approach by combining econometric analysis with the EU-EMS regional economic model. A critical innovation relative to existing practice is the use of panel econometric estimation to derive region- and sector-specific growth parameters directly from historical data, rather than relying on expert judgment or simple disaggregation rules. This econometric step allows the scenario storylines to be grounded in statistically estimated relationships between regional growth, structural change, and macroeconomic conditions, thereby reducing the arbitrariness inherent in purely assumption-driven scenario translation. The estimated parameters are then used to calibrate the EU-EMS model under each WLO scenario, producing internally consistent regional and sectoral projections that are simultaneously anchored to historical growth patterns and responsive to the scenario-specific macro-economic environment. To our knowledge, this combination of econometric baseline estimation and regional CGE simulation represents a methodological contribution to the regional long-term scenario literature, offering a replicable approach for translating national qualitative narratives into quantitative sub-national projections.

3. Methodology

In this section we will describe the development of the scenarios, the storylines and the qualitative drivers, as well as argue why the EU-EMS model is of particular added benefit for the purposes of this paper. This includes a detailed description of the data informing the quantitative implementation of the scenarios.

The scenarios discussed in this publication are part of the WLO (Welfare, Prosperity, and the Living Environment) 2025 project (PBL, 2025a), which aims to provide policy makers in the Netherlands with 'baseline' fully consistent scenarios across various domains where policy is assumed to remain unchanged. The variation in outcomes is thus driven by external factors, such as high- or low economic growth on a global scale. The project team, with the help of many external experts developed four scenarios along two axes: the degree of worldwide economic growth, and the speed of climate adaptation and mitigation. The main storylines are based on the global Shared Socioeconomic Pathways (O'Neill et al., 2017), where SSP1 ('Sustainability') is taken as a starting point for the high-growth scenario, and SSP3 ('Regional Rivalry') for the low-growth scenario. The translation of the general storylines into the scenarios discussed in this article was further aided by a separate group of economic experts in various sessions (PBL & CPB, 2025).

The translation of SSP narratives into sector- and country-specific economic assumptions was carried out in two dedicated workshops, drawing on the expertise of economists and sector specialists within PBL Netherlands Environmental Assessment Agency. Rather than applying a formalised participatory scenario method such as Intuitive Logics, the process followed a structured expert reasoning approach in which participants worked systematically through the implications of the SSP1 and SSP3 overarching narratives for each economic sector and for different groups of countries. The aim was to construct internally consistent storylines. This implies ensuring that assumptions about for example trade intensity, sectoral specialization, and labor market dynamics were mutually coherent within each scenario and differentiated appropriately between high-income and low-income country groups. We acknowledge that this approach differs from more extensively participatory qualitative scenario processes in which a broader group of external stakeholders deliberates on deep uncertainty. The WLO economic scenarios are better understood as structured expert scenarios: they provide coherent and logically consistent representations of divergent futures rather than claiming to capture the full range of Knightian uncertainty. The quantitative modeling is therefore not intended to resolve or absorb deep uncertainty, but to map the structural economic consequences of each narrative within a consistent accounting framework.

The WLO scenarios are developed for a wide range of topics so as to accommodate various policy domains. To do so, the general scenarios were then developed further into separate but interconnected subjects, such as transportation, climate, energy use, macroeconomics, national demographics, land use, and others, ultimately culminating in five publications in addition to the main publication describing the general storylines. For the quantitative implementation of the sectoral, and regional economic scenarios, see Sections 3 and 4 of this publication. In order to ensure quantitative consistency, the various subjects' quantitative implementations were linked in a sequence, where each subject's model(s) output would be used as input for other subjects' model(s).

3.1. Conceptual Framework

The methodology employed in this study utilizes a scenario-modeling approach to address the inherent ontological uncertainties associated with long-term regional development. Recognizing that strategic investments in physical infrastructure and the living environment involve commitments that span several decades, this framework avoids deterministic forecasting in favor of exploring a spectrum of plausible trajectories for the 2040–2060 horizon. By synthesizing qualitative narratives with quantitative modeling, the approach identifies a range of potential outcomes that allow for the "stress-testing" of regional policies.

To analyze these dynamics within the Dutch regional context, the European Economic-Environmental Model System (EU-EMS) is applied as a multi-regional, subnational Computable General Equilibrium (CGE) model. The primary strength of utilizing a subnational CGE framework lies in its capacity to deliver internally consistent scenarios that respect fundamental macro-economic constraints, market-clearing conditions, and inter-sectoral dependencies. Unlike partial equilibrium models, the EU-EMS ensures that regional development paths are theoretically grounded and harmonized through endogenous price mechanisms and labor market interactions. This consistency is particularly vital for the Netherlands, where regional specialization, ranging from knowledge-intensive service hubs to industrial and agricultural clusters, leads to varied responses to shifts in international trade regimes. By modeling the economy as an integrated system, the subnational CGE approach provides a robust basis for understanding how external shocks and structural changes are redistributed across sectors and regions, ensuring that local growth or decline is assessed within the broader equilibrium of the national and international system.

Fig. 1 presents the data flow and modelling framework used to translate the qualitative WLO scenario narratives into quantitative regional and sectoral projections. The framework combines three independent streams of input data. The first draws on qualitative SSP storylines (specifically SSP1 and SSP3) together with assumptions about EU and global economic conditions regarding trade, globalisation, and climate change. These are translated into the WLO High and WLO Low scenario storylines, which define the structural logic governing the direction of sectoral change in each scenario. The second stream concerns technological development: country-level total factor productivity trajectories are derived from the MaGE 3.1 model of CEPII (Fontagné, Perego and Santoni, 2022), for SSP1 and SSP3 scenarios, and subsequently distributed across Dutch provinces and sectors through a panel econometric model estimated on CBS and EU-KLEMS data (Bontadini, Corrado, Haskel, Iommi and Jona-Lasinio, 2023). The third stream provides the demographic foundation of the projections, drawing on IIASA population projections (KC and Lutz, 2017) and Eurostat's

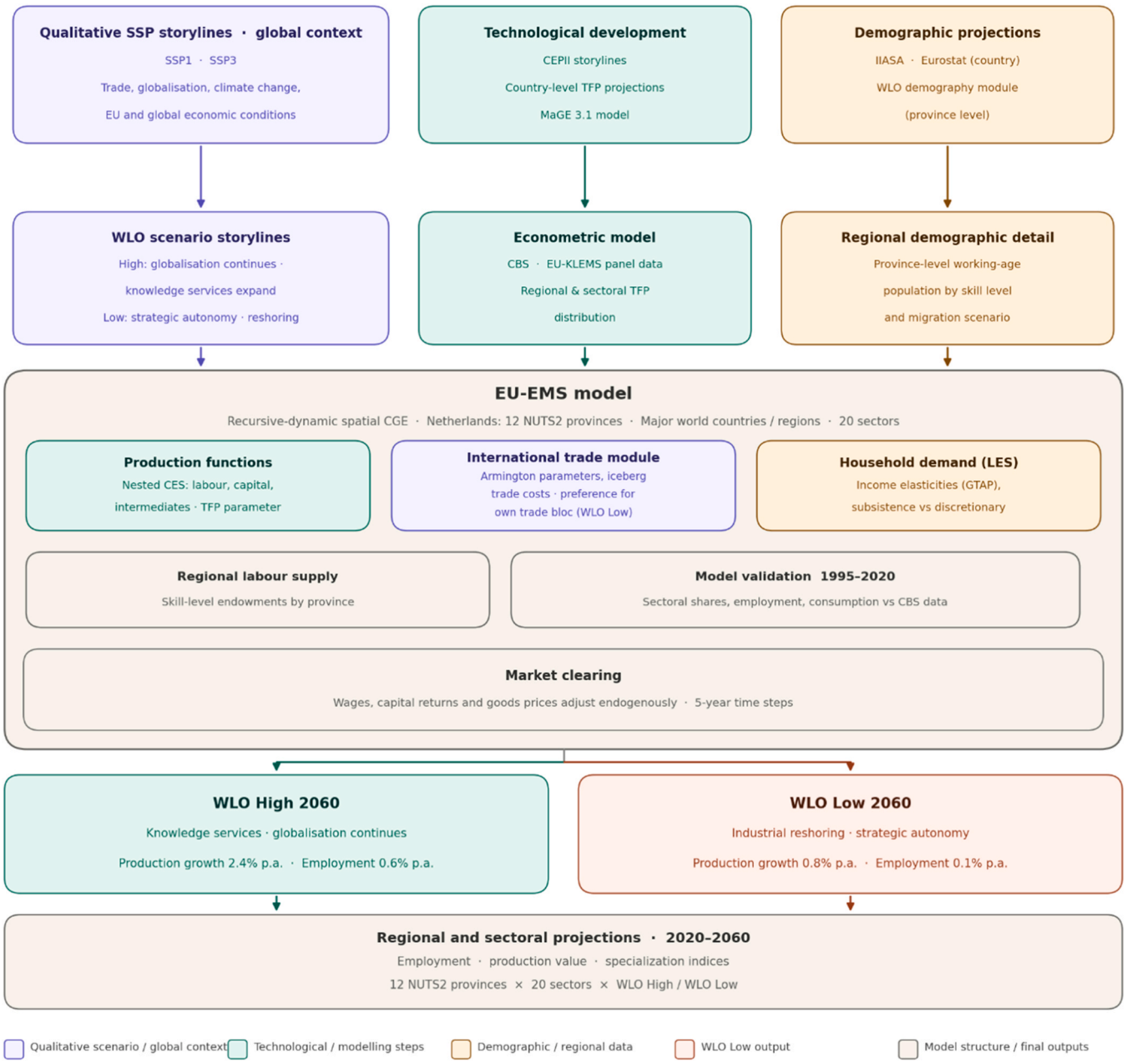


Fig. 1. Data flow and modeling framework for the quantification of WLO scenarios at the regional and sectoral level.

EUROPOP2023 projections (Eurostat, 2023) at the country level, which are then disaggregated to the provincial level through the WLO demography module.

These three streams are jointly fed into the EU-EMS model, a recursive-dynamic spatial computable general equilibrium model covering the Netherlands at the level of twelve NUTS2 provinces, twenty economic sectors, and major world countries and regions. Within the model, production is governed by nested CES functions with an explicit TFP parameter; international trade is modelled through Armington elasticities and iceberg trade costs, with an additional preference shift toward own-bloc trade in the WLO Low scenario; and household demand is represented by a Linear Expenditure System with income elasticities derived from the GTAP database (Aguiar, Chepeliev, Corong & van der Mensbrugghe, 2019), capturing the endogenous shift in consumption patterns as real incomes rise or stagnate across provinces. Regional labor supply by skill level is taken directly from the WLO demographic module (PBL, 2025b), and all model results are validated against CBS historical data for the period 1995–2020. The model solves for a market-clearing equilibrium in which wages, capital returns, and goods prices adjust endogenously, with development simulated in five-year time steps.

The framework produces two sets of projections for the horizon year 2060 (WLO High and WLO Low), which differ structurally in the pace of production growth (2.4% versus 0.8% per annum) and employment growth (0.6% versus 0.1% per annum) at the national level. These macro-level differences propagate through the spatial CGE structure to generate province- and sector-specific trajectories for employment, production value, and specialization indices, which form the empirical basis for the regional resilience analysis presented in the remainder of this paper.

A fundamental methodological tension in combining qualitative scenario narratives with a CGE model concerns the ontological assumptions underlying each approach. Qualitative scenario methods are designed to accommodate Knightian or "true" uncertainty: conditions in

which the probability distribution of future states is not merely unknown but unknowable (Derbyshire, 2024). CGE models, by contrast, are built on neoclassical equilibrium foundations that assume optimizing agents, clearing markets, and parametric risk, a framework that is, as Derbyshire (2024) notes, structurally at odds with the deep uncertainty that scenario methods seek to address.

We do not claim to resolve this tension. Rather, we follow the position that the two approaches address different analytical objectives that can be usefully combined in a layered, non-reductive way. The qualitative scenario narratives define the structural logic and directionality of each future. The CGE model then operates within each of those rule-sets, tracing the economic implications under the assumption that, conditional on the scenario's structural parameters, agents and markets behave as the model specifies. The result is not a probabilistic forecast but a structured comparison of conditional economic trajectories. This combination does not suppress uncertainty; rather, it translates the uncertainty captured in the qualitative storylines into scenario-specific structural parameters, making explicit what each future implies for regional employment, production, and specialization. The limitations of this approach is the inability to model genuine structural surprises or discontinuities that fall outside the model's parameter space, hence the results should be read accordingly as internally consistent conditional projections rather than predictions.

3.2. Scenario Storylines and Qualitative Drivers

The Shared Social-economic Pathways are differentiated by the degree to which climate change mitigation and adaptation are challenging. In the SSP-scenario 3 (‘Regional Rivalry’) the world experiences fragmentation and economic deglobalization. Consequently, climate changes will offer high challenges both for mitigation, as well as adaptation. In contrast, SSP-scenario 1 (‘Sustainability’) features effective international cooperation, both for governmental organizations as well as the private sector (O’Neill et al., 2017).

The key drivers considered in our scenarios expand on the diverging globalization, through the degree of intensity of international trade and cooperation, which is assumed to be a key driver for technological innovation. A world with greater technological innovations would see higher levels of income and wealth, but more importantly for scenarios that describe sectoral compositional change on a regional level, shifting production chains, but also causing wages to rise heterogeneously across the globe, thus influencing international migration and consumption patterns. In addition, high- and low income countries, face different demographic dependencies. High-income countries face the costs of existing aging populations, whereas low-income countries face high birth rates and the associated costs. The demographic costs will be felt differently in each scenario.

The high-growth scenario envisions ongoing globalization with increased specialization via international trade. High-income countries prioritize high-value manufacturing and knowledge-intensive services, fuelled by technological exchange and sustainable technology investments. Low-income countries expand in high-value manufacturing due to worldwide technological advancements and better education Economic growth leads to increased consumption, impacting energy and resource use, while low-income countries follow development patterns seen in high-income countries. Investments in education and human capital rise, with female labor participation increasing. Technological innovations, such as AI and robotics, boost demand for highly educated workers, reducing low-skilled job availability and increasing wages across sectors. Aging in high-income countries boosts healthcare demand, which is met by technological innovations. Skilled worker migration supports labor supply, while rising incomes in low-income countries enhance their global market presence and shift trade patterns.

In contrast, low-growth scenario envisions a shift away from globalization, focusing on autonomy and trade within blocs like the EU. Trade barriers slow economic growth and hinder investments in technology and education, leading to slower income growth and reduced luxury consumption in high-income countries. Healthcare demand increases, in part because of an aging population, which is costly without technological advances. Migration from low-income countries stays stable. In high-income countries, production of both low- and high-value manufacturing and agriculture grows within trade blocs. In Europe, production of other and high-value manufacturing increases due to reshoring from countries like China, India, and the US. Knowledge-intensive services lose importance, while luxury and leisure sectors shrink. Fragmented world markets impede low-income countries' progress, concentrating economic activity on essential sectors like agriculture, consumer goods, healthcare, and construction, while high-value industries and knowledge services fall behind. In low-income countries, high fertility rates and slow educational improvements cause gradual income growth, with consumption centered on basic needs like food, clothing, energy, and housing.

Consequently the different effects of the variation in the key drivers allows us to model global changes into sectoral compositional changes on a local, regional scale, through shifting worldwide production, changing consumption patterns, international migration and labor market supply of workers and dependency levels. In the next two section we will further detail the scenarios.

3.3. The EU-EMS Model Structure

The quantitative core of this research is the European Economic System Model (EU-EMS), a recursive-dynamic, multi-regional Computable General Equilibrium (CGE) framework maintained by the PBL Netherlands Environmental Assessment Agency. Designed to assess long-term structural changes, the EU-EMS operates on a neoclassical general equilibrium logic where regional markets for goods and factors clear through price adjustments. The model's spatial resolution is aligned with the NUTS2 classification, enabling a granular representation of the twelve Dutch provinces within the broader European economic landscape.

The EU-EMS model has been extensively validated through its application in high-level policy and academic assessments. It serves as the analytical foundation for the WLO 2025 (Welfare and the Living Environment) study, which explores the long-term spatial-economic structure of the Netherlands under diverse global scenarios (PBL & CPB, 2025). On a broader European scale, the model was recently employed by the European Commission to assess regional vulnerabilities to global fragmentation and technological change, highlighting the risks of increasing regional disparities in a more competitive global landscape (European Commission, 2025). Methodological advancements have further enhanced the model's precision; for instance, recent research has demonstrated the model's refined capability to distribute complex direct and indirect impacts across granular European regions and sectors, offering insights into regional economic restructuring (Cortés Arbués et al., 2024). Furthermore, the model's versatility is evidenced by its integration with other modeling paradigms to capture economy-wide feedbacks resulting from behavioral and structural changes, ensuring a comprehensive representation of how local dynamics scale up to national economic outcomes (Niamir, Ivanova and Filatova, 2020).

The production side of the EU-EMS is characterized by a hierarchical structure of Constant Elasticity of Substitution (CES) functions, allowing for the substitution between capital, labor, energy, and intermediate materials. A distinctive feature of the model is its detailed representation of the labor market and energy-environment interactions. Labor is disaggregated by skill level, low, medium, and high, allowing the model to capture the regional economic impacts of demographic shifts and varying speeds of technological adoption across the Dutch provinces. This makes the EU-EMS particularly well-suited for the long-term scenario analysis required to explore the Netherlands' economic trajectory in the coming decades.

Spatial economic interactions are governed by the Armington

assumption, which treats products as imperfect substitutes based on their region of origin. This enables the simulation of regional trade dynamics and the "home bias" often observed in sub-national economies. The consumption side is modeled through a representative household in each region that maximizes utility according to a Linear Expenditure System (LES) or nested CES structure, depending on the specific model configuration used for long-term projections. These demand-side dynamics are linked across regions through a multi-stage trade nest, where agents first distinguish between domestic and imported goods and then allocate demand among specific NUTS2 regions. Such a structure is critical for identifying how localized shocks in one Dutch province, such as shifts in the industrial clusters of the Maasvlakte or the service-heavy Randstad, propagate through the national and European value chains.

To project economic developments until 2060, the EU-EMS employs a recursive-dynamic approach, solving a sequence of static equilibria linked by inter-period equations. The model's dynamics are driven by endogenous capital accumulation, where investment is allocated across regions based on relative rates of return, and by exogenous drivers including population growth, labor participation rates, and Total Factor Productivity (TFP) improvements. By calibrating these dynamic paths to the historical validation data and the qualitative scenario storylines, the framework provides a robust tool for exploring how different policy narratives translate into divergent regional economic outcomes. This integration of a high-resolution JRC empirical database with the structural rigor of the PBL's EU-EMS model ensures that the 2060 scenarios for the Netherlands are both theoretically sound and spatially explicit, meeting the standards for rigorous policy-relevant regional science.

3.4. Data, Calibration, and Historical Validation

The empirical integrity of the EU-EMS framework is anchored in a high-resolution dataset that captures the structural characteristics of the Dutch regional economies. The primary data source is the European Regional Social Accounting Matrices (SAMs) developed by the Joint Research Centre (JRC), which provide a comprehensive and consistent representation of the economic transactions between production sectors, factors of production, and institutional accounts at the NUTS2 level. Specifically, this study utilizes the updated regional SAM database, as detailed in the JRC's recent methodological frameworks, which integrates the Full International and Global Accounts for Research in Input-Output (Thissen et al., 2019) to ensure that inter-regional trade flows within the Netherlands are consistent with national and international accounts. This database enables a detailed sectoral disaggregation, covering 64 NACE Rev. 2 sectors, which is essential for capturing the heterogeneous industrial landscapes of the twelve Dutch provinces, from the logistics-heavy hubs in Zuid-Holland to the high-tech manufacturing clusters in Noord-Brabant.

The calibration process ensures that the model's initial state replicates the benchmark equilibrium defined by the 2018 regional SAMs. Key behavioral parameters, such as the substitution elasticities in the nested CES production functions and the Armington elasticities for trade, are either econometrically estimated or sourced from established regional science literature to reflect the specificities of the Dutch market. For instance, the Armington elasticities are calibrated to reflect the high degree of openness and spatial integration of the Dutch provinces within the Single Market. Furthermore, the Linear Expenditure System (LES) governing household consumption is calibrated using regionalized income elasticities, ensuring that the demand-side response to the 2060 scenario shocks is grounded in observed consumer behavior. This calibration ensures that the model is "internally consistent," meaning that in the absence of exogenous shocks, the model remains in the benchmark equilibrium.

To establish the "external validity" of the model for long-term projections until 2060, a rigorous historical validation procedure was conducted. This involved a "backcasting" exercise where the model was initialized using historical data from the 2010–2022 period to determine its ability to replicate observed regional economic trajectories in the Netherlands. By comparing the model's simulated outputs for regional GDP growth, sectoral employment shifts, and inter-provincial trade volumes against historical time-series data from Statistics Netherlands (CBS) and Eurostat, the model's dynamic parameters, such as Total Factor Productivity (TFP) trends and labor participation rates, were fine-tuned. This validation step is crucial for long-term forecasting, as it confirms that the EU-EMS can accurately capture the structural peculiarities and regional resilience of the Dutch economy. Consequently, the validated model provides a reliable baseline from which the qualitative scenario storylines for 2060 are quantitatively explored, ensuring that the resulting policy insights are both empirically robust and spatially relevant.

Model validation was performed by initializing the simulation in 1995 and comparing projected trajectories of sectoral employment shares, production values, and consumption patterns with actual CBS data for 2020. The validation confirms that the model reproduces the major structural trends of the past quarter-century, including the gradual servicification of the Dutch economy, the relative decline of basic industry, and the persistence of regional specialization patterns, without mechanically extrapolating these trends as forecasts. The WLO High scenario is therefore not a projection of past trends but an internally consistent future in which the dominant logic of the past continues to operate under different demographic and technological boundary conditions. The WLO Low scenario represents a structural break from that logic, in which the drivers of servicification and globalization weaken and a different set of regional comparative advantages comes to the fore. Taken together, the two scenarios provide a coherent stress test of Dutch regional economies under contrasting global structural configurations, offering the basis for the regional resilience analysis developed in the remainder of this paper.

3.5. Quantification of Scenarios

The quantitative operationalization of the WLO storylines uses the European Economic Modeling System (EU-EMS), a multi-regional, recursive-dynamic CGE framework developed at PBL (Niamir, Ivanova & Filatova, 2020; Ivanova, 2020). The model has been applied in regional scenario and evaluation studies including EIB cohesion financing impact assessment across EU−28 regions (EIB, 2020), sea-level rise analysis across European regions and sectors (Cortés Arbués et al., 2024), and regional economic scenarios for EU NUTS2 regions under contrasting structural futures (European Commission, 2025).

The model represents the Dutch economy across twelve NUTS2 provinces (Groningen, Friesland, Drenthe, Overijssel, Gelderland, Flevoland, Utrecht, Noord-Holland, Zuid-Holland, Zeeland, Noord-Brabant, and Limburg) and twenty economic sectors ranging from agriculture and extractive industries through construction, manufacturing, knowledge-intensive services, transport and business services, and public services (Table 1). Production in each sector is governed by multi-level nested Constant Elasticity of Substitution (CES) functions, allowing for substitution between three skill categories of labor, sector-specific capital, and a range of intermediate inputs including materials, energy, and machinery. This nested structure captures both the possibility of capital–labor substitution, reflecting automation and technological change, and partial substitutability between skill levels within the labor input bundle. The model is embedded in a global trade architecture in which the Netherlands trades with twelve distinct country groups, including major European partners, the United States, China, India, Japan, and rest-of-world regions.

The spatial dimension of the model is central to the contribution of this paper. Each of the twelve Dutch provinces is modelled as a distinct regional economy with its own factor markets, sectoral structure, and trade linkages. Regional labor markets are characterized by imperfect inter-regional mobility: labor can move between provinces in response

Table 1
Key scenario parameters in the EU-EMS implementation of the WLO High and Low scenarios.

Parameter	Baseline (2018 SAM)	WLO High	WLO Low	Model mechanism
A. Total factor productivity				
Annual national TFP growth rate	~1.0% p.a. (historical avg. 1995–2020)	1.5% p.a.	0.4% p.a.	Labor-augmenting TFP shift parameter in CES production function; distributed across sectors and provinces via panel econometric model
Sectoral TFP distribution	Calibrated to CBS / EU-KLEMS historical shares	Weighted toward knowledge-intensive services and high-tech manufacturing	Weighted toward basic and other industry; lower service-sector growth	Econometrically estimated regional-sectoral TFP shares applied to national trajectory
B. International trade structure				
Monetary trade costs (NL ↔ non-EU partners)	Calibrated to 2018 observed trade shares	Unchanged or slightly decreasing (continued trade openness)	Raised substantially (deglobalization; higher trade frictions)	Upper Armington CES nest; raises effective import price from non-EU partners
Armington preference shift toward intra-EU supply chains	Calibrated to 2018 observed trade shares	Unchanged (global sourcing patterns continue)	*20% preference shift toward EU-origin goods*	Armington share parameters in lower CES nest recalibrated to favor intra-EU suppliers
Trade balance and closure	Endogenous via net transfer from abroad	Active global capital and trade flows; open current account	Predominantly EU-internal flows; reduced non-EU trade volumes	Walrasian equilibrium; difference between imports and exports equals net transfers from abroad
C. Demographics and labor supply				
Net international migration (national)	~80,000–100,000 p.a. (CBS 2018–2020 avg.)	High positive inflow; continued skilled-worker migration	Near-zero after 2035; stable migration from outside EU	Exogenous labor supply by skill level from WLO Demography module (PBL, 2025b)
Labor force participation rate	2020 CBS values by skill and age group	Increasing; especially female and older workers	Stable to slight decline	Exogenous input to skill-differentiated labor supply; affects wage dynamics endogenously
Annual national employment growth	Historical avg. ~0.8% p.a. (1995–2020)	0.6%–0.7% p.a.	~0.1% p.a.	Derived endogenously from labor supply, wage-clearing, and sectoral demand
D. Investment and capital				
Origin of foreign direct investment	Mixed EU and non-EU (calibrated to 2018)	Global; active non-EU FDI flows to knowledge-intensive provinces	Primarily EU-domestic and intra-EU capital flows	Investment bank allocation rule; discrete-choice formula allocates savings pool across sectors and provinces
Government expenditure on R&D and education	2020 public expenditure shares (CBS)	Higher; consistent with SSP1 human capital investment narrative	Lower; fiscal constraints under low-growth path	Affects TFP catch-up rate and skill-specific labor supply in dynamic calibration
E. Household demand				
Household demand system	Linear Expenditure System (LES) calibrated to 2018 income and consumption data	Rising real incomes shift consumption toward discretionary / luxury services	Constrained real income growth; subsistence share remains elevated; limited shift to services	LES income elasticities (from GTAP database); endogenous shift from necessities to discretionary goods as income rises

to wage differentials, but capital goods are largely sector-specific and immobile in the short to medium run. As a consequence, structural change in the regional sectoral composition is modelled as a gradual process unfolding over multiple decades, with the model simulating economic development in five-year time steps. This feature is important for capturing the path-dependent nature of regional industrial restructuring, where the existing capital stock, skill base, and agglomeration economies constrain the speed at which regions can transition between growth trajectories.

The translation of qualitative WLO storylines into the quantitative framework proceeds through a stepwise methodology. National-level labor productivity projections are derived from the MaGE 3.1 macroeconomic model of CEPII (Fontagné, Perego & Santoni, 2022), as elaborated in Part 1 of the WLO 2025 Cahier Economie (PBL 2025b). These national projections impose an economy-wide productivity constraint: the sum of sectoral TFP growth must equal the aggregate national trajectory. The distribution of this aggregate productivity across sectors and regions is then estimated using a panel econometric model calibrated on Statistics Netherlands (CBS) and EU-KLEMS data (Bontadini et al., 2023; EUKLEMS, 2025), which accounts for observed differences in productivity levels and economic structure across Dutch provinces. This econometric step represents a key methodological contribution of the paper: rather than relying on assumption-driven or expert-elicitation approaches to scenario disaggregation, the parameterization is grounded in statistically estimated historical relationships between regional growth, sectoral composition, and macroeconomic conditions.

In the WLO High scenario, the labor-augmenting TFP parameter is set to an annual growth rate of 1.5%, consistent with a regime of continued technological innovation, international knowledge diffusion, and sustained globalization (PBL 2025b). International trade is modelled as continuing to expand broadly along the patterns of the past quarter-century, with Armington trade cost parameters and preference weights calibrated to reflect a world of relatively open markets, falling non-tariff barriers, and deep participation in global value chains. Under these conditions, Dutch high-income regions are projected to deepen their comparative advantage in knowledge-intensive services and high-tech manufacturing, as factor reallocation within and across provinces responds to globally-driven demand signals. Inter-regional capital flows from outside Europe remain active in this scenario, as the high rate of return on knowledge-intensive investment attracts foreign direct investment particularly to the technologically advanced provinces of Noord-Holland, Utrecht, and Zuid-Holland. Labor supply is raised to reflect high net inward migration and increased participation rates, with the demographic input derived from the WLO Demography module (PBL, 2025b).

In the WLO Low scenario, TFP growth is reduced to 0.4% per year, simulating a productivity slowdown associated with fragmented international knowledge exchange, declining investment in education and research, and limited technology diffusion across geopolitical blocs (PBL 2025b). The trade architecture of the model is restructured fundamentally to reflect a world of deglobalization and strategic autonomy. Trade increasingly occurs within geographically proximate blocs, primarily the EU, rather than globally. This is operationalized in EU-EMS through two complementary mechanisms. First, iceberg trade costs between the Netherlands and non-European trade blocks are raised substantially, making long-distance imports and exports more costly and reducing the

competitiveness of Dutch sectors that depend on global supply chains or export markets outside Europe. Second, Armington preference parameters are recalibrated to favor shorter, intra-European supply chains over globally dispersed ones, capturing the shift in consumer and firm preferences toward domestic and regional sourcing. Together these two modifications generate a structural incentive for reshoring: basic and other industry, as well as hightech manufacturing, become cost-effective again within Europe and the Netherlands as the price differential between domestic and imported production narrows. Investment in this scenario originates predominantly from European sources, including Dutch domestic capital and intra-EU flows, replacing the global investment streams of the High scenario. Labor supply is set close to static, reflecting near-zero net migration and stable participation rates, with demographic stagnation concentrated in the peripheral northern provinces of Groningen, Friesland, and Drenthe.

It is worth noting that scenario variables in EU-EMS are applied symmetrically across trading partners: changes in trade costs and Armington preference parameters affect Dutch import and export competitiveness simultaneously, and the global growth environment is imposed consistently from SSP1 and SSP3 scenario projections for each scenario. The Dutch economy is treated as a price-taker in global markets, meaning that domestic economic outcomes do not feed back into global conditions within the model. This is a standard assumption for a small open economy and implies that any feedback effects of Dutch adjustment on global trade flows are assumed negligible. The scenario parameters governing trade costs and investment flows are therefore fully exogenous in the simulation.

A further dimension of the scenario differentiation concerns the endogenous response of household consumption patterns to changes in real income across provinces. Consumption demand in EU-EMS is governed by a Linear Expenditure System (LES), which distinguishes between subsistence consumption, which is price-inelastic and covers basic necessities such as food, energy, housing, and healthcare, and discretionary spending, which responds to both price and income changes. The critical property of the LES for this analysis is that as real incomes rise, the share of subsistence goods in total consumption falls while the share of discretionary goods and services rises. Income elasticities for each sector and each Dutch province are calibrated using regional CBS data on household income and consumption patterns, so that the income-driven structural shift in consumption is estimated from observed Dutch regional behavior rather than imposed from national averages.

In the WLO High scenario, rising real incomes, particularly in the Randstad provinces, drive consumption progressively away from basic goods and toward luxury services, including knowledge-intensive services, cultural and recreational activities, and high-quality healthcare. This demand-side effect reinforces the supply-side specialization of high-income provinces in services, as the growing domestic market for premium services provides an additional driver of sectoral expansion beyond export demand. In contrast, the WLO Low scenario constrains real income growth, particularly in peripheral provinces where demographic stagnation and low TFP growth interact. Under these conditions, the share of subsistence consumption in household budgets remains elevated, and discretionary spending grows slowly. This suppresses the demand-side expansion of services, particularly in rural and peripheral provinces, and contributes to the relative resilience of basic industry, whose products face stable demand for necessities even as income growth stagnates.

An ageing population is incorporated in both scenarios through the demographic module, amplifying the share of healthcare in subsistence consumption over time, though at different rates depending on immigration assumptions. Government consumption follows a parallel logic, with public expenditure on education, research and development, and infrastructure modelled as higher in WLO High, consistent with the scenario narrative of continued investment in human capital, and lower in WLO Low, where fiscal constraints and lower growth expectations reduce public investment capacity (PBL 2025b).

4. Results and discussion

Section 4 presents the results of the WLO High and Low scenario simulations across the twelve Dutch NUTS2 provinces and discusses their implications for regional economic resilience. The section begins with national-level findings, documenting the projected deceleration in employment and production growth relative to the historical average and contrasting the sectoral composition of growth under each scenario: continued servicification and knowledge-intensive expansion under WLO High versus industrial reshoring and a halt to deindustrialization under WLO Low. It then turns to the regional dimension, presenting projected employment and GDP growth rates by province and examining how the two scenarios generate markedly different spatial distributions of economic activity. The analysis of sectoral specialization follows, showing how the share of industrial employment and knowledge-intensive services evolves across provinces under each scenario. Drawing on these findings, the section concludes with a resilience assessment that maps the twelve provinces onto four groups and derives scenario-specific and scenario-robust policy implications for each.

4.1. Sectoral developments

While the Dutch economy expands across all WLO scenarios through 2060, growth remains consistently below the 2.1% historical average recorded between 1995 and 2020. In the WLO High scenario, annual GDP growth of 2.0%–2.1% is sustained by 1.5% labor productivity gains and 0.6%−0.7% employment growth, with total production value rising by approximately 2%. Conversely, the WLO Low scenario indicates a structural slowdown to 0.5% annual GDP growth, constrained by household consumption of 0.6% and government consumption of 0.8%. This stagnation is largely attributed to the cessation of net external migration after 2035, which restricts employment growth to a marginal 0.1% and forces the economy to rely almost entirely on a modest 0.4% annual increase in labor productivity.

Analysis in this paper focuses on structural changes within the Dutch economy, specifically the sectoral shares of total production value and employment. The Dutch economy is predominantly composed of public services, business and other services, and high-value manufacturing, while agriculture and construction represent the smallest sectors by share of total production value Fig. 2.

In the High growth scenario, the trend toward a service economy continues. The share of knowledge-intensive services in total production value grows significantly, while the shares of industry and agriculture decline. Although public services and transport grow in absolute terms, their relative shares decrease. The construction sector expands significantly due to robust economic and demographic growth.

In the Low growth scenario, the shift toward a service economy halts, favoring a larger share of industry in both production and employment. The share of knowledge-intensive services slightly declines, while high-value manufacturing and basic industries (such as food and clothing) increase. The construction sector remains stable in these scenarios.

Across both scenarios, the relative share of agriculture and public services declines, outpaced by growth in knowledge-intensive services (High) or industry (Low). In the High scenario, agricultural production decreases in both relative share and absolute economic value.

High-value manufacturing grows in absolute terms across all scenarios, but its share in total production varies. In the High scenario, rising education levels in low-income regions prompt the relocation of some manufacturing, mirroring previous industrial shifts. Consequently, high-income countries specialize in knowledge-intensive services, which experience the greatest productivity growth.

In the Low growth scenario, slowing globalization and the rise of trade blocs (such as the EU) increase the pursuit of economic autonomy. This leads to the partial reshoring of manufacturing to Europe,

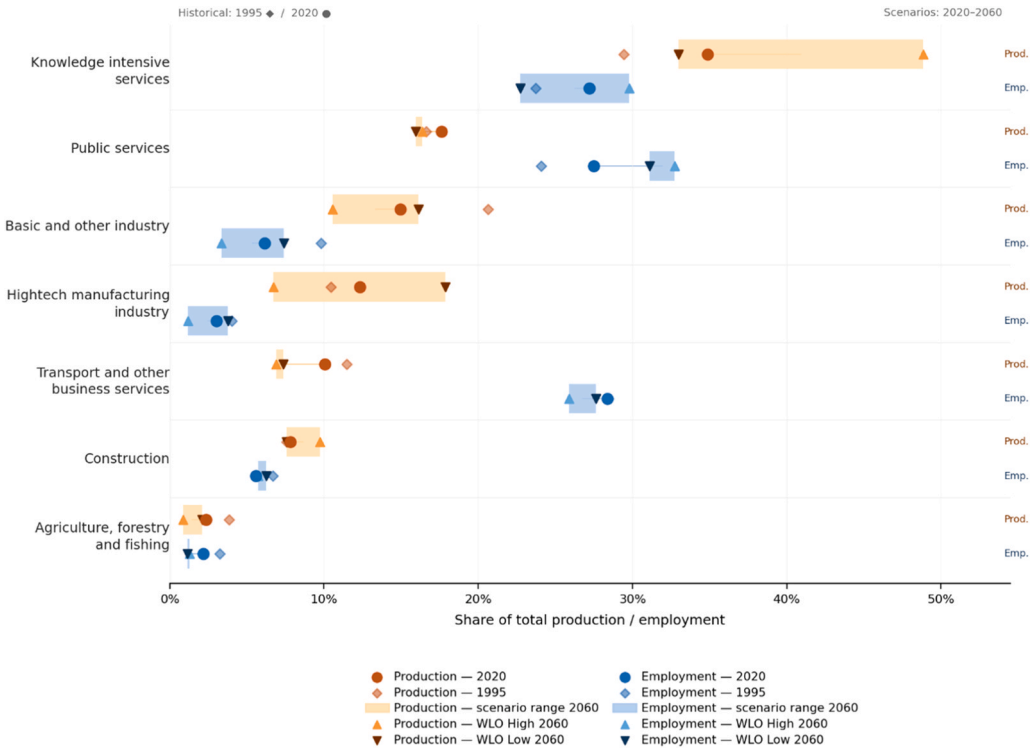


Fig. 2. Sectoral share in total value of production and in total employment.

increasing its share at the expense of services and transport. This reshoring may also result in increased raw material consumption within the Netherlands and the EU.

In addition to analyzing sectoral shares in total production value, we examine shifts in sectoral shares of total employment in the Netherlands. As of 2020, over 80% of employment is concentrated in the service sector, evenly distributed among knowledge-intensive services, transport and other services, and public services. In the High growth scenario, employment in knowledge-intensive services grows to 30%, while public services rise to 33%, driven by increased demand for healthcare and education due to a growing and aging population. Public services are labor-intensive, resulting in lower productivity growth compared to other sectors, which explains the increase in employment share without a corresponding rise in production value share. Technological innovations boost labor productivity, particularly in knowledge-intensive services and industry. Innovation helps maintain the construction sector's stable share of total employment, despite its growing share in total production value.

In the Low growth scenario, employment in knowledge-intensive services declines, while employment in industrial sectors increases. By 2060, the shares of high-value manufacturing and basic and other industries in total employment in the Low scenario resemble their 1995 levels, due to limited reshoring of industrial production to the Netherlands. Across all scenarios, the share of agriculture in total employment decreases, while the construction sector maintains a consistent share.

4.2. *Regional developments*

According to the data from Statistics Netherlands, between 1995 and 2020 regional employment in the Netherlands experienced an annual growth rate exceeding 1% in several areas, including Utrecht, Noord-Holland (home to Amsterdam), and Drenthe (Statistics Netherlands (CBS),2023). Flevoland, particularly the newly developed city of Almere, exhibited the highest employment growth during this period.

Projected employment trends under the WLO scenarios indicate a deceleration and potential reversal from past trends. In the WLO Low scenario, many peripheral regions such as Groningen, Friesland, Drenthe, Overijssel, Zeeland, and Limburg face employment declines. Conversely, the WLO High scenario predicts continued growth, albeit at a reduced rate compared to historical averages, especially in Flevoland, where Almere's expansion is slowing. This scenario forecasts relatively high employment growth in urbanized regions like Utrecht, Zuid-Holland, and Noord-Holland, which are prominent destinations for migrants and feature a substantial share of employment in services, particularly knowledge-intensive services.

Under the WLO Low scenario, only half of the regions experience employment growth, with Flevoland and Zuid-Holland leading, followed by Noord-Holland. Notably, Utrecht does not rank among the highest-growing regions in this scenario. Groningen and Limburg are projected to experience the most significant employment declines. These projections underscore the shifting dynamics of regional employment, highlighting the impact of urbanization and sectoral composition on growth trajectories in the Netherlands Fig. 3.

The order of regions with the highest and lowest GDP growth differs between scenarios, largely influenced by sectoral specialization and scenario-specific narratives. In the WLO Low scenario, regions like Noord-Brabant and Limburg, which focus on industrial employment, experience the highest GDP growth due to the reshoring of industrial production to Europe and the Netherlands. Flevoland and Gelderland, which have gained industrial specialization, also show relatively high growth. Additionally, large regions such as Utrecht and Zuid-Holland benefit from relatively high growth under this scenario.

The WLO High and Low scenarios depict contrasting narratives for the Dutch economy. WLO High envisions continued globalization and increased specialization in services, while WLO Low emphasizes reshoring and a growing share of industrial production, aiming for strategic autonomy in a world marked by conflicts and slowed globalization. This divergence is reflected in the share of industrial employment, as shown in Error: Reference source not found.

Under the WLO High scenario, the average share of industrial employment in the Netherlands is 5%. This scenario supports a high-

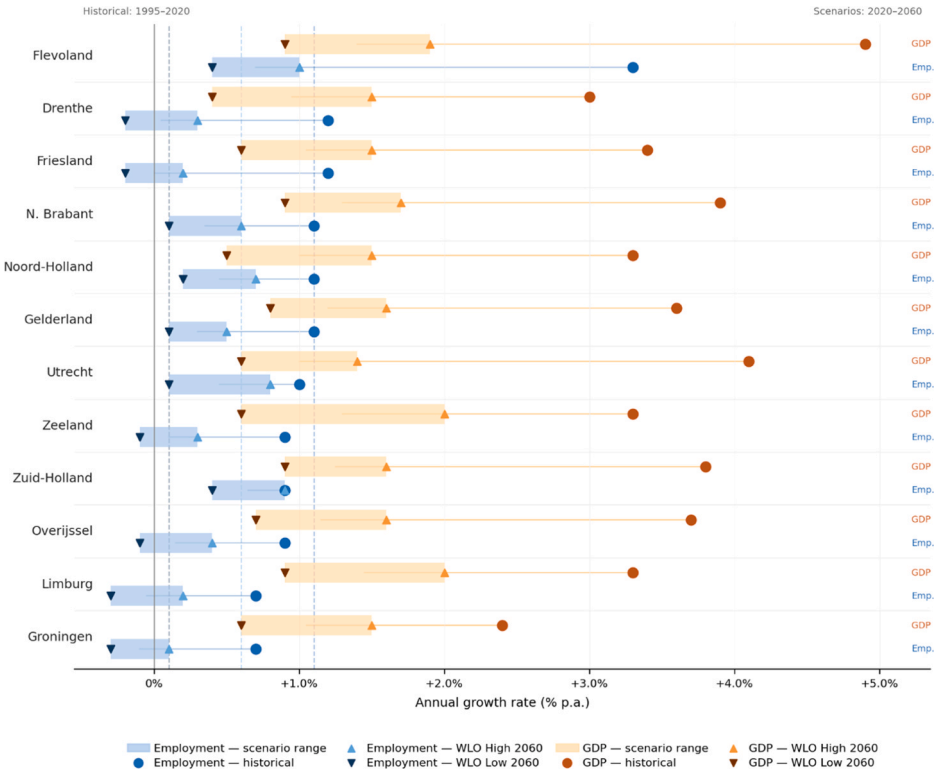


Fig. 3. Annual regional employment and GDP growth under WLO High and Low scenarios in percent.

tech growth path, with an increasing focus on knowledge-intensive services, resulting in low regional variation in industrial employment. The highest shares are found in Noord-Brabant, home to ASML, and Zeeland, with its significant container port, as well as in Limburg with its large chemical cluster.

Conversely, the WLO Low scenario projects a substantially higher average industrial employment share of 12.4%. This scenario reveals significant regional variation, aligned with historical specialization patterns. Regions such as Noord-Brabant, Limburg, and Zeeland, which had high industrial employment shares in 2000, continue this trend under WLO Low. In contrast, urbanized regions like Utrecht, Zuid-Holland, and Noord-Holland maintain a lower share of industrial

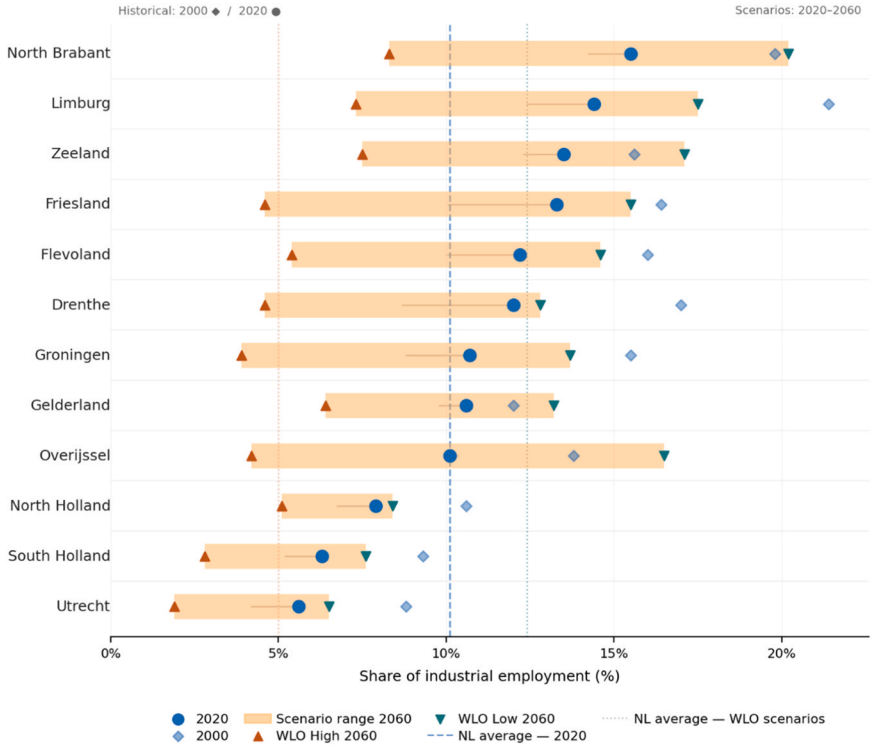


Fig. 4. Share of industrial employment in the region historically and for WLO scenario's.

employment. These scenarios highlight the potential shifts in economic structure and regional specialization, driven by differing global and domestic priorities Fig. 4.

The sectoral specialization of Dutch regions follows distinct paths under the WLO High and Low scenarios, with Error: Reference source not found illustrating these developments. These tables measures specialization as the difference between a region's share in industrial employment or employment in knowledge intensive services and the region's share in total national employment, expressed in percentage points. A higher indicator denotes greater industrial specialization or higher specialization in knowledge intensive services.

In the WLO High scenario, existing specialization trends are amplified. Regions such as Noord-Brabant and Limburg continue to exhibit strong industrial specialization. In contrast, highly urbanized areas like Utrecht, Zuid-Holland, and Noord-Holland maintain their focus on knowledge intensive services, reflecting the scenario's emphasis on high-tech and knowledge-intensive growth. The WLO Low scenario presents more dynamic changes, with several regions increasing their industrial specialization compared to historical data from 2000. Notably, Overijssel, Flevoland, and Friesland show significant shifts toward industrial employment, diverging from the trends observed under the WLO High scenario. The historical trend for more specialization in knowledge intensive services continues for Utrecht and Zuid-Holland under WLO Low scenario, whereas Noord-Holland loses its degree of specialization under this scenario Fig. 5.

4.3. *Final remarks and policy implications*

This paper makes a methodological contribution by translating broad WLO scenario narratives into a rigorous regional and sectoral quantitative framework. Using a combination of econometric analysis and the EU-EMS computable general equilibrium model, we transform abstract global storylines into sub-national projections of output and employment growth across the twelve Dutch NUTS2 provinces. This dual-model approach operationalizes qualitative uncertainty in a way that allows policymakers to stress-test regional economies against divergent futures before those futures materialise.

Our central empirical finding is that the Dutch economy is projected to grow in employment, production, and consumption across all scenarios, but at a rate substantially below the historical average of 1995–2020. This systemic deceleration is not uniform: it is heavily differentiated by sector and region, and the nature of the growth challenge differs fundamentally between scenarios. Under WLO High, knowledge-intensive services emerge as the dominant driver, with their production share projected to reach nearly 49% nationally by 2060, up from 35% in 2020. Under WLO Low, the picture reverses: industrial production rebounds, with several provinces recovering or exceeding their 2020 employment shares in manufacturing, while knowledge-intensive services grow more modestly.

A structural feature of the WLO Low scenario that carries particular resilience significance is the near-complete decoupling of GDP growth from employment growth. With employment expanding by only 0.1% annually at the national level and declining in several peripheral provinces after 2035, the modest overall growth under this scenario is driven almost entirely by productivity gains in capital-intensive sectors. This creates a resilience challenge of a different kind from those emphasized in the growth management or deindustrialization narratives: it is not a problem of economic contraction per se, but of growth that fails to generate broad-based labor market participation. For peripheral provinces where employment is already the binding constraint on household income and social cohesion, a productivity-led Low scenario offers limited relief and may in practice exacerbate existing disparities even under conditions of aggregate GDP growth.

The findings of this paper should be interpreted through the lens of regional economic resilience, a concept that has gained considerable traction in economic geography and regional science over the past two decades. Regional resilience is broadly understood as the capacity of a regional economy to anticipate, withstand, and recover from shocks or structural disruptions, while retaining its core functions and adapting its development trajectory over time (Martin, 2012; Bristow, 2010). Early treatments of the concept drew heavily on ecological and engineering analogies, emphasising the ability of a system to return to its pre-shock equilibrium, a notion of resilience as "bouncing back" (Pendall et al., 2010). However, this static interpretation has been widely critiqued as inadequate for understanding regional economic change, where shocks frequently reveal or accelerate pre-existing structural weaknesses rather

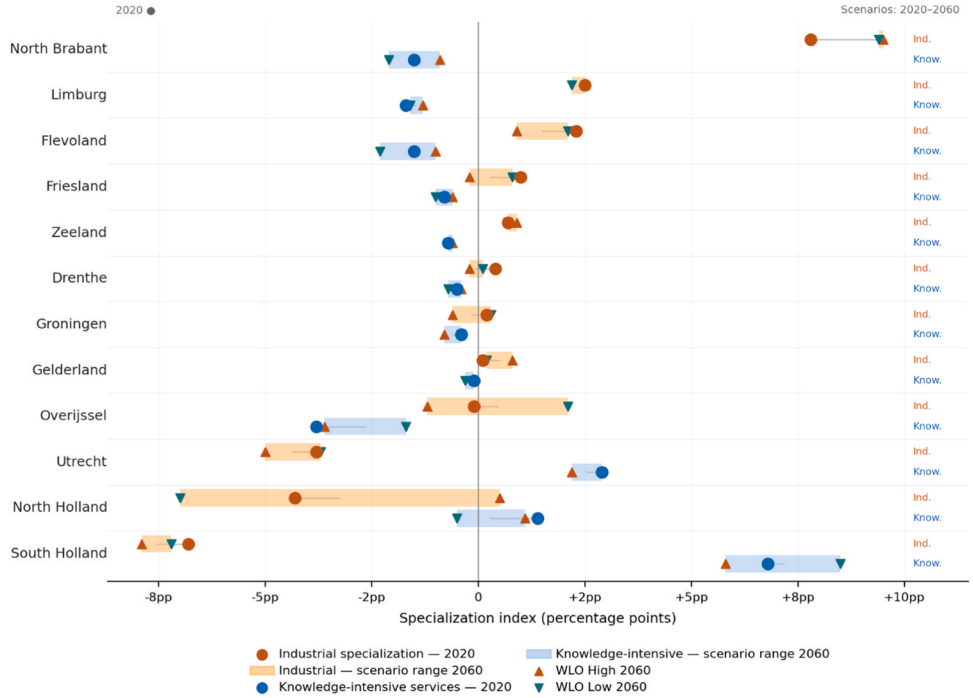


Fig. 5. Difference between share of region in industrial and knowledge intensive services employment and in total employment, in percentage points.

than constituting discrete, reversible events (Pike et al., 2010). More recent scholarship has therefore shifted toward an evolutionary perspective, conceptualizing resilience as "bouncing forward," meaning the capacity of regions not merely to recover but to adapt their economic structures, institutions, and capabilities in response to changing external conditions (Simmie & Martin, 2010; Boschma, 2015). This adaptive view aligns closely with the concept of regional path plasticity developed by Hassink (2010), which emphasizes that resilient regions are those capable of diversifying into related activities and building new growth paths rather than becoming locked into declining industrial structures.

Applied to the Dutch context, this paper argues that resilience cannot be assessed in isolation from the global macroeconomic developments within which a region operates: the same province may face an absorptive resilience challenge under one scenario and a transformative one under another, requiring fundamentally different policy responses.

This sectoral divergence maps onto a clear regional typology. A first group, comprising the knowledge-economy hubs of Zuid-Holland, Utrecht, and Noord-Holland, faces growth management as its primary challenge under WLO High. These provinces are projected to attract the largest shares of knowledge-intensive employment and production, yet their capacity to sustain this trajectory depends critically on resolving existing bottlenecks in housing, infrastructure, and skilled labor supply. Under WLO Low, this same group faces a more uncomfortable adjustment: Noord-Holland in particular shows a wide scenario range in industrial specialization, suggesting structural uncertainty about its long-run economic profile. This scenario sensitivity makes Noord-Holland a province where adaptive policy design rather than long-run structural commitment is most urgently needed. Locking the province into a single development path based on either scenario carries above-average downside risk.

A second group, comprising the industrial heartland provinces of Noord-Brabant, Limburg, and to a lesser extent Zeeland and Overijssel, faces an inverse challenge. Under WLO High, these regions experience continued deindustrialization, with industrial employment shares declining sharply toward single digits. Under WLO Low, however, they emerge as the primary beneficiaries of reshoring and strategic autonomy dynamics, with Noord-Brabant's industrial employment share potentially recovering to over 20% by 2060. The resilience challenge here is not managing rapid growth but preparing for a structural transition that may or may not materialise depending on global trade trajectories.

A third group, comprising the demographically vulnerable northern and peripheral provinces of Groningen, Friesland, and Drenthe, faces the most difficult outlook across both scenarios. Employment growth is projected to be the slowest in the country, and under WLO Low, employment growth turns negative. These provinces have the narrowest economic base to absorb shocks, and their resilience cannot be addressed through market mechanisms alone.

A fourth group, less clearly bounded but analytically distinct, consists of provinces undergoing emerging structural transition: Flevoland and Gelderland. Unlike the established industrial heartland of Noord-Brabant and Limburg, these provinces are not historically defined by manufacturing, yet the model projects relatively strong GDP growth under WLO Low as a result of growing industrial specialization. From a resilience perspective, this emergent trajectory is double-edged: it represents an opportunity for economic diversification but also a source of structural vulnerability, as the growth path depends heavily on a global deglobalization dynamic that is by definition scenario-contingent. Policy frameworks for these regions should focus on building absorptive capacity, ensuring that emerging industrial clusters are sufficiently embedded in local supply chains and skills ecosystems to be sustainable under either scenario, rather than dependent on a single external condition.

These findings carry concrete policy implications. First, there is a case for distinguishing between no-regret investments, meaning those warranted regardless of which scenario materialises, and scenario-contingent ones. Investments in housing and public transport capacity in the Randstad metropolitan regions fall in the former category: both scenarios project continued concentration of knowledge-intensive activity there, and infrastructure deficits will be binding constraints in either future. Similarly, broadband and digital infrastructure in the northern provinces represents a low-regret intervention given their vulnerability under all scenarios.

A further no-regret observation concerns the role of public services as a structural resilience anchor across the provincial typology. Healthcare and education demand grows under both scenarios as a result of demographic ageing, making public services employment relatively robust to trade and productivity shocks. In peripheral provinces with limited private-sector diversification, maintaining adequate public services capacity is not merely a social policy objective but an economic resilience strategy: it sustains local employment and household income in environments where market-driven growth is weakest. This argues for protecting public services investment in peripheral regions against fiscal consolidation pressures that might arise under WLO Low conditions, precisely at the moment when those regions are most economically vulnerable.

Scenario-contingent investments require a different logic. Vocational retraining programmes oriented toward advanced manufacturing in Noord-Brabant and Limburg are highly valuable under WLO Low but carry significant opportunity costs under WLO High. This argues for designing adaptive policy instruments, meaning funding mechanisms and institutional frameworks that can be scaled up or redirected as global trade conditions become clearer over the 2020 s and 2030 s. The EU-EMS framework developed here is well-suited to support this kind of rolling scenario assessment, and we recommend its periodic updating as new baseline data become available.

The model results also carry an implicit inter-regional dimension that merits acknowledgement. The concentration of knowledge-intensive employment growth in the Randstad under WLO High does not occur in a vacuum: it is partly sustained by labor inflows from other provinces, as wage differentials and employment opportunities attract skilled workers from peripheral and intermediate regions. For Groningen, Friesland, and Drenthe in particular, the strong Randstad growth under WLO High may compound rather than counteract their own employment weakness, by accelerating the outmigration of working-age skilled labor. Resilience policy for peripheral provinces therefore cannot be designed purely in terms of local economic conditions; it must account for the inter-regional competitive dynamics that a concentrated national growth path generates.

Several limitations of this study warrant acknowledgement. The NUTS2 spatial resolution conceals substantial intra-provincial heterogeneity: the economic profile of Eindhoven differs markedly from the rural parts of Noord-Brabant, yet both are captured within a single regional unit. Future research should explore downscaling these projections to NUTS3 or functional urban area level to better inform local planning decisions. Additionally, the WLO scenarios do not explicitly model the economic implications of the energy transition and climate adaptation investments, which are likely to reshape the sectoral composition of Dutch regions in ways that cut across both high and low-growth trajectories. Integrating these dynamics into the CGE framework represents a productive avenue for future work.

In sum, this paper argues that Dutch regional resilience is not a single condition but a family of distinct challenges that vary by provincial context and scenario. Effective policy must be geographically differentiated, scenario-aware, and institutionally flexible, built not around the assumption of a single future, but around the capacity to adapt as uncertainty resolves.

Operationally, this paper measures resilience in a comparative cross-scenario sense. A region is considered more resilient if its economic performance in terms of employment growth, production value, and sectoral diversification is relatively robust across both the High and Low scenarios, rather than dependent on a single favorable structural

trajectory. This definition corresponds to what the literature terms "adaptive resilience" (Boschma, 2015) or "robustness across scenarios" (Wardekker et al., 2012), understood as the capacity to sustain core economic functions under contrasting structural conditions rather than to return to a specific pre-shock equilibrium. We acknowledge that this approach does not capture dynamic adjustment processes such as impulse responses to discrete shocks, recovery speed, or short-run reallocation, which would require a different modeling framework oriented toward disequilibrium dynamics. The scenarios provide structural baselines rather than shock-and-recovery simulations, and the resilience assessment is correspondingly structural: it identifies which regional economies are inherently better positioned for long-run adaptation, rather than measuring recovery capacity from a defined disturbance.

CRediT authorship contribution statement

Ivanova Olga: Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Data curation. **Theodoros Chatzivasileiadis:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Kristian Bakker:** Writing – review & editing, Visualization, Formal analysis. **Sacha den Nijs:** Writing – review & editing, Writing – original draft, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Annex I. : Description of the EU-EMS model

Overview of the modelling system

EU-EMS is a spatial computable general equilibrium (SCGE) model build by PBL Netherlands Environmental Assessment Agency that includes the representation of 62 countries of the world and one Rest of the world region. The model uses database for 2018 that has detailed regional dimensionality for EU28 countries and includes them as consisting of 276 NUTS2 regions. Sectoral and geographical dimensions of the model are flexible and can be adjusted to the needs of specific policy or research question.

The model is used for policy impact assessment and provides sector-, region- and time-specific model-based support to Dutch and EU policy makers on structural reforms, growth, innovation, human capital and infrastructure policies. The current version of EU-EMS covers 276 NUTS2 regions of the EU28 Member States and each regional economy is disaggregated into 63 NACE Rev. 2 economic sectors.

The regional Social Accounting Matrices used to calibrate the EU-EMS model are drawn from the interregional Supply and Use table database constructed for all 276 EU28 NUTS2 regions by Thissen et al. (2019). This dataset provides a system of multiregional input-output tables in which interregional and cross-border trade flows in goods and services are estimated from freight transport data, airline flight data, and business travel data, using a probability-based methodology that avoids imposing a prior geographical structure on the data. The resulting tables capture the full set of sectoral interdependencies and inter-regional trade linkages at NUTS2 resolution, making them the primary empirical foundation for the spatial trade structure of the EU-EMS model.

Goods and services are consumed by households, government and firms, and are produced in markets that can be perfectly or imperfectly competitive. Spatial interactions between regions are captured through trade of goods and services (which is subject to trade and transport costs), factor mobility and knowledge spill-overs. This makes EU-EMS particularly well suited for analyzing policies related to human capital, transport infrastructure, R&I and innovation.

The model represents a real economy with no inflation or banking sector. There is no monetary authority in the model. All prices in the model are relative prices and calculated in terms of the numeraire. A GDP deflator is used as the numeraire in the model. Because there is no banking sector in the model the economic agents do not have the possibility to borrow money and the interest rate is fixed exogenously in the model.

The model utilizes the notion of the aggregate economic agent. They represent the behavior of the whole population group or of the whole industrial sector as the behavior of one single aggregate agent. It is further assumed that the behavior of each such aggregate agent is driven by certain optimization criteria such as maximization of utility or minimization of costs. The model is neo-classical and assumes average costs pricing and no excess profits. The excess profits are normally due to the existence of monopoly or oligopoly on the market. Normal profits of the firms are paid in the form of dividends (return to capital) to the households who own all capital goods in the economy.

Modelling of labour and capital flows in the model is strongly influenced by the data availability. There is no data about these flows at NUTS2 level for the whole of EU. Migration data are available for intra-country migration at NUTS2 level; hence we model only intra-county bi-regional migration flows. Capital flows (FDI) data are available only at the country level; hence we model country-to-country flow of capital. At the country level we model a pool of the total investments which consists partly of domestic savings and partly of savings coming from other EU country and from RoW. This pool is further redistributed by the investment bank between the regions and sectors in the form of physical capital investments according to a certain investment rule.

The modelling of interregional trade flows is also influenced by data availability. The only data available at EU-wide level is the data on the total origin-destination flow of commodities between the regions by type of commodity. There is no information about the trade between the regions in services. There is also no information about differences in the geographical mix of the commodities bought by different sectors and households in the region. Then lack of data results in a simplified structure of the model, where we assume no trade in services between the regions. We also assume that there is no difference in the geographical mix of the commodities bought by various sectors and households in a particular region… Given this assumption, it is possible to represent the decisions of both sectors and households about buying commodities from a particular region of EU as the decision of a representative agent called “wholesaler”. There is one wholesaler per region and per commodity type, who decides upon the geographical mix of commodities. Regional households and sectors further use the composite commodity, which is produced by the wholesaler. In this way both production sectors and households use the same geographical mix.

The model includes the representation of the micro-economic behavior of the following economic agents:

- At the regional level - several types of households differentiated by five income quintiles, production sectors differentiated by NACE95 classification categories; regional governments; wholesalers differentiated by NACE95 classification categories;
- At the national level - investment banks; federal governments and external trade sector.

Each household group in the model consists of the individuals differentiated by three types of education levels.

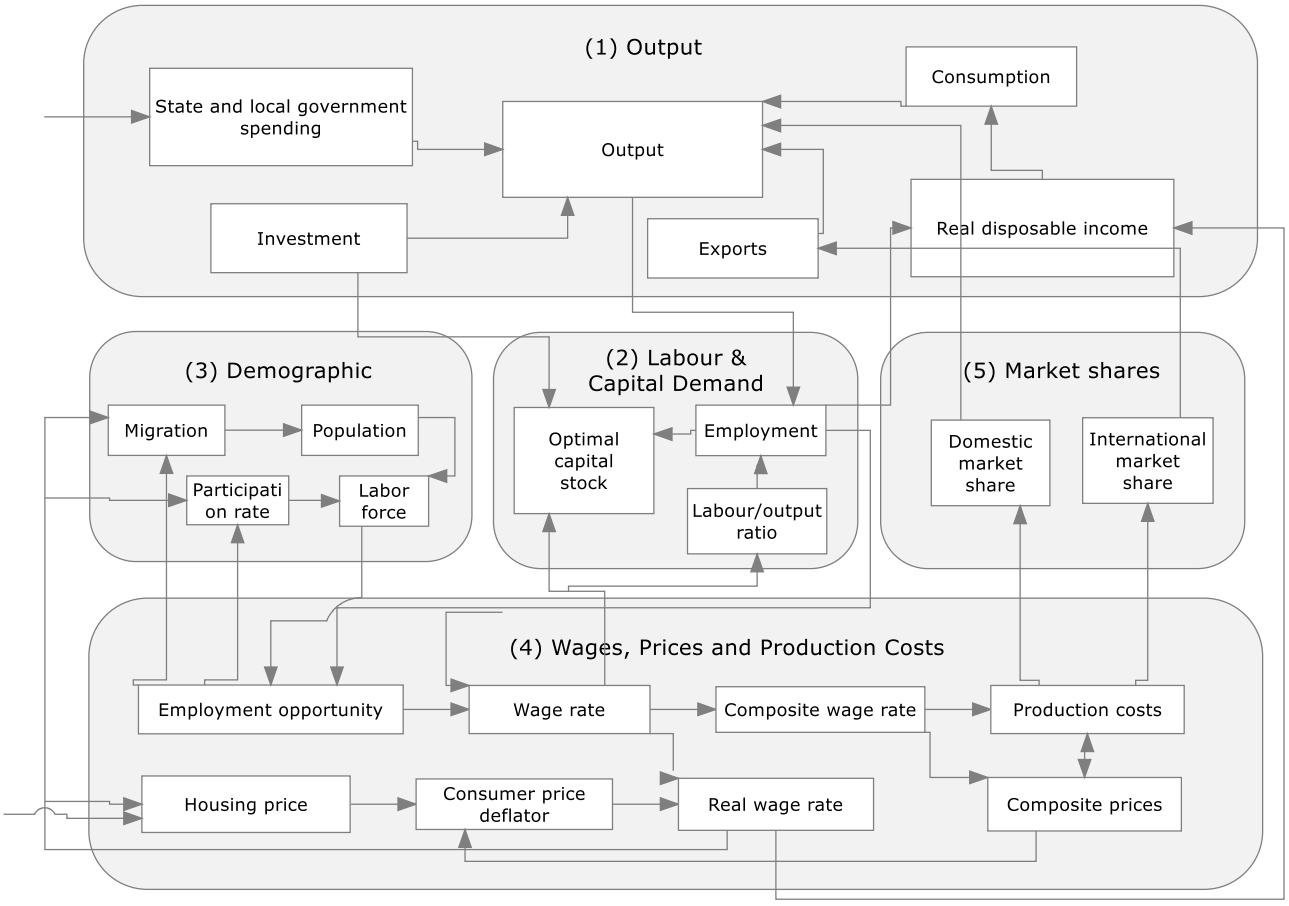


Fig. 6. Links between different part of the model

In the sections below we present the main equations that represent the core of the EU-EMS spatial CGE model. We first discuss the modelling of household preferences, and subsequently firm behavior, international and interregional trade, labour markets, capital markets, good markets and recursive dynamics.

Household preferences and governmental sector

The households' and governmental demand for goods and services is represented by the generally used linear expenditure (LES) system that is derived as a solution to the Stone-Geary utility maximization problem:

$$U_r = \prod_i (C_{ri} - \mu_{ri})^{\gamma_{ri}} \tag{1}$$

The resulting demand system C_{ri} of household in region r for good i where I_r denotes households' disposable income and P_{ri} are consumer prices of goods and services that include taxes, subsidies, transport and trade margins can be written as follows

$$C_{ri} = \mu_{ri} + \gamma_{ri} \cdot \frac{1}{P_{ri}} \cdot \left(I_r - \sum_j \mu_{rj} \cdot P_{rj} \right) \tag{2}$$

Households always consume a certain minimum level of each good and services $\mu_{ri}$where this level reflects the necessity of the good or service that determines the price elasticity. Necessities such as food have low price elasticity and hence a higher minimum level of consumption. The disposable income of the households equals its total expenditures and household's savings. This disposable income consist of wages, return to local capital, social transfers from the government minus the income taxes. $\gamma_{ri}$is the households preference parameter for certain goods and services, making the demand for goods and services linear in the total demand less necessities.

The government levies production, consumptions and income taxes. This tax revenue is used for social transfers and the purchase of goods and services for public consumption that includes investments.

Firms behaviour

Firms are assumed to maximize their profit (or minimize their costs) given domestic production X^D_{ri} using a nested-CES production technology of KLEM type, where K is the capital, L is the labour, E is the energy and M is the materials (intermediate goods used in production).. Fig. 3 represents the nests in the KLEM production function used in the model with the rest of the production inputs being used according to the fixed Leontief input coefficients in the production process. The energy in the model is differentiated between electricity and other types of energy with some substitution possibilities between them. The labour is differentiated according to three education levels according to International Labour Organization (ILO) classification.

The domestic production is generated according to nested production CES function that is described by the following set of composite CES functions that follow the production structure from top to the bottom nest[4]

$$X^D_{ri} = \left[(a_{ri}\cdot M_{ri})^{\rho_{M,KLE}} + ((1-a_{ri})\cdot KLE_{ri})^{\rho_{M,KLE}}\right]^{1/\rho_{M,KLE}} \tag{3}$$

$$KLE_{ri} = \left[(b_{ri}\cdot E_{ri})^{\rho_{E,KL}} + ((1-b_{ri})\cdot KL_{ri})^{\rho_{E,KL}}\right]^{1/\rho_{M,KLE}} \tag{4}$$

$$KL_{ri} = \left[(c_{ri}\cdot K_{ri})^{\rho_{K,L}} + ((1-c_{ri})\cdot L_{ri})^{\rho_{K,L}}\right]^{1/\rho_{K,L}} \tag{5}$$

$$E_{ri} = \left[\left(d_{ri}\cdot E^{NELEC}_{ri}\right)^{\rho_E} + \left(\left(1-d_{ri}\right)\cdot E^{ELEC}_{ri}\right)^{\rho_E}\right]^{1/\rho_E} \tag{6}$$

$$L_{ri} = \left[\sum_e \left(f_{rie}L^{ED}_{rie}\right)^{\rho_L}\right]^{1/\rho_L} \tag{7}$$

Where a_{ri}, b_{ri}, c_{ri}, d_{ri} and f_{rie} are the share parameters of the corresponding production function nests and $\rho_{M,KLE}$, $\rho_{E,KL}$, $\rho_{K,L}$, ρ_E and ρ_L represent the substitution possibilities for each of the production function nests in sector i in region r. The inputs into the production are denoted as M_{ri} input of materials, KLE_{ri} composite capital-labor-energy nest,E_{ri} energy inputs,KL_{ri}composite capital-labor nest, K_{ri} capital input, L_{ri}labor input, E^{NELEC}_{ri}input of non-electric energy, E^{ELEC}_{ri}input of electric energy and L^{ED}_{rie} inputs of labor by type of education e.

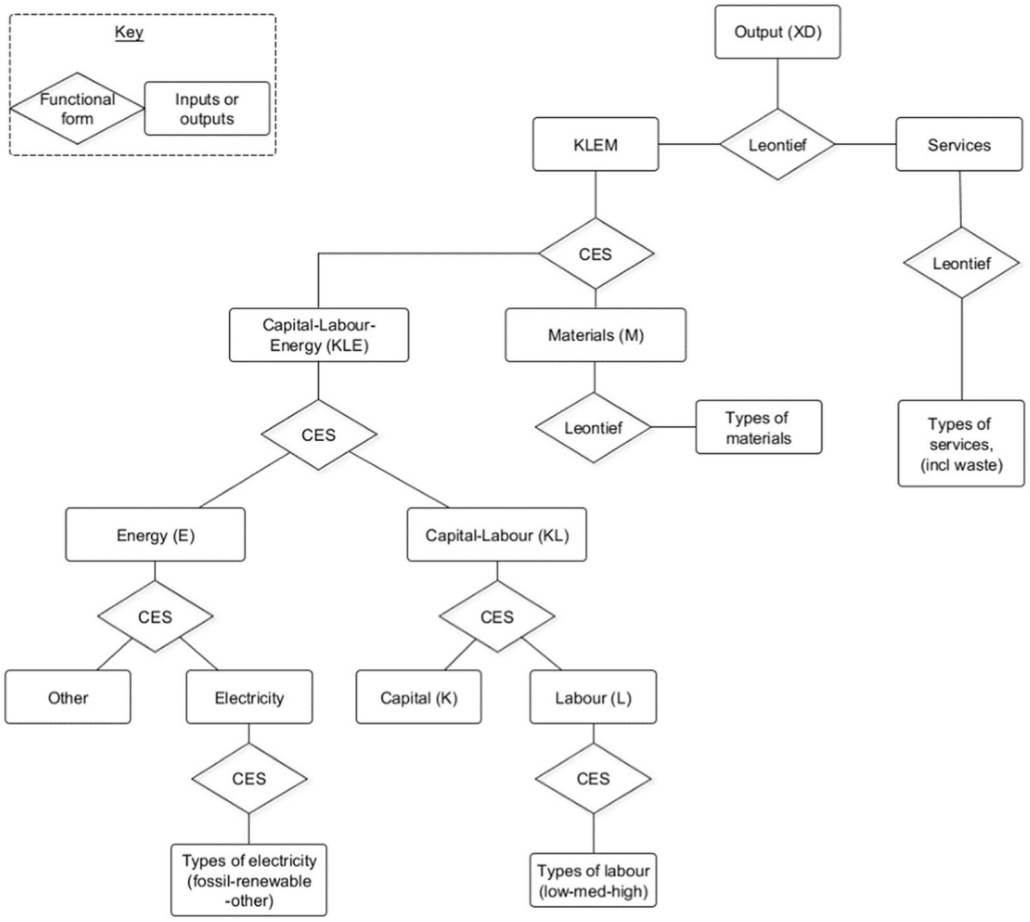


Fig. 7. Structure of KLEM production functions in the model

[4] Substitution elasticities in the production function are only sector specific and not differentiated between regions

International and inter-regional trade

The total sales X_{ri} of tradable goods and services i in region r in the model is an Armington Constant Elasticity of Substitution (CES) composite between domestic output $X_{ri}^{D}$and imports X_{ri}^{M}such that

$$X_{ri} = \left[\left(\alpha_{ri}^{D}.X_{ri}^{D}\right)^{\rho_i} + \left(\alpha_{ri}^{M}.X_{ri}^{M}\right)^{\rho_i}\right]^{1/\rho_i} \tag{8}$$

Where $\alpha_{ri}^{D}$and α_{ri}^{M} are the calibrated share parameters of the CES function and $\rho_i = \frac{\sigma_i - 1}{\sigma_i}$ with $\sigma_i$being the Armington elasticity of substitution between domestic and imported tradable goods and services. The elasticity of substitution varies between different types of goods and services depending on the available empirical estimates. In case of non-tradable the composite is equal to the domestically produced product.

Imported goods can come from various regions and countries represented in the model, and the composite imported goods and services are represented by CES composite that uses a higher Armington elasticity of substitution as compared to the upper Armington nest. We assume as in the GTAP model that the elasticity of substitution between the same type of goods and services coming from different countries is twice as large as the elasticity of substitution between domestic and aggregate imported goods and services. The aggregate imported good demand function is determined according to the following composite CES function

$$X_{ri}^{M} = \left[\sum_{s}\left(\alpha_{sri}^{T}X_{sri}^{T}\right)^{\rho_i^T}\right]^{1/\rho_i^T} \tag{9}$$

Where α_{sri}^{T} is the calibrated share coefficient of the CES production function,X_{sri}^{T} is the flow of trade in commodity i from country $s$to country r.The coefficient $\rho_i^T = \frac{\sigma_i^T - 1}{\sigma_i^T}$ where $\sigma_i^T$is the elasticity of substitution between commodities produced in different countries.

Labour, capital and goods markets

Market equilibrium in the economy results in equalization of both monetary values and quantities of supply and demand. Market equilibrium results in equilibrium prices that represent in case of CGE models the solution to the system of nonlinear equations that include both intermediate and final demand equations as well as accounting constraints that calculate households' and government incomes, savings and investments as well as trade balance. EU-EMS model represents a closed economic system meaning that nothing appears from nowhere or disappears into nowhere, everything is made by someone and paid for by someone else. This feature of the CGE model constitutes the core of the Walrasian equilibrium. Since all production is paid for and all income earned is spend the system allows for one equation to be skipped from the model without affecting the solution and ensures that even if one excludes any single equation of the model it will still hold. This is the property of CGE models called Walras law that tells us that in the closed economic system if n−1 markets are in equilibrium the last n^{th} market will also be in equilibrium. The counterpart of skipping an equation is that also an endogenous variable can be fixed. This is commonly a price in the model. All outcomes of the model will be relative to this price (the numerair).

In our EU-EMS model the static equilibrium is described by the set of commodity and factor prices, total outputs, final demands of households and government, investments, savings and net transfers from abroad such that (1) markets for goods and services clear, (2) total investments equal total savings, (3) total households' consumption is equal to their disposable income minus savings, (4) total governmental consumption is equal to its net tax revenues minus transfers to households minus savings, (5) total revenue of each economic sector is equal to its total production costs and (6) difference between imports and exports is equal to the net transfers from abroad.

Recursive dynamics

EU-EMS is a dynamic model and allows for the analysis of each period of the simulation time horizon. This horizon is currently set at 2060 but it can be extended to longer time periods. For each year of the time horizon, EU-EMS calculates a set of various economic, social and environmental indicators. The economic growth rate in EU-EMS depends positively on investments in R&D and education. By investing in R&D and education each region is able to catch up faster with the technological leader region and better adopt its technologies.

Time periods in EU-EMS are linked by savings and investments. By the end of each time period, households, firms and government in the model save a certain amount of money. This money goes to the investment agent, distributing it as investments between the production sectors of the various regions. The allocation decisions of the investment bank sectors depend on the sector's financial profitability. The model runs in time steps of five years for the period 2015–2060.

The capital stocks evolve according to the dynamic rule presented below, where the capital stock in period t is equal to the capital stock in period t−1 minus the depreciation plus the new investments into the capital stock

$$K_{tri} = K_{t-1ri}(1 - \delta_i) + I_{tri}. \tag{10}$$

At the end of each period there is a pool of savings S_r available for investments into additional capital stocks of the sectors. This pool of savings comes from households, firms and foreign investors. Savings of households are proportional to their net income, savings of the government are fixed in the model and the savings of firms are equal to their annual depreciation. We assume that along the equilibrium path investments are equal to the savings of the previous period, hence savings determine investments in the model.

The sector investments I_{tri} are derived as a share of the total savings in the economy according to the discrete choice formula that is homogenous of degree zero in prices

$$I_{tri} = \frac{ST_{t-1r} B_{ri} K_{t-1ri} e^{\vartheta \cdot WKR_{t-1ri}}}{\sum_j B_{rj} K_{t-1rj} e^{\vartheta \cdot WKR_{t-1rj}}}. \quad (11)$$

with

$$WKR_{t-1ri} = \frac{r_{t-1ri}}{PI_{t-1r}} \cdot (g_r + \delta_{ri}). \quad (12)$$

Where WKR_{t-1ri} denotes the capital remuneration rate, $g_r$the steady-state growth rate, $B_{ri}$the calibrated gravity attraction parameter and $\vartheta$the speed of investment adjustments.

Estimation and projection of sectoral TFP

The sectoral total factor productivity (TFP) trajectories that drive structural change in the EU-EMS simulations are not assumed but econometrically estimated and projected, following a three-step procedure: (i) sectoral TFP is computed from historical data; (ii) its determinants are estimated; and (iii) the estimated relationships are combined with national TFP projections from the MaGE–CEPII model in a constrained nonlinear system that distributes the national trajectory across sectors. The procedure is summarised here; the full estimation and results are reported in PBL (2025b).

Sectoral TFP and its determinants are constructed from the EUKLEMS & INTANProd database (Bontadini et al., 2023) over 1995–2020 for fifteen EU, UK, US and Japanese economies, aggregated to eleven sectors. Three determinants enter the analysis, all measured quantitatively: tertiary education (the share of the active population with tertiary attainment, a proxy for the quality of human capital), R&D (real research-and-development capital), and the OECD Product Market Regulation (PMR) indicator (Koske et al., 2015), where higher values denote more restrictive regulation and weaker institutional quality.

For each sector *s*, the log of TFP is estimated as a function of its determinants with country fixed effects:

$$\ln TFP_{i,s,t} = \alpha_s + \beta_1 Education_{i,t} + \beta_2 \ln R\&D_{i,t} + \beta_3 PMR_{i,t} + \eta_i + \varepsilon_{i,t} \quad (13)$$

where *i* indexes countries and *t* years, η_i is the country fixed effect, and ε_{it} the error term. The model is estimated by IV-GMM (2SLS), instrumenting education and R&D with their one-period lags to address endogeneity, with standard errors clustered by period. The estimated coefficients (Table A.1) are sector-specific elasticities of TFP to human capital and innovation, and differ markedly across sectors. We find positive and significant for high- and low-tech manufacturing and utilities, negative for mining, which is what generates divergent sectoral responses to the same national scenario.

Table 2
Sectoral TFP determinant estimates

Sector	Education	ln R&D	PMR	Constant	Obs.
Agriculture	0.00268	0.157**	−0.0897***	348	Agriculture
Community	0.00924***	−0.405***	0.0533***	348	Community
Construction	−0.00846***	0.00639	0.0553***	348	Construction
Government	0.00178	−0.216***	−0.00189	348	Government
High_Tech	0.0202***	0.322**	−0.117***	347	High_Tech
Low_Tech	0.00914***	0.319***	−0.0470**	347	Low_Tech
Mining	−0.0234***	−0.462***	0.135**	348	Mining
Services	0.0208***	−0.147***	0.0359***	348	Services
Transport	0.0170***	0.122	−0.0135	348	Transport
Utilities	0.0488***	0.621***	0.398***	323	Utilities
Wholesale	0.000277	−0.362***	−0.0840***	348	Wholesale

Notes: dependent variable is sectoral ln TFP. IV-GMM (2SLS) with country fixed effects; education and ln R&D instrumented by one-period lags; standard errors clustered by period. *** $p < 0.01$, ** $p < 0.05$. PMR is the OECD Product Market Regulation indicator. Sample 1995–2020, 15 economies

.

National labour-productivity growth is taken from the MaGE–CEPII model (Fontagné et al., 2022), recalibrated to the WLO storylines, and set to 1.5% per year under WLO High (SSP1) and 0.4% per year under WLO Low (SSP3), consistent with the main text. The estimated elasticities are used to distribute this national trajectory across sectors within a constrained nonlinear system following the logic of Leibman et al. (1992), subject to the requirement that the value-added-weighted sum of sectoral TFP reproduces the national level in every period:

$$TFP^{macro}_{i,t} = \sum_s w_{s,t}\, TFP_{i,s,t}, \sum_s w_{s,t} = 1 \quad (14)$$

where $w_{s=t}$ is the value-added share of sector *s*. A correction term reconciles the econometric sectoral levels with the MaGE national trajectory, guaranteeing that the projection is simultaneously consistent with the estimated determinant relationships and with the aggregate national path. The determinants are extrapolated to 2060 along the scenario lines in Table A.2; the resulting sectoral TFP paths are then mapped from the eleven estimation sectors onto the twenty EU-EMS sectors and allocated across the twelve provinces using CBS provincial data, forming the technological input to the simulations reported in the main text.

Table 3
Scenario assumptions for the TFP determinants, 2020–2060

Driver	SSP1 (WLO High)	SSP3 (WLO Low)
Tertiary education	+30%	—30%
R&D	+50%	—50%

(*continued on next page*)

Table 3 (*continued*)

Driver	SSP1 (WLO High)	SSP3 (WLO Low)
OECD PMR (regulatory restrictiveness)	−50%	+50%
Population and educational attainment	IIASA	IIASA
National labour-productivity growth	1.5%/yr (MaGE–CEPII)	0.4%/yr (MaGE–CEPII)

Notes: determinant extrapolations follow the WLO 2025 storylines (PBL 2025b) and correspond to the scenario specification in the main text; population and educational attainment are taken from IIASA and Eurostat EUROPOP2023. National labour-productivity growth (1.5%/0.4%) is the constraint to which the value-added-weighted sum of sectoral TFP is calibrated.

Table 4
Netherlands: sectoral TFP deviation from the constant−2020 baseline in 2060

Sector (EU-EMS grouping)	SSP1 (WLO High)	SSP3 (WLO Low)
Energy and utilities	+50.8%	−49.4%
High-value manufacturing	+44.7%	−44.3%
Basic and other industry	+24.7%	−33.5%
Transport and storage	+18.2%	−23.0%
Agriculture	+11.7%	−22.1%
Knowledge-intensive and business services	+8.4%	−9.9%
Public services (administration, health, education)	−9.1%	+9.4%
Trade	−12.4%	+19.3%
Construction	−13.1%	+7.4%
Hospitality, culture and other services	−13.9%	+23.0%
Mining	−41.9%	+91.8%

Notes: percentage deviation of scenario TFP from baseline TFP in 2060, where the baseline holds each sector's TFP at its 2020 level. National figures; the same sectoral TFP path applies to all twelve provinces, so regional differentiation in the main results arises from sectoral composition rather than from province-specific TFP. Detailed EU-EMS sectors sharing an estimation aggregate are grouped.

For the Netherlands, the two scenarios imply sharply contrasting sectoral technology paths (Table A.3). Under WLO High, sectoral TFP rises most in energy and utilities (+51%) and high-value manufacturing (+45%), with further gains in basic and other industry, transport and agriculture, while mining (−42%) and the more domestically-oriented sectors such as construction, trade, hospitality and public services that fall relative to baseline. Under WLO Low the pattern broadly reverses: mining rises steeply (+92%) and domestically-oriented sectors gain modestly, whereas high-value and basic manufacturing (−34% to −44%), energy and utilities (−49%) and knowledge-intensive services contract. These are productivity (TFP) changes: under WLO Low the lower manufacturing TFP coexists with a rising manufacturing share of output and employment in the main results, as reshoring and higher trade costs shift production back toward Europe despite weaker technological progress. The divergent sectoral TFP trajectories are the proximate technological driver of the structural change explored in the EU-EMS scenarios.

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