A Structural Model Based Evaluation of Digital Innovations for Sustainable Resource Management

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Abstract

The research question relates to the quantitative impact of digitalization on sustainable resource management. A New Keynesian model is extended by the factor of sustainable resource management in production and in the utility function of the household. Digitalization is assumed to be capital augmenting. The marginal effect of an unexpected 20 percent increase in digitalization is a rise of 4 percent at maximum. The quantitative effect in perfect foresight of the digitalization process, which affects 20 percent of the capital stock from the years 2023 to 2027, is over 6.17 percent around the first quarter of 2026.

Keywords: Digitalization, Sustainable Resource Management, Production, New Keynesian model

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1 Introduction

The research question is the quantitative impact of digital innovations on sustainable resource management. Instead of providing a literature review based on existing estimates, a micro founded model is extended to evaluate the effects and intersections of a bulk of economic variables and to come up with a quantitative estimate for the research question. The model applied is a New Keynesian DSGE model with the extension of sustainable resource management in the constant returns to scale, Cobb-Douglas production function. To introduce sustainable resource management as a factor of production with a price attached to both households and firms is derived from the discussion on the intensity of land utilization with its price, with reference to TUM@Freising (2023). Additional references are Hubacek and van den Bergh (2002) who elaborate the conceptualization of land in economics and Solow (1973) for the production function with natural resources. The additional factor of production might be interpreted as capturing characteristics of both the use of land and human resources, as the list of activities subsumed under the management in Eurostat (2024) reveals. Besides the distinguished input of production, the consumers assign a specific value to the sustainable resource management to form part of the utility function. The effects of digitalization on the sustainable resource management is gauged by an univariate process attached to the formation of physical capital in the economy, which is calibrated to the data observed for Germany on digitalization from dataset European Commission (2025). The corresponding analysis is twofold: firstly, the marginal effects of digitalization on the economy are displayed whereby participants did not expect an innovation to digitalization to occur. Secondly, the quantitative impact of the forecast digitalization process on the economy from the years 2023 to 2027 is computed. The assumption is a linear projection of the growth rate of digitalization in the end of year 2022. The results are the following: The marginal effect of an unexpected 20 percent increase in digitalization on sustainable resource management is roughly EUR 1.96 billion at its peak after two quarters. The quantitative effect in perfect foresight of the digitalization process on sustainable resource management from 2023 to 2027 is roughly EUR 3.02 billion at its peak around the first quarter of 2026.

The remainder of the paper is organized as follows: Section 2 summarizes the model. Section 3 outlines the calibration strategy, lists the parameter and the steady state values. Section 4 displays the Impulse Response Functions (IRFs) for the marginal effects of digitalization and the perfect forecast scenario from 2023 to 2027. Section 5 concludes.

2 New Keynesian Model with Digitalization and Sustainable Resource Management

The benchmark model is the New Keynesian model applied in Ireland (1997), Pichler (2008) and, closely related, Dürmeier (2016) and Dürmeier (2022). The economy is populated by households, intermediate goods and final goods producers as well as the central bank. Conventional monetary policy is described by the standard Taylor rule. The simplifying assumption of a representative agent for each of the actors in the economy applies. The intermediate goods producers face monopolistic competition in the markets of the respective inputs and price adjustment costs. The households incur capital adjustment costs in the investment decision. The model is extended by an additional variable of sustainable resource management in the utility function of the household, in the production function of the intermediate goods producer, by a digitalization process and by constant government spending.

2.1 Households

The representative household maximizes the utility function with respect to consumption c_t, money holdings m_t, labor h_t and sustainable resource management s_t,

$$\max U = \mathbb{E}_0 \sum_{t=0}^{T} \beta^t [\frac{c_t^{1-\tau} - 1}{1-\tau} + \chi_m log(m_t) + \chi_h(1-h_t) + \chi_s(1-s_t)], \tag{1}$$

where the subscript indicates the time period. β is the discount factor with the superscript of the time period. χ_m marks the preference for m_t, χ_s the one for sustainable resource management, χ_h the disutility from labor, $1-\tau$ the elasticity to consumption. The function is concave in c_t and m_t while linear in $1-h_t$ and $1-s_t$.

Utility is maximized subject to the cash flow:

$$\frac{m_{t-1}}{\pi_t} + \frac{b_{t-1}}{\pi_t} + w_t h_t + r_{k,t} k_t + p_{s,t} s_t + g_t + div_t + l_t - c_t - x_t - cac_t - m_t - \frac{b_t}{i_t} \geq 0, \tag{2}$$

w is the wage, $p_{s,t}$ the price of s_t, $r_{k,t}$ rent on capital k_t, x_t investment, cac_t quadratic adjustment costs of capital, b_t bond holdings with nominal interest rate i_t, π_t the rate of inflation, div_t the dividends and g_t public spending. κ is the cost parameter for the quadratic adjustment costs of capital $cac_t = (\kappa/2)(x_t/k_t - \delta)^2 k_t$. The lump-sum transfer $l_t = m_t - \frac{m_{t-1}}{\pi_t}$.

The law of motion for capital depends on investment,

$$x_t = k_{t+1} - (1-\delta)k_t, \tag{3}$$

where δ is the depreciation rate of capital at time t.

2.2 Final goods producer

The firms are split into producers of final and intermediate goods. The final goods producer is assumed to be perfectly competitive, i.e. all the profits are wiped out by competition. The final goods producer resorts to a constant returns-to-scale technology and use the intermediate goods $y_{j,t}$ as inputs where the intermediate goods producer is indexed by $j \in [0,1]$:

$$y_t = \left(\int_0^1 y_{j,t}^{\frac{\theta-1}{\theta}} \, dj \right)^{\frac{\theta}{\theta-1}}, \tag{4}$$

where θ is the elasticity of substitution between two intermediate inputs and y_t is the final output. Regarding the final good, the firm will not be able to produce as much if it has to substitute one input with another. In other words, the reshuffling of inputs consumes resources. Likewise, the imperfect substitutability gives the intermediate goods producer market power because each intermediate good producer is a monopolist in the market of the single input and can set the price accordingly.

The maximization problem with respect to $y_{j,t}$ reads:

$$\max \left[y_t p_t - \int_0^1 y_{j,t} p_{j,t} \, dj \right] = \max \left[\left(\int_0^1 y_{j,t}^{\frac{\theta-1}{\theta}} \, dj \right)^{\frac{\theta}{\theta-1}} p_t - \int_0^1 y_{j,t} p_{j,t} \, dj \right] \tag{5}$$

2.3 Intermediate goods producer

The representative firm maximizes the discounted value of expected real dividends div_t with respect to $k_{j,t}$, $s_{j,t}$, $h_{j,t}$ and $p_{j,t}$:

$$\max \mathbb{E}_0 \sum_{t=0}^{T} \beta^t \lambda_t div_t = \max \mathbb{E}_0 \sum_{t=0}^{T} \beta^t \lambda_t \left(\frac{p_{j,t} y_{j,t}}{p_t} - r_{k,t} k_{j,t} - w_t h_{j,t} - p_{s,t} s_t - pac_t \right), \tag{6}$$

with λ_t the Lagrangian multiplier from the budget constraint of the household, i.e. the shadow price of one unit of its additional wealth. $p_{j,t}$ denotes the price of the intermediate goods $y_{j,t}$, p_t the price of the final goods and pac_t quadratic price adjustment costs. The household works for the intermediate goods producer, provides physical capital and receives in turn the wage and the rent, respectively.

The firm faces the constraint of the constant returns-to-scale Cobb-Douglas production function,

$$y_{j,t} = (d_t k_{j,t})^{\alpha} s_{j,t}^{\gamma} h_{j,t}^{1-\alpha-\gamma}, \tag{7}$$

by which d_t is a capital augmenting digitalization process, α is the elasticity of output to $(d_t k_{j,t})$ and γ the elasticity of output to $s_{j,t}$, where $0 < \alpha < 1$, $0 < \gamma < 1$ and $\alpha + \gamma < 1$.

The firms are subject to quadratic price adjustment costs pac_t in line with Rotemberg (1982). Price changes are costly while the changes are compared to the steady state inflation $\bar{\pi}$. The underlying assumption is that, varying from industry to industry, price changes are costly, as customer relationships are destructed or due to menu costs. The costs adjusted for the general price level in the economy are:

$$pac_t = \frac{\phi}{2}(\frac{p_{j,t}/p_{j,t-1}}{\bar{\pi}} - 1)^2 y_t. \tag{8}$$

The optimal decision regarding the input price results in the New Keynesian Phillips Curve with price adjustment costs parameter ϕ and elasticity of substitution in between inputs θ:

$$0 = \frac{1}{c_t^{\tau}}[1 - \theta + \theta \frac{w_t h_t}{(1-\alpha-\gamma)y_t} - \phi(\frac{\pi_t}{\bar{\pi}} - 1)\frac{\pi_t}{\bar{\pi}}] + \beta E_t[\frac{1}{c_{t+1}^{\tau}}(\frac{\pi_{t+1}}{\bar{\pi}} - 1)\phi \frac{\pi_{t+1}}{\bar{\pi}} \frac{y_{t+1}}{\bar{y}}] \tag{9}$$

It is forward-looking due to the price adjustment costs. It features an expression for the costs of production in terms of labor, a gap in inflation, and additionally the expected deviations of both inflation and output from their steady states. In comparison to the standard New Keynesian model, the adjustment of the costs of production in terms of labor is done by $1/(1-\alpha-\gamma)$, owing to the change in the stochastic discount factor on the production constraint.

The optimality conditions for h_t, s_t, b_t and k_{t+1} yield the following conditions in the symmetric equilibrium after market clearing:[1]

$$\frac{p_{s,t}}{c_t^{\tau}} = \chi_s, \tag{10}$$

$$\frac{p_{s,t}}{c_t^{\tau}} = \frac{\beta}{(1-\alpha-\gamma)} \frac{w_t h_t}{s_t}, \tag{11}$$

$$\alpha w_t h_t = (1-\alpha-\gamma) r_{k,t} k_t, \tag{12}$$

Equation (10) states that the price of the resource management in terms of consumption units equals the preferences indicator which the household assigns to it. Equation (11) displays the inverse relationship in between the price in terms of consumption and the resource management. Like in the New Keynesian Phillips Curve, the discounting includes the elasticity of output to sustainable resource management, which is also visible in the condition (12) equalizing the marginal products of capital and labor.

[1] The remaining equilibrium conditions are as in Ireland (1997), Pichler (2008) and, closely related, Dürmeier (2016) and Dürmeier (2022). The Appendix lists all the equilibrium conditions.

2.4 Conventional Monetary Policy

Conventional monetary policy focuses on the policy rate which gets described by the policy rule with intertia with reference to Taylor (1993):

$$log(\frac{i_t}{\bar{i}}) = rho_i log(\frac{i_{t-1}}{\bar{i}}) + rho_y log(\frac{y_t}{\bar{y}}) + rho_\pi log(\frac{\pi_t}{\bar{\pi}}) + \epsilon_{i,t}, \tag{13}$$

$\bar{r_s}$, $\bar{y}$ and $\bar{\pi}$ are targets or steady state values and $\epsilon_{r,s,t}$ is a normal monetary shock with mean zero and standard deviation $\sigma_{r,s}$.[2]

2.5 Shocks

Aside the monetary policy shock, the process of digitalization is introduced which takes the shape of AR(1) processes in log deviation from the steady state in the stochastic case,

$$\log(d_t) = (1 - \rho_d) \log(\bar{d}) + \rho_d \log(d_{t-1}) + \epsilon_{d,t}, \tag{14}$$

where the disturbance $\epsilon_{d,t} \approx N(0, \sigma_d^2)$ and $\rho_d \in [0, 1)$. The innovation is normally distributed with the mean zero and the variance σ_d^2.

2.6 Public Sector

To obtain more realistic steady state values of the macroeconomic aggregates, g_t is introduced with

$$g_t = \bar{g} \tag{15}$$

with the bar above a variable denoting the steady state value, such that in steady state $\bar{y} = \bar{x} + \bar{c} + \bar{g}$ holds.

3 Parameter values and Steady States

3.1 The Digitalization Process

The process of digitalization, d_t, is constructed on the basis of the Digital Economy and Society Index (DESI) 2022 from dataset European Commission (2025), for Germany. The process of digitalization is attached to the factor of physical capital because it is interpreted in the model as affecting primarily the machinery, computer, information technology, automation systems and so forth. It is assumed to be capital augmenting. In the basic setting, the composite DESI is composed of 25.00 percent of each of

[2]The IRFs for the monetary policy shock are available upon request.

the following factors: Human Capital, Connectivity, Integration of Digital Technology, Digital Public Services. Arguably, at least the expenses on human capital are better interpreted as labor augmenting in the production function.[3] Firstly, to get quarterly data, the annual data is interpolated linearly. Secondly, the assumption of a linear extrapolation of the data from the year 2022 on towards 2027 is made:[4] The following graph shows the resulting process:

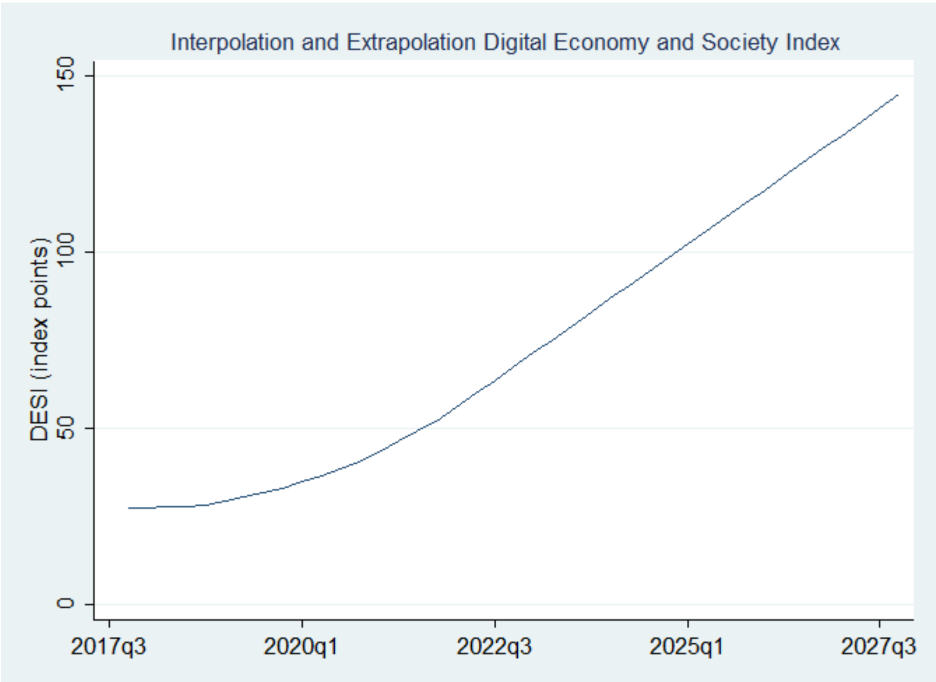

Figure 1: Interpolation and Extrapolation Digital Economy and Society Index

From equation (7) the question arises how much of the overall capital stock is fuelled due to digitalization. In the forecast scenario, it is accounted for that not all of the stock is affected. More specifically in the context of the digitalization process, what is the corresponding amount in terms of the capital stock? Due to lack of data, the critical assumption is made that 20 percent of the capital stock is affected by the digitalization process for the years 2023-2027. The adjustment downwards is pursued by multiplying the forecast growth rates in digitalization which correspond to the whole capital stock by 20 percent.[5]

[3]To be perfectly consistent with the model formulation, one would need to set the share of expenses on human capital to zero and adjust the remaining shares to apply accordingly to the input of capital. The adjustment with the use of additional data sources is out of the scope of the analysis.

[4]The extrapolated growth in digitalization at the end of the year 2022 is the highest in the sample. Obviously, it can be discussed whether the assumption is too optimistic or pessimistic. The statistical software Stata 12.0 is used.

[5]Consistently, the implementation is done via the growth rates based on the steady state level of 1 in Q4 2022. The equation of the digitalization process is listed in the Appendix. The computational software Dynare is used.

3.2 Parameter values

The parameter values in sequence are used from Pichler (2008):[6]

Table 1: Parameter Values

PARAMETER	*VALUE*
Taylor Rule coefficient inflation gap ρ_π	1.5
Taylor Rule coefficient output gap ρ_y	0.5
Taylor Rule coefficient interest rate lag ρ_i	0.7
Depreciation rate of capital δ	0.025
Elasticity of substitution between any two intermediate inputs θ	6
Elasticity to consumption τ	2
Capital adjustment costs parameter κ	10

The preference parameter for money holdings of 0.1 is close to the one calibrated in Dürmeier (2016), the time discount factor is at the standard value of 0.99. The price adjustment costs parameter of 30 is found by Angeloni and Faia (2010) to match the Calvo-Yun approach in the Rotemberg framework based on the frequency of price adjustment of four quarters. The remaining parameter values are amended or calibrated such that the steady state values are implied. As such, the elasticity of output to sustainable resource management is set to 0.01 to be roughly consistent with the share of sustainable resource management in production.

Table 2: Parameter Values (continued)

PARAMETER	*VALUE*
Preference parameter for money holdings χ_m	0.1

(Continued on next page)

[6] The values are for business cycle analysis based on US data. The corresponding calibration to German data is out of the scope of the analysis.

Table 2: (continued)

PARAMETER	*VALUE*
Time discount factor β	0.99
Price adjustment costs parameter ϕ	30
Preference parameter sustainable sustainable resource management χ_s	60
(Non-) preference parameter labor χ_h	4
Share of capital in production α	0.35
Standard deviation for the unexpected shock to digitalization σ_d	0.2
Persistence parameter in the unexpected shock to digitalization ρ_d	0.95
Elasticity of output to sustainable resource management γ	0.01

3.3 Steady States

The value of sustainable resource management in steady state $\bar{s}$, as an approximate value in 2022, is extracted from the dataset Eurostat (2025) of resource management activities (CReMA) within the environmental goods and services sector (EGSS) accounts. The list of activities include items such as management of water, forest areas, energy resources and minerals.[7] The source of data for GDP is dataset German Federal Statistical Office (2025). For Germany, the ratio to GDP evolves from approximately 0.0086 in 2014 to approximately 0.012 in 2021. $\bar{s}$ is below but close to 0.014 in 2022. The steady values (rounded to two decimals) of the macroeconomic aggregates are in ratio to GDP:

Table 3: Steady States

VARIABLE	*STEADYSTATE*
Production $\bar{y}$	1
Constant public spending $\bar{g}$	0.16
Wage income $\bar{w}$	1.6
Price sustainable resource management $\bar{p_s}$	24.06

(Continued on next page)

[7]The complete list of activities according to Eurostat (2024) is included in the appendix.

Table 3: (continued)

$VARIABLE$	$STEADY STATE$
Consumption $\bar{c}$	0.63
(Quarterly) rent on capital $\bar{r_k}$	0.035
Capital $\bar{k}$	8.36
(Quarterly) gross nominal interest rate $\bar{i}$	1.014
Sustainable resource management $\bar{s}$	0.014
Investment $\bar{x}$	0.21
Labor $\bar{h}$	0.33
Money holdings $\bar{m}$	2.88
(Quarterly) gross inflation rate $\bar{\pi}$	1.004
Dividends of intermediate goods producer $\bar{div}$	-0.16

When calibrated, the model delivers a remarkable result in the context of the sustainable resource management: in order to ensure its very low steady state value of close to 0.014, the preference of the household for that kind of management must be set to 60 in order to drive up the price of sustainable resource management sufficiently. The price level obtained is 24.06. That is, the households assign substantial value to the resource management and ask for a respective, very high compensation for it. In comparison to the average wage in the economy of 1.6, the required price of sustainable resource management is 15.04 times higher. A more accurate modeling would assign a larger role of public policy to the pricing of the resource management in Germany. The huge gap in prices is targeted by subsidy and/or tax policy, which affects the public debt level. Without any targeted fiscal policy, in equilibrium, the dividends of the goods producer are negative at the level of -0.16.[8] Given the remaining levels in equilibrium, it becomes clear that the factor of sustainable resource management with its price attached cuts the profits of the companies deeply.

4 Economic Analysis

4.1 IRFs Marginal Effects of Digitalization

The IRFs display the marginal effects for a 20 Percent increase in digitalization. By construction, the AR(1) process is attached to the overall capital stock. The IRFs are in deviation from steady state:

[8] The corresponding steady state ratio in Dürmeier (2016) is +0.09, in Dürmeier (2022) +0.16. Moreover, that level even accounts for the costs of raising funds in financial markets.

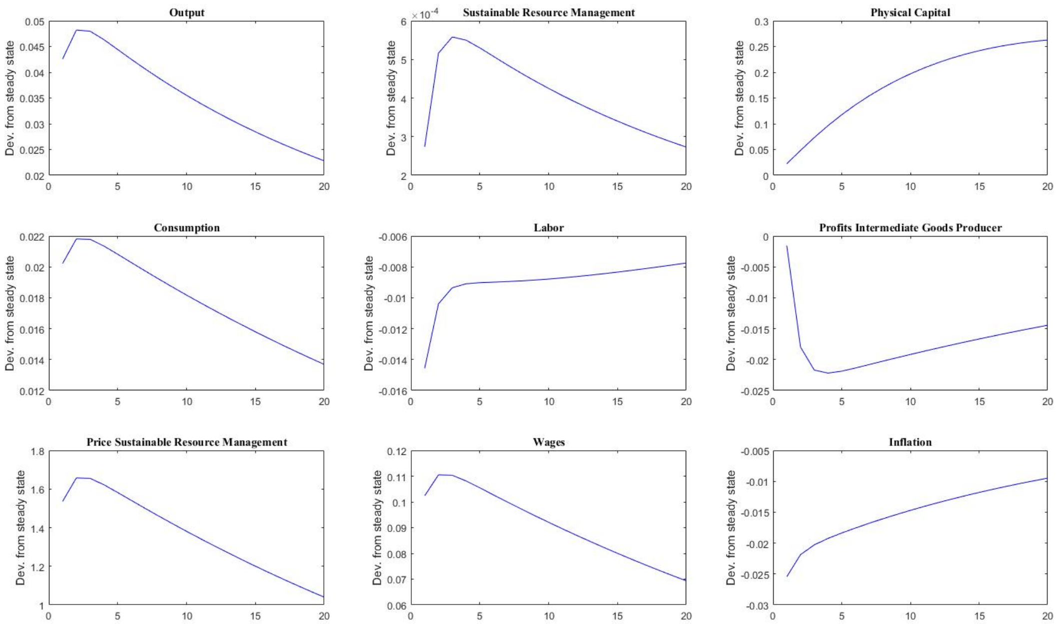

Figure 2: IRFs Marginal Effect of Digitalization

From the start, there is accumulation in physical capital associated with the digitalization process, which dissipates slowly with a persistence parameter of 0.95. The economy enjoys higher investment and capital stock is built up until the end of 20 quarters to reach its plateau at an increase of over 3 percent. In face of the higher wage level, consumption is spurred. The trajectory of output closely aligns with the one of consumption. The increase in output at its peak after two quarters amounts to 4.8 percent. The production sector weights the marginal product of capital against the one of labor. By the higher wage level, there is a drop in labor induced. Rearranging equation (11), a comovement of the factors of labor and sustainable resource management at constant equilibrium prices results, ceteris paribus. Nevertheless, the wage and consumption increases are of such an extent that the empirical result is a tradeoff in between labor and the sustainable resource management. The result even holds for the upward dynamics of the associated real price which curtails the activities surrounding sustainable resources. In other words, due to digitalization, employment is reduced while the activities gain pace. It rises by 4 percent at maximum after two quarters which amounts to roughly EUR 1.96 billion. By the drop in employment, the overall effect on inflation becomes negative, in spite of the higher trajectories of the remaining aggregates.

4.2 IRFs Quantitative Impact of Digitalization from 2023 to 2027

In sequence, the IRFs depict the effects when agents perfectly forecast the process of digitalization from 2023 to 2027. The linear projection after 2022 is equivalent to assuming that the agents simply project the same growth rate observed in the end of 2022 to pertain until the end of 2027. The responses are given in levels:

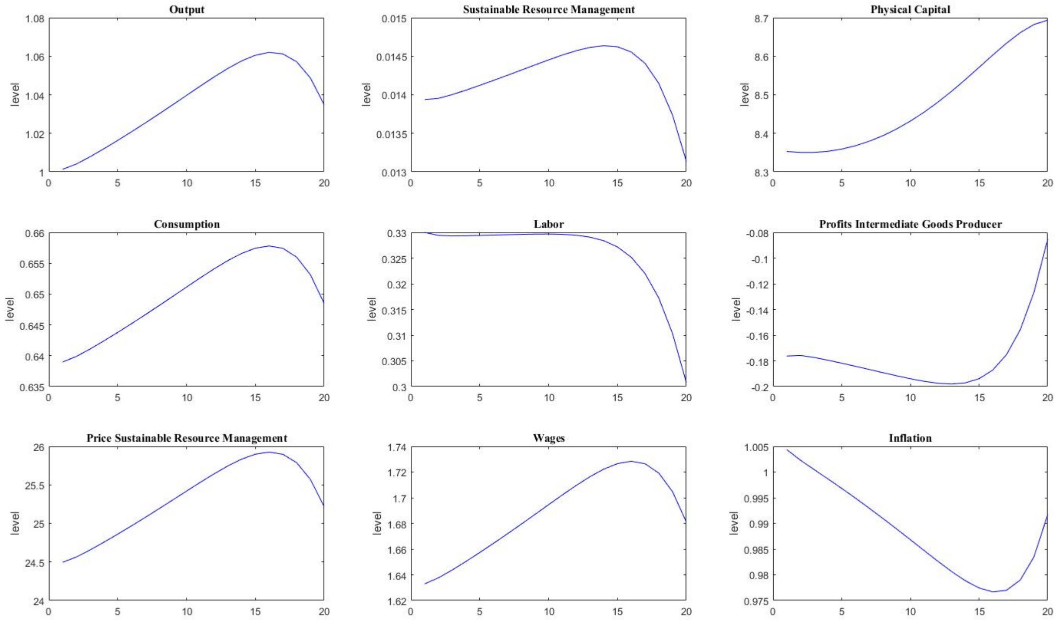

Figure 3: IRFs Quantitative Impact of Digitalization from 2023 to 2027

The dynamics reveal similar patterns in the macroeconomic aggregates. The capital stock is steadily rising as are wages, consumption, output and sustainable resource management. They reach its peak after about 15 quarters, which corresponds to Q3 2026. Like in the stochastic case, the household request a higher compensation for that kind of management. Employment shows contrary dynamics to fall from Q1 2023 on, while gaining momentum after 10 quarters. Inflation falls at a steady pace until Q3 2026. Output is spurred by over 6 percent at the maximum, sustainable resource management by over 6.17 percent. The latter amounts to roughly EUR 3.02 billion.

5 Conclusion

At maximum, the positive effect of an unexpected 20 percent increase in digitalization on sustainable resource management is 4 percent. The IRFs display an empirical result which is particularly interesting in the context of the demographic change: due to digitalization, employment is reduced. While confirming intuition, the theory-based model calibrated to the data implies that the projected shortage of labor due to demographics can be counteracted by digitalization. The economy enjoys higher economic growth despite the development of a diminishing working force. Goodhart and Pradhan (2020) provide a comprising macroeconomic analysis of the demographic change. The quantitative effect in the perfect foresight scenario from 2023 to 2027 is over 6.17 percent at maximum.

Clearly, the estimates rest on the assumptions of the elasticity of sustainable resource management in production, for which the reference value is its steady state value, and on the process of digitalization with its impact on the capital stock. The calibration falls short of an thorough ex-ante empirical analysis. That is, it is expected that the estimates will be higher if more than 20 percent of the capital stock are affected in the forecast, if the digitalization process gains more momentum or if the production function exhibits increasing returns to scale.

The model can be combined with a heterogenous agent life-cycle model, like in Gertler (1997), to study the intersection of digitalization and demographics. Within the New Keynesian model, future research might focus on the resulting price for sustainable resource management, which can in principle be substituted to account for overall energy and environmental management. Thereby, the factor of energy costs in production is considered. As noted for the calibration, there can be specific fiscal policies assigned to that price in the form of taxes or subsidies. Varying incentive schemes applying to the different fiscal policies are to be included and the economic effects to be evaluated in a phase of accelerating deindustrialization.

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Appendix A: Equilibrium conditions

$$0 = -\chi_h + \frac{w_t}{c_t^\tau} \tag{16}$$

$$0 = \frac{1}{c_t^\tau} - \beta \frac{1}{c_{t+1}^\tau} \frac{i_t}{\pi_{t+1}} \tag{17}$$

$$0 = \chi_m - \frac{1}{c_t^\tau}(1 - \frac{1}{i_t})m_t \tag{18}$$

$$0 = \chi_s - \frac{p_{s,t}}{c_t^\tau} \tag{19}$$

$$0 = y_t - p_{s,t}s_t - r_{k,t}k_t - w_t h_t - \frac{\phi}{2}(\frac{\pi_t}{\bar{\pi}} - 1)^2 y_t - div_t \tag{20}$$

$$0 = k_{t+1} - (1-\delta)k_t - x_t \tag{21}$$

$$0 = \bar{g} - g_t \tag{22}$$

$$0 = (d_t k_t)^\alpha s_t^\gamma h_t^{1-\alpha-\gamma} - y_t \tag{23}$$

$$0 = \frac{1}{c_t^\tau}[1 + \kappa(\frac{x_t}{k_t} - \delta)] - \beta E_t \frac{1}{c_{t+1}^\tau}\{(r_{k,t+1} + 1 - \delta - (\frac{\kappa}{2})[(\frac{x_{t+1}}{k_{t+1}} - \delta)^2] + \kappa(\frac{x_{t+1}}{k_{t+1}} - \delta)(\frac{x_{t+1}}{k_{t+1}} - \delta + 1))\} \tag{24}$$

$$0 = (1-\alpha-\gamma)r_{k,t}k_t - \alpha w_t h_t \tag{25}$$

$$0 = \frac{\beta}{(1-\alpha-\gamma)} \frac{w_t h_t}{s_t} - \frac{p_{s,t}}{c_t^\tau} \tag{26}$$

$$0 = y_t - \frac{\phi}{2}\{[(\frac{\pi_t}{\bar{\pi}}) - 1]^2\}y_t - c_t - x_t - (\frac{\kappa}{2})[(\frac{x_t}{k_t} - \delta)^2]k_t - g_t \tag{27}$$

$$0 = \frac{1}{c_t^\tau}[1 - \theta + \theta\frac{w_t h_t}{(1-\alpha-\gamma)y_t} - \phi(\frac{\pi_t}{\bar{\pi}} - 1)\frac{\pi_t}{\bar{\pi}}] + \beta E_t[\frac{1}{c_{t+1}^\tau}(\frac{\pi_{t+1}}{\bar{\pi}} - 1)\phi\frac{\pi_{t+1}}{\bar{\pi}}\frac{y_{t+1}}{\bar{y}}] \tag{28}$$

$$0 = \rho_i log(\frac{i_{t-1}}{\bar{i}}) + \rho_y log(\frac{y_t}{\bar{y}}) + \rho_\pi log(\frac{\pi_t}{\bar{\pi}}) + \epsilon_{i,t} - log(\frac{i_t}{\bar{i}}) \tag{29}$$

$$0 = (1-\rho_d)\log(\bar{d}) + \rho_d \log(d_{t-1}) + \epsilon_{d,t} - \log(d_t) \tag{30}$$

for the forecasting, respectively,

$$0 = \bar{d} + \epsilon_{d,t} - d_t \tag{31}$$

Appendix B: Overview Activities Sustainable Resource Management

The list of activities according to Eurostat (2024) :

CReMA 10: management of water (aka water saving)

CReMA 11: management of forest resources, of which,

CReMA 11.A: management of forest areas

CReMA 11.B: minimisation of the intake of forest resources

CReMA 12: management of wild flora and fauna

CReMA 13: management of energy resources

CReMA 13A: production of energy from renewable resources

CReMA 13B: heat/energy saving and management (aka energy efficiency)

CReMA 13C: minimisation of the use of fossil energy as raw materials

CReMA 14: management of minerals

CReMA 15: research and development activities for resource management

CReMA 16: other resource management activities