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„A társadalmi fenntarthatóság gazdasági modellezéséről”

GÁCSÉR Norbert György¹ – VAJAI Balázs²

¹⁻²PhD hallgató, Soproni Egyetem, Lámfalussy Sándor Közgazdaságtudományi Kar,
Széchenyi István Gazdálkodás- és Szervezéstudományok Doktori Iskola

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- Social Sustainability
- Equal Opportunities
- Matthew Principle
- Modelling

ABSTRACT

On the economic modelling of social sustainability | The political and scientific prominence of sustainability goes back for a few decades. In science of sustainability the different disciplines and different researchers use their unique concepts and approaches, thus creating somewhat inconsistent systems to parallelly coexist offering partial solutions to sustainability problems. Despite this, the lawmakers of several nations and also the European Community have already came up with their own obligatory regulations for sustainability considerations. A vital part of sustainability concerns remained less addressed, namely, the social sustainability aspect and the nature of the economic environment inherently intertwined with it. Most likely the difficulties arising from complexity, the contradictions and limitations inherent in this area, political considerations and the fear of opposing existing paradigms all partake in why this dimension is less researched. Our aim is to fill this gap using the tool of simulations of the economic environment, taking the phenomenon of the Matthew-principle into account to better comprehend sustainability problems. We first built a simple model and we expanded it by adding more variables one by one. In it's current state our simulation already offers partial results, which may open interesting new avenues in this research area.

JEL-codes: M14, M40, Z13, A13, B55

KULCSSZAVAK

- társadalmi fenntarthatóság
- esélyegyenlőség
- Matthew-elv
- modellezés

ABSZTRAKT

A fenntarthatóság politikai és tudományos jelentősége néhány évtizedes múltra tekint vissza. A fenntarthatóság tudományában a különböző tudományágak és kutatók egyedi koncepciókat és megközelítéseket alkalmaznak, így inkonzisztens rendszereket hoznak létre, amelyek párhuzamosan egymás mellett léteznek és részleges megoldásokat kínálnak a fenntarthatósági problémákra. Ennek ellenére több nemzet és az Európai Közösség törvényhozói is előálltak már saját kötelező előírásaikkal fenntarthatósági szempontok érvényesítése érdekében. Álláspontunk szerint a fenntarthatóság tudományának lényegi

¹ E-mail: gacser.norbert.gyorgy@phd.uni-sopron.hu
MTMT: 10079471 | ORCID: 0000-0002-0944-2986

² E-mail: vajai.balazs@phd.uni-sopron.hu
MTMT: 10080831 | ORCID: 0000-0001-6971-8916

eleme kevésbé kutatott, nevezetesen a társadalmi fenntarthatóság aspektusa és a vele összefonódó gazdasági környezet természete. Valószínűleg a komplexitásból adódó nehézségek, az e területben rejlő ellentmondások és korlátok, politikai megfontolások és a létező paradigmákkal való szembefordulástól való félelem egyaránt szerepet játszanak abban, hogy miért „alulkutatott” ez a dimenzió. A célunk, hogy ezt a hiányt pótoljuk a gazdasági környezet vizsgálatával a szimuláció eszközével, figyelembe véve a Máté-elv jelenségét a fenntarthatósági problémák jobb megértése érdekében. Első lépésként egy egyszerű modellt építettünk, amelyet lépésenként újabb változókkal bővítettünk. A jelen állapotában a szimulációnk már kínál részeredményeket, amelyek érdekes új utakat nyithatnak meg ezen a kutatási területen.

JEL-kód: M14, M40, Z13, A13, B55

A fenntarthatóság problémaköre

A fenntarthatóság fogalmának legelterjedtebb megfogalmazását a Környezet és Fejlődés Világbizottságának 1987. évi, „Közös jövőnk” című Brundtland-jelentésben találjuk: „A fenntartható fejlődés olyan fejlődés, amely kielégíti a jelen szükségleteit anélkül, hogy veszélyeztetné a jövő nemzedékek esélyét arra, hogy ők is kielégíthessék szükségleteiket”. Napjainkra a cégek, a kormányok és általánosságban a társadalom egyre inkább törődnek a fenntarthatóság kérdésével, mivel a globális felmelegedés, a környezetszennyezés, az életmód és jövedelemeloszlás különbségei egyre égetőbb problémát jelentenek (Hódiné, 2013). A fenti definíció a mára általánosan elfogadott gazdasági, környezeti és társadalmi aspektusok együttes kielégítését vetítette előre. Ahogy Gácsér és Szóka (2003) írta „a fenntartható, azaz egy környezeti szempontokat is figyelembe vevő és társadalomtudatos fejlődés egyre inkább napi aktualitássá és vitatémává válik mind az egyéneknek, mind kormányok és nemzetközi szervezetek szintjén”. A témával kapcsolatos kiemelt figyelem termékeny politikai és tudományos területté tette a fenntarthatóság eposzát.

A téma popularitása ellenére továbbra sem tisztázott az egyes aspektusok természete és egymás közötti összetett kapcsolatrendszere, ahogy az egyes aspektusok közötti hierarchia sem egyértelmű (Littig & Griessler, 2005). Elkington (1999) véleménye szerint a gazdasági racionalitás elsődleges minden döntésben, ezért a társadalmi és környezeti fenntarthatóság csak ennek figyelembevételével teremthető meg. Gentzner (1999) szerint a környezet keretein belül létezik a társadalom, amelynek egy kivetülése, illetve eszköze a gazdaság. A Brundtland Bizottság véleménye szerint a gazdaság csak eszköz, a társadalom szükségletkielégítésének eszköze a környezet által szabott lehetőségek között.

Véleményünk szerint a fenti vélemények nem mondanak ellent egymásnak, a fenntarthatóságnak az embert kell szolgálnia, így az elsődleges prioritásnak az embernek, azaz a társadalmi pillérnek kell lennie, a gazdaságnak azt kell szolgálnia a környezet szabta limitek között. Az ezirányú kutatások során azonban figyelembe kell venni, hogy az egyéni gazdasági érdek – mint racionalitás – minden vizsgálati szinten (egyén, ország, nemzetek együttese) az elsődleges motiváció. Másként fogalmazva, a prioritás a társadalmi érdek, de az annak megvalósítására alkalmas rendszer nem hagyhatja figyelmen kívül, hogy a gazdasági (ön)érdek a rendszer szereplőinek elsődleges hajtóereje. A környezet ebben a megközelítésben pusztán erőforrás, amelynek használata a gazdasági rendszer részére input, azaz a környezeti aspektus figyelembevételének sajátosságai is a gazdasági rendszer által meghatározottak. Kutatásunk központi témaköre mindezekre tekintettel a társadalmi fenntarthatóság és a gazdaság rendszere közötti kapcsolat vizsgálatára irányul.

Társadalmi fenntarthatóság és a Máté-elv

A fenntarthatóság társadalmi aspektusához kötődő konkrét definíciók kutatásonként eltérnek, azzal, hogy az Elkington által lefektetett a társadalmi dimenzióhoz kötődő tartalommal átfedést mutatnak. A vizsgált szintek között is heterogenitás figyelhető meg (nemzetek közösségét érintő társadalmi, nemzeti, helyi közösségi vagy szervezeti szint) (Gácsér & Szóka, 2023). Mindent átfogó pontos lehatárolása a területnek azért is nehéz, mert az egyes társadalmi prioritások is változatosak és helyzetfüggők, valamint a politikai és ideológiai kérdésekkel is gyakran összefonódnak (Scoones, 2016).

Kiemelt figyelmet élvez az „esélyegyenlőség”, mint szempont, amire a társadalmi fenntarthatóság Gyulai (2013) szerint egyre inkább korlátozódik. Az esélyegyenlőség megteremtésére két ideológiai irányzat alakult ki, amelyek az egyenlőség, vagy esélyek egyenlősége („equality of chance”) valamint a méltányosság, azaz a kimenetek egyenlősége („equity” vagy „equity of outcome”). Mindkét megközelítés szerint az egyének versenyeznek egymással, melynek eredményeként hierarchiába rendeződnek (lehetőségekhez és erőforrásokhoz való hozzáférés). Az esélyek egyenlősége alapján az egyének személyes erőfeszítése és képességei szerint lesznek képesek a versenyben előnyökre szert tenni, felfele mozogni a hierarchiában. További alapvetése, hogy az szolgálja a közösség érdeke is, hogy az egyének motiváltak legyenek a személyes maximum teljesítményüket nyújtani, mivel ezzel adják

a társadalom számára is a legnagyobb hozzáadott értéket. Utóbbi okból kifolyólag a fair verseny megteremtésére helyezi a hangsúlyt (Barry, 1989). A méltányosság pedig ugyanezen versenyre vonatkozó feltételezése, hogy az egyes szereplők nem azonos körülmények között indulnak, ezért az eltérő kimenetek kiigazításában látja a fair minőség megteremtésének alapját. Vonatkoztatott alapja jellemzően nem, rassz, életkor, szexuális beállítottság. Utóbbi megközelítés hátránya, hogy egy pozitív diszkrimináció bevezetésével hoz létre negatív diszkriminációt minden más taggal szemben, ezzel torzítva az igazságos versenyt, kiemelten, mert axiómaként feltételezi, hogy a nemi, faji, korcsoport szerinti hovatarozás és a versenyben adott lehetőségek között egyértelmű és arányos kapcsolat áll fenn, míg az ugyanezen alapon nem-hátrányos csoportok tagjait érintő, hozott körülmények közötti különbségeket figyelmen kívül hagyja.

A felhalmozás lehetősége a fair verseny egy jelentős változója, tárgyalása megköveteli a Máté-elv ismeretét. A szociológus Robert K. Merton által elnevezett Máté-elv (angol nyelvterületen: Matthew-principle) a nevét egy Máté evangéliumából vett idézet alapján kapta, amely szerint a szegény szegényebb, a gazdag gazdagabb lesz (Merton, 1968). Lényege, hogy az egyének a meglévő eredményeikkel arányosan képesek felhalmozni további előnyöket (többek között: státuszt, hírnevet, tőkét). A Máté-elv tudományos elemzéséről írt legátfogóbb művek egyike Rigney, D. (2010) nevéhez kötődik, aki részletesen írt a szociológiai következményekről is. A preferenciális kötődés elmélete kapcsán továbbá feltétlen említést érdemel még a hálózat-kutatásban ismert Barabási és Albert (1999) munkája, ami szerint az új kapcsolatok hajlamosak a már jól kapcsolt csomópontokhoz (pl. vagyonos szereplőkhöz) csatlakozni, ezzel erősítve a meglévő egyenlőtlenségeket. Ez a „preferenciális kötődés” egyre nagyobb figyelmet kap az elmúlt fél évtizedben, mára egy általános, az ember természetéhez kapcsolódó természeti jelenségként definiálva azt. Társadalmi következménye, hogy a fentebb említett egyének közötti versenyben az ún. alacsony-rangú egyéneknek jellemzően az idő előrehaladtával egyre nehezebb a helyzetük és annak megváltoztatása (mobilitás), míg a magasabb rangú egyének egyre könnyebben képesek további eredményeket elérni. Ugyanez a jelenség igaz a szervezetek vagy nemzetállamok szintjén is (Gladwell, 2008). Az egyes szereplők közötti különbségek így idővel felerősödnek a társadalmon belül, valamint a társadalmak (nemzetek) között és polarizáció alakul ki. Ezt a szereplők döntései, reakciói befolyásolhatják, de a jelenséget és annak természetét megszüntetni nem lehetnek képesek (Merton, 1968).

A Máté-elv következményei túlmutatnak az egyéni vagyonfelhalmozáson, hatással vannak a társadalmi struktúrákra. A növekvő vagyoni különbségek a társadalmi kohézió csökkenéséhez és a különböző társadalmi-gazdasági osztályok közötti feszültségek növekedéséhez vezetnek. Ezt súlyosbítja, hogy a hagyományosan a tőke ellensúlyaként működő társadalmi szervezetek elvesztik befolyásukat, mert hatására a tőke előnyt élvez a munkával szemben – a tőke hozamai meghaladják a munka hozamait –, ami hozzájárul a növekvő egyenlőtlenséghez (Jiankun & Hairuo, 2022; Piketty, 2013). Ráadásul a vagyonkoncentráció növekedésével a magas rangú egyének politikai befolyása is növekszik, lehetővé téve, hogy a politikák alakításában olyan módon használják hatalmukat, hogy tovább erősíti előnyeiket (Jiankun & Hairuo, 2022; Ferge Zsuzsa, 2002).

A preferenciális felhalmozás által okozott kihívások kezelése rendszer szintű megközelítést és a probléma mélységi ismeretét igényli. A politikai döntéshozóknak fel kell ismerniük, hogy a vagyon újraelosztását és a hátrányos helyzetűek esélyeinek növelését célzó beavatkozások nélkül gazdasági stagnálást és társadalmi nyugtalanságot kockáztatnak. Így a polarizáció hatásainak megértése és mérséklése kulcsfontosságú, különösen a növekvő globális gazdasági bizonytalanságok és a környezeti kihívások fényében (Felipa, 2023).

Végül szót érdemel a vizsgálat szintjének megválasztása. Robert Hunter Wade 2004-ben megjelent munkája, a Matthew-elv, a globalizáció és a társadalmi fenntarthatóság összefüggéseit vetette fel. Wade (2004) szerint az ún. „abszolút szegénység” a ’80-as évek óta világviszonylatban csökkenően van, de a polarizáció folyamatosan emelkedik az országokon belül és nemzetállamok között is. A gazdasági-politikai együttműködési térben egy változó, amely az egyik országnak versenyelőny, a másik országnak externália.

Fenntarthatóság és a makroökonómia

A fenntarthatóság elméleti alapjai összefonódnak a makrogazdasági elméletekkel, mivel mindkét terület foglalkozik az erőforrások gazdaságon belüli elosztásával és ezeknek a jövőre gyakorolt hatásával, azzal, hogy a fenntarthatóság az erőforrásokkal való felelős gazdálkodásra helyezi a hangsúlyt.

Missimer (2015) szerint „sok rendszerünk alapvetően fenntarthatatlan alapokon nyugszik, a fenntarthatóság felé való haladás rendszerszintű változást igényel”. A jelenlegi makrogazdasági modellek a bonyolult gazdasági

kapcsolatok és politikai hatások megértésére próbálnak adni. Régebbi módszerek, mint többek között az IS-LM modell és az összesített kereslet – összesített kínálat (AD-AS) elsősorban azt vizsgálják, milyen összefüggés van az áru és pénzpiac között, hogyan hatnak egymásra a kibocsátás, a kamatlábak és az árszintek. Az aggregált termelés, a foglalkoztatási ráta, az infláció és a gazdasági növekedés kulcsfontosságú mutatók, amelyek Felipa (2023) és Steven (2018) szerint hűen képesek tükrözni egy gazdaság egészségét.

A klasszikus makrogazdasági modellek a GDP növelésére összpontosítanak, figyelmen kívül hagyva olyan alapvető társadalmi tényezőket, mint a jövedelmek egyenlőtlensége. Ugyanakkor a gazdasági döntések társadalmi hatásainak figyelmen kívül hagyása fenntarthatatlan társadalmi problémákhoz vezethet (Hardt et al., 2017). A fenti modellek nem veszik figyelembe a fenntarthatóságot, környezeti és társadalmi tényezőket nem tartalmaznak, amit az új makroökonómiai elméletek a fenntarthatóság tudományterületéről származó ötletek, megfontolások hozzáadásával kívánnak ellensúlyozni. Modern makroökonómia kutatások alapján léteznek jobb modellezési módszerek, amelyek tartalmazzák társadalmi fenntarthatósági mutatókat is, támogatva a döntéshozókat társadalmilag megfelelőbb eredmények elérésében (Aponte et al., 2023). Ezzel nemcsak a gazdaság vizsgálatát teszik teljesebbé, de egy összetettebb rendszerszintű gondolkodás felé való elmozdulást is ösztönöznek, ami jobban informált politikai intézkedések lehetőségét teremtheti meg. A makrogazdasági modellek újragondolása fontos egy fenntartható gazdasági gyakorlat megteremtéséhez, ezt igazolja a Világ Fejlődési Jelzőértékek jelentés, amely rávilágít a gazdasági növekedés és a társadalmi igazságosság közötti kapcsolatra (World Bank, 2012).

A fiskális és monetáris politikák szerepet játszanak a fenntarthatóság előmozdításában makrogazdasági kereteken belül. A költségvetési politika, a kormányzati kiadások és az adózási rendszer ösztönözheti a fenntartható gyakorlatokat (például megújuló energiával kapcsolatos projektek finanszírozásával, környezetbarát kezdeményezések adókedvezményeivel). A monetáris politika befolyásolhatja a hitelkamatokat, hogy ösztönözzön fenntartható technológiákba történő befektetéseket. Az éghajlatváltozással és az erőforrások végeességével kapcsolatos tudatosság emelkedésével a fenntartható makrogazdasági stratégiák jelentősége kritikus, így a fenntarthatóság integrálása a makrogazdasági elméletbe nem csak a jelenlegi gazdasági helyzet megértésében segít, hanem a kiegyensúlyozott és méltányos gazdaság megvalósításának kereteinek megteremtését is ösztönzi. Azaz segítségükkel a kormányok lépést tehetnek olyan gazdálkodás irányába, amely a fejlődése

fenntartása mellett védi a környezetet, miközben növeli a társadalmi jólétet (Felipa, 2023).

A preferenciális kötődés és felhalmozás modellezése

A későbbi felhasználási célt és fejlesztési elgondolásokat figyelembe véve építettünk egy játékelméleti modellt, amellyel szimulációkat tudunk végrehajtani a preferenciális felhalmozás jelenségének a társadalmi csoportok vagyonaára gyakorolt hatásának vizsgálatára. A Máté-elv jelenségét modellezni nem újkeletű elképzelés, így tett Miia Bask és Mikael Bask is a kumulatív előnyről és a Máté-elv hatásáról írt a 2015-ös kutatásában (Bask & Bask, 2015).

Az általunk felépített matematikai szimulációban két populáció van, az „A” populáció és a „B” populáció, mindkettő 1000 tagot számlál. Kezdetben minden szereplőnek 100 érmeje van, ami a személyes vagyont testesíti meg, így a populációk vagyona csoportonként 100.000 érme. Az interakciók kétoldalúak, minden résztvevő kölcsönhatásba lép egymással, így az „A” résztvevők interakcióba lépnek más „A” résztvevőkkel és „B” résztvevőkkel is és fordítva. Két fő változó van:

- a „konfliktus” (C, Conflict) a résztvevők között, ami egy – vagy vagyon elvétellel (0-100%) vagy vagyon átadásával (-100%-0) járó – mechanizmus a konfliktusban érintett résztvevő szereplők szerint CAA (az A-A résztvevők közötti interakció esetén) és CAB változók (a konfliktusban érintett A-B résztvevők számára).
- a „konfliktus megnyerésének esélye” (P, Possibility), az utóbbit nevezük PWAA-nak és PWAB-nak az előző logikának megfelelően.

A nyerési esélynek megfelelően a populáció tagjainak száma is változik, az A-k B-tagokká válhatnak és fordítva. Minden tag csak más tagoktól szerezhet vagyont (azonos vagy a másik csoport tagjaitól). A sztochasztikus eljárást leíró általános képletek a következők:

$$POA = POA_{t-1} * [1 - (CAA * PWAA)]$$

$$POB = POB_{t-1} + * [POB_{t-1} * CAA * PWAA]$$

$$WA = WA_{t-1} + (WB_{t-1} * CAB * PWAB)$$

$$WB = WB_{t-1} - (WB_{t-1} * CAB * PWAB)$$

Ahol:

POA t-1: A populáció a szimulációs ciklus előtt

POB t-1: B populáció a szimulációs ciklus előtt

CAA: Konfliktus A és A között

CAB: Konfliktus A és B között

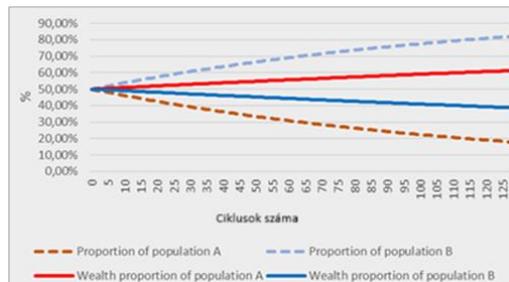
PWAA: Annak esélye, hogy A megnyerje a konfliktust egy A-val szemben

PWAB: Annak esélye, hogy A megnyerje a B-vel szembeni konfliktust

WA: A vagyona

WB: B vagyona

A megalkotott modell segítségével kísérleteztünk, az első esetben a konfliktusokat (CAA és CAB) egyformán 1%-ban határoztuk meg, míg a nyeresé esélye Pareto-eloszlást követett, az A populáció számára a konfliktus megnyerésének esélye 80%, a B populáció esetében pedig 20% volt. A szimuláció eredményét mutatja be az 1. ábra:



1. ábra.

Forrás: saját szerkesztés.

Az eredmények a B népesség összesített vagyonának és a népesség tagjai átlagos személyes vagyonának csökkenését mutatják, az A népességre ennek fordítottja igaz. E mellett a B populáció tagjainak száma folyamatosan növekszik, míg az A populáció számossága csökken. Az 500. ciklusban az A népesség mindössze 18 főből áll, akik a két népesség vagyonának 81,62%-át tulajdonolják. A 860. ciklusban 1 személy (aki gyakorlatilag a teljes A népességet jelenti) birtokolja a teljes vagyon 91,06%-át. Eltérő (pozitív) nyeresi esélyekkel is futtattunk szimulációkat, de mindegyik kimenetele hasonló mintázatot eredményezett, ugyanez történt, ha mindkét populáció esetében egyenlő nyeresi esélyeket határoztunk meg, de az egyik csoportban torzítottuk a konfliktus mértékét.

Nem evidens, de kiolvasható, hogy a B populáció egyes résztvevői át tudtak kerülni az A populációba, esetenként felülkerekedve az A populáción belüli versenytársakon is. A probléma forrása, hogy minél több ciklus zajlik le, annál nagyobb a szakadék a csoportok között, ami egy idő után gyakorlatilag lehetetlenné teszi, hogy a hátrányos helyzetű csoport tagjai átjussanak a két népesség egy főre jutó átlagos vagyona közötti szakadékon. A hátrányos helyzetű csoport tagjának esélye csak egy (bármilyen módon propagált vagy rákényszerített) kiegyenlítő mechanizmuson keresztül létezhet.

Kiemelendő még, hogy a szimulációkban nem helyeztünk el semmilyen alcsoportot a populációkon belül, nem lehet különbséget tenni nem, életkor vagy bőrszín alapján, mégis a fent leírt eredményeket kaptuk.

A szimulációban leírt rendszer egyensúlyi állapota az lenne, ha a PWAA és a PWAB kölcsönösen nullák, következésképpen a konfliktus szintje irrelevant és maga a rendszer is stabil és változatlan.

Egy koncepcionális makroökonómiai modell megalkotása

A klasszikus makroökonómia elméleti keretének újragondolása, fejlesztése olyan modellek megalkotásához vezethet, amelyek a társadalmi fenntarthatóságot is magukban foglalják. Ez túlmutat a neoklasszikus közgazdaságtan összefüggésein, amely gyakran figyelmen kívül hagyja a gazdasági rendszerek és a társadalmi egészség közötti kölcsönhatásokat. Mindazonáltal a klasszikus makroökonómiai tényezők és a róluk felhalmozott ismeretek figyelembevétele a modell építése során biztos alapot jelent.

A kutatásunk célja olyan modell létrehozatala, amely segíti a társadalmi fenntarthatóság és a gazdaság közötti kapcsolatok megértését, ezért a modell alaptézise a Máté-elv mechanizmusa. Mivel a preferenciális felhalmozás az egyének, szervezetek, nemzetállamok szintjén is létező jelenség a modellnek mindezek kapcsolatrendszerét le kell tudnia fedni.

Modellünk sajátos igényei miatt egyedi módszertant igényel.

Kézenfekvő módszertani lehetőség lenne játékelméleti modellt alkotni. Játékelméleti modellben a játékosok döntéseit előre definiált ekvivalens struktúrákra építik (egyensúlyi állapotok), ami alkalmas az egyszerű, izolált döntési helyzetekre, de nem nyújt képet az időbeli dinamikáról és kialakuló összefüggésekről, valamint dinamikus modellek esetén a kimeneti valószínűségek definiálása jelentős erőforrást igényel, a finomhangolási lehetőségek

pedig nehezebben kivitelezhető. További problémát jelent, hogy a klasszikus játékelmélet feltételezi, hogy az emberek racionálisan döntenek és minden információval rendelkeznek, ezek hiányában a módszer pontatlan és korlátolt lehet (Simon, 1955). A valós helyzetekben a játékosok stratégiai sokkal bonyolultabbak és komplexebbek lehetnek, mint amit játékelméleti modellek kezelni tudnak (pl. magas dimenziójú stratégiai terek) (Axelrod, 1984). E szempontok alapján a módszertan használatát elvetettük.

A következő alternatívaként hálózatkutatói módszertan alkalmazásának lehetőségét vetettük fel. A hálózat kutatás hatékony az egyenlőtlenségek és a kapcsolathálózatok struktúrájának feltérképezésében (pl. preferenciális kötődés, kisebbségi csoportok kapcsolati hálója), de nem képes időbeli fejlődést, valamint viselkedési változásokat modellezni, nem támogatja megfelelően az olyan beavatkozások (például adózás vagy oktatáspolitikai) közvetlen tesztelését, amelyek nem kizárólag a struktúrát, de az egyének viselkedését is befolyásolják. A klasszikus hálózatmodellek gyakran statikus gráfokkal dolgoznak, miközben a valós hálózatok (pl. közösségi hálók, biológiai kapcsolatok) folyamatosan változnak (Castellano et al., 2009). A hálózati modellek jelentős része továbbá feltételezi, hogy a hálózatok skálafüggetlenek (pl. Barabási-Albert modell), míg a valós adatok gyakran nem követik ezt az eloszlást (Barabási et al., 2019). Mivel a hálózat kutatás kevésbé alkalmas a makrogazdasági összességű és az időbeli változás szimulálására, az alkalmazásának lehetőségét elvetettük.

A peremfeltételek miatt döntésünk egy ágens-alapú mikroszintű adatokra épülő makroökonómiai modellre megalkotására esett. Az ágens-alapú modellezés Epstein (1999) definíciója szerint „Az ágens-alapú modellek számítógépes modellek, amelyek önálló ágensok cselekvéseit és interakcióit szimulálják annak érdekében, hogy értékelni lehessen ezek hatását a rendszer egészére”.

A Cincotti et al. (2022) által megfogalmazott minimum követelményei az ágens-alapú modellezésnek (angolul Agent Based Modelling, röviden ABM) a következők:

- meghatározott szereplők,
- egyértelmű interakciós mechanizmusok,
- dinamikus környezet (befolyásolva az ágenseket, interakciókat),
- idő dimenzió,
- kirajzolódó jelenség vagy viselkedés,

- számítási keretrendszer, amely lehetővé teszi több ezer vagy millió ágens szimulációját, megkönnyítve ezzel a bonyolult számításokat és interakciókat.

Az ABM azért különösen értékes módszertan, mert nem előre meghatározott egyensúlyokra, hanem valóság-hű dinamizmusra épít, így különösen alkalmas komplex társadalmi-gazdasági rendszerek tanulmányozására. Az ágens-alapú modellezés egyedülállóan lehetővé teszi, hogy az egyéni döntések dinamikusan felépülő folyamatokon keresztül eredményezzen makroszintű, emergens társadalmi-gazdasági mintázatokat és mindezt heterogén, adaptív ágensecsoportok és empirikusan alátámasztott politikai beavatkozások segítségével. Ez az a rugalmasság, amit sem a játékelméleti, sem a hálózati megközelítés nem tud egyedül biztosítani, különösen abban a kontextusban, ahol a preferenciális halmozódás komplex hatásait kell vizsgálni.

Modellünk változóit a klasszikus makroökonómia területéről válogattuk, így egyrészt az egyes mutatók tartalma és természete támaszkodik a tudományos eredményekre, másrészt a modell hasznossága megítélhető a valóságból merített értékek behelyettesítésén és a kimenetek valósággal való összevetésén keresztül. A mikrofundált makroökonómiai modellünk jelen állapotában az alábbi változócsoportokat tartalmazza:

- konfliktus,
- nyeresi esély,
- jövedelem,
- fogyasztás,
- külföldi jövedelem (külföldi munkaerőigény),
- megtakarítás,
- beruházás („innováció”),
- amortizáció,
- kormányzati transzferek,
- adó,
- Áfa,
- vagyon,
- kormányzat fenntartásának kiadásai,
- fogyasztói árindex
- infláció,
- banki alaptőke,

- tőke megfelelési mutató,
- nem-teljesítő hitelek aránya,
- hitelkamat,
- betéti kamat,
- likvid vagyon aránya.

Az interakciókat leíró általános képleteket az 1. sz. melléklet tartalmazza. A modell egy **ágens-alapú, makroökonómiai szimuláció**, amely két fő populációt vizsgál: „A” (**preferált**) és „B” (**diszpreferált**) csoportokat. A modell a következő fő elemekkel dolgozik:

- Interakciós szabályok
 - CAA, CAB – konfliktusintenzitás az A–A, A–B csoportok között
 - PWAA, PWAB – nyeresi esélyek a kétféle konfliktusban
- Gazdasági változók (idősorosan)
 - Vagyon (WA, WB, WAF, WBF)
 - Jövedelmek (IncA, IncB, stb.)
 - Fogyasztás, megtakarítás, beruházás, transzferek, adóterhek
 - Banki mutatók: hitelnagyság, kamat, banki nyereség, nem teljesítő hitelek
- Kimeneti indikátorok
 - A-csoport és B-csoport vagyona, azok aránya
 - Kihasztnálatlan hitelnagyság
 - Beruházás és maximálisan elérhető hitel
- Idődimenzió
 - Az időbeli szimuláció ciklusonként építkezik.

A változók szinte teljes körűek (jövedelem, vagyon, adó, bank, transzfer, külföldi munka). Az interakciók explicit módon szabályozottak (CAA, CAB, PWAA, PWAB). A modell dinamikusan építkező, idősoros (növekvő ciklusokkal), a vagyoni egyenlőtlenség így nem előre kódolt, hanem emergens módon jön létre. A beépített mutatók révén a politikai beavatkozások hatása is vizsgálható.

A modell további fejlesztés alatt áll, ennek egyrészt tartalmi másrészt validációs vetülete van. A munkaerőpiac beépítése, finomhangolása folyamatban van (pl. jelenleg a külföldi munkaerőarányok rögzítettek, nem adap-

tívak). Tervezünk olyan döntési szabályt bevezetni, amellyel a szereplők mobilitásáról sztochasztikusan döntenek (pl. amennyiben a hazai jövedelem alacsony, akkor emelkedik a migráció). További fejlesztési célunk a fogyasztási és beruházási függvények endogén modellezése: jelenleg ezen mutatók látzólag sztatikusak, helyesebb ezeket jövedelemarányos vagy hasznosság-maximalizáló szabályokkal helyettesíteni. Az utolsó folyamatban lévő fejlesztési irány a hálózati dimenzió bevezetése. A modell aktuális formájában minden szereplő minden szereplővel kapcsolatba lép (teljes gráf logika), azonban a valóságban a társadalmi hálózatok szelektívek, nem lép kapcsolatba minden szereplő minden szereplővel (pl. térbeli közelség vagy pont a preferenciális kapcsolódások). Emiatt a modellben a vagyoneeloszlás gyorsabb vagy egyenletesebb változásokat mutathat.

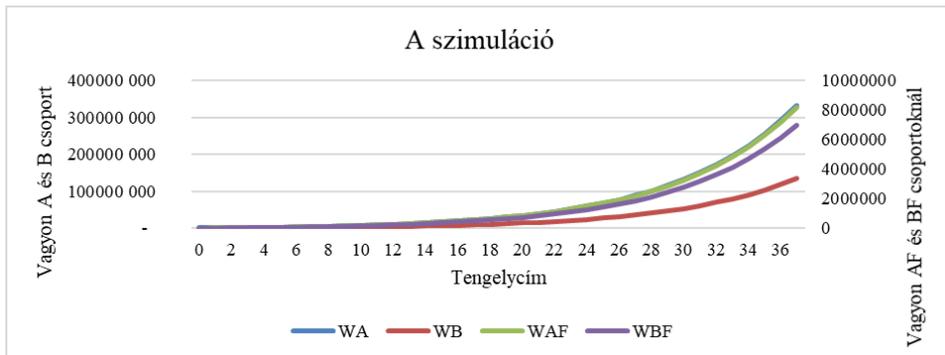
A modell véglegesítését követően validációja szükséges valós adatokon keresztül. A modell tesztelésére a szimulált eredmények összevetésre kerülnek valódi makrogazdasági adatokkal (például Eurostat, OECD vagy World Inequality Database forrásokból szerzett adatokkal). Amennyiben a valós adatok és a szimuláció eredményei közötti illeszkedés magas a modell igazoltan alkalmas gazdasági és társadalmi összefüggések újszerű vizsgálatára, azok mélyebb megértésére.

A modellünk segítheti többek között politikai és gazdasági döntések meghozatalát, egyszersmind minősítheti is a meghozott döntéseket. Modellünk eredményei hozzájárulhatnak a modernkori globális makrogazdaság problémáinak tudományos megértéséhez és választ is adhat több létező problémára, segítve a tudományos megalapozottság előretörését a különböző ideológiai megközelítésekkel szemben.

Szimulációk eredményei

Alap szimuláció („A” szimuláció)

Alacsony konfliktus arány mind az A (CAA:1% PWAA:10%) és mind a B (CAB:1% PWAB:10%) csoport között. Eredmény, hogy a vagyonban szereplő olló folyamatosan növekszik, amely elsősorban a jövedelmi viszonyok eltéréséből fog adódni (A_IncA:250 A_IncB:150) valamint az eltérő fogyasztási arányból a teljes bruttó jövedelemhez képest (P_CCA:15% P_CCB:30%).

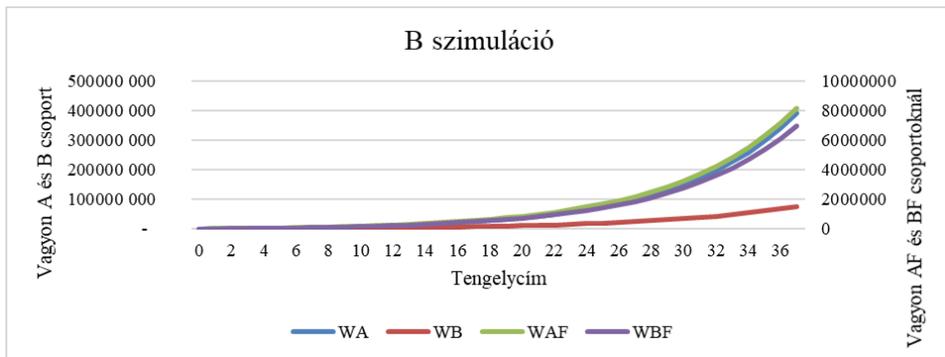


2. ábra.

Forrás: saját szerkesztés.

„B” szimuláció: A és B csoport között a konfliktus arányának növelése

Alacsony a konfliktus arány az A csoport esetén (CAA:1% PWAA:10%) és közepes a konfliktus szint az A és B csoport (CAB:15% PWAB:15%) között. Eredmény, hogy mindez a vagyonkülönbségekben gyors és szignifikáns változást fog eredményezni.



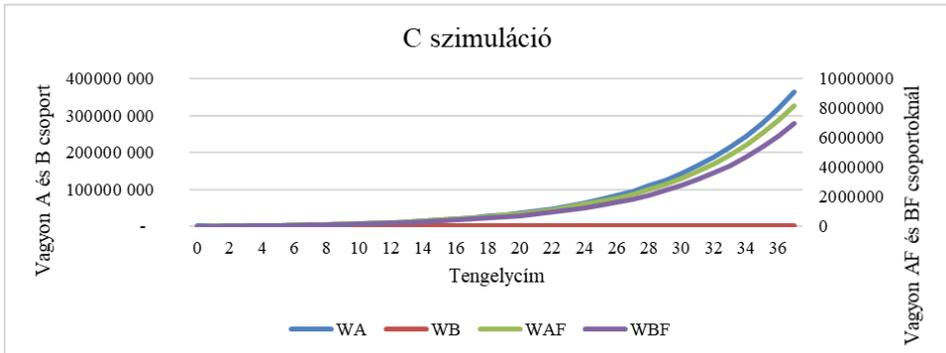
3. ábra.

Forrás: saját szerkesztés.

„C” szimuláció: A csoporton belüli, valamint A és B csoport között a konfliktus aránya magas

Magas konfliktus arány az A csoport esetén (CAA:50% PWAA:50%) és magas a konfliktus szintje az A és B csoport (CAB:50% PWAB:50%) között. A vagyonváltozás szignifikáns különbségének eredményeképpen az A csoport

vagyona olyan növekedési szintet ér el, amely mellett a B csoport vagyonának mértéke eltörpül.



4. ábra.

Forrás: saját szerkesztés.

Korlátok

A modell rendelkezik korlátokkal, amelyek egy része a további fejlesztéseken keresztül feloldható. Ilyen többek között, hogy a modell nem mutat ki explicit mobilitási változót, azaz nincs modellezve a társadalmi mobilitás tényleges mechanizmusa (elméletileg lehetséges A csoportból B csoportba kerülés, de B csoportból A csoportba váltás már nem lehetséges). Az egyes szereplők kapcsán nincs adaptáció vagy tanulási képesség, a modell fix szabályrendszert alkalmaz, amelyben az ágensek intelligenciája egyszerűsített (minden ágens azonos döntési logikát követ, nincsenek döntési torzítások, mint például bizalom a kormányzatban vagy a különböző kulturális hátterek). Ehhez hasonlóan, a modell jelenleg nem tartalmaz visszacsatolási szabályrendszert és nem reagál automatikusan aggregált állapotokra. Például (ceteris paribus) amennyiben nő a polarizáció egy bizonyos ponton beiktatható lehet automatikus kormányzati reakció (az állami beavatkozás a modellben jelenleg egyszerűsített és statikus).

1. sz. melléklet

Vagyon	
Vagyon A csoport	$WA_t = WA_{t-1} + (WB_{t-1} * CAB + PwAB) + (IncA - PTA_t - CCA + TRA_t) + (IA-LA)+(SA*S_{iA})-(IA*C_{iA})$
Vagyon B csoport	$WB_t = WB_{t-1} - (WB_{t-1} * CAB + PwAB) + (IncB - PTB_t - CCB + TRB_t)+(IB-LB)+(SB*S_{iB})-(IB*C_{iB})$
Vagyon Külföld foglalkoztatott A csoport	$WAF_i = WAF_{i-1} + (IncAF - PTFA - CFA + TRFA) + (IFA - LAF)+(SFA*S_{iAF})-(IFA*C_{iAF})$
Vagyon Külföld foglalkoztatott B csoport	$WBF_i = WBF_{i-1} + (IncBF - PTFB - CFA + TRFB) + (IFB - LBF)+(SFB*S_{iBF})-(IFB*C_{iBF})$
Vagyon összesen	$W_i = WAF_i + WBF_i + WB_t + WA_t$
Fogyasztás	
A csoport fogyasztása	$CCA = (P_{CCA} * (TRA + IncA)) * (1 + IA)$
B csoport fogyasztása	$CCB = (P_{CCB} * (TRB + IncB)) * (1 + I_B)$
Külföldön foglalkoztatott A csoport fogyasztása	$CFA = (P_{CFA} * (TRFA + IncAF)) * (1 + I_{FA})$
Külföldön foglalkoztatott B csoport fogyasztása	$CFB = (P_{CFB} * (TRFB + IncBF)) * (1 + I_{FB})$
Fogyasztás összesen	$CC = CCA + CCB + CFA + CFB$
Adó	
Fizetett Adó A csoport esetén	$PTA = POA * (A_{IncA} * TA)$
Fizetett Adó B csoport esetén	$PTB = POB * (A_{IncB} * TB)$
Fizetett Adó a külföldnek dolgozó A csoport esetén	$PTFA = CAF * (A_{IncAF} * TFA)$
Fizetett Adó a külföldnek dolgozó B csoport esetén	$PTFB = CBF * (A_{IncBF} * TFB)$
Adó összesen	$TT = PTA + PTB + PTFA + PTFB$
Megtakarítás	
Megtakarítás A csoport esetén	$SA = (POA * A_{IncA}) - CCA + TRA - PTA - IA$
Megtakarítás B csoport esetén	$SB = (POB * A_{IncB}) - CCB + TRB - PTB - IB$
Megtakarítás külföldön foglalkoztatott A csoport esetén	$SFA = (CAF * A_{IncAF}) - CFA + TRFA - PTFA - IFA$
Megtakarítás külföldön foglalkoztatott B csoport esetén	$SFB = CBF * (A_{IncBF}) - CFB + TRFB - PTFB - IFB$
Megtakarítás összesen	$SS = SA + SB + SFA + SFB$

Beruházás	
Megtakarítás A csoport esetén	$IA = IA\% * (IncA + TRA)$
Megtakarítás B csoport esetén	$IB = IB\% * (IncB + TRB)$
Megtakarítás küldölnök dolgozó A csoport esetén	$IFA = IFA\% * (IncAF + TRFA)$
Megtakarítás küldölnök dolgozó B csoport esetén	$IFB = IFB\% * (IncBF + TRFB)$
Megtakarítás összesen	$I = IA + IB + IFA + IFB$
Kormányzat	
Kormányzati bevételek	$G_{inc} = PTA + PTB + PTFA + PTGB + Credit_G$
Kormányzati kiadások	$G_{expenses} = Ginc * G_ktg\% + (1 - G_ktg\%) * Ginc$
Transzfer	$G_transzfer_összege = (1 - G_ktg\%) * Ginc$
Tras_A egyén esetén	$G_transzfer_szum * TRA\% / POA$
TRA	$G_transzfer_szum * TRA\%$
Bank	
Hitelkinálat	$MAX_{hitelinalagysag} = \frac{Bank\ alaptoke\ (eredmennyel\ növelt\ értéke)}{Tökemegfelelési\ mutató}$

Ahol:

POA t-1: A populáció a szimulációs ciklus előtt

POB t-1: B populáció a szimulációs ciklus előtt

CAA: Konfliktus A és A között

CAB: Konfliktus A és B között

PWAA: Annak esélye, hogy A megnyerje a konfliktust egy A-val szemben

PWAB: Annak esélye, hogy A megnyerje a B-vel szembeni konfliktust

WA: A vagyona

WB: B vagyona

WAF: a külföldön foglalkoztatott A csoport vagyona

WBF: a külföldön foglalkoztatott B csoport vagyona

IncA: A csoport jövedelme

IncB: B csoport jövedelme

IncAF: a külföldön foglalkoztatott A csoport jövedelme

IncBF: a külföldön foglalkoztatott B csoport jövedelme

CCA: A csoport fogyasztása

CCB: B csoport fogyasztása

CFA: a külföldön foglalkoztatott A csoport fogyasztása

CFB: a külföldön foglalkoztatott B csoport fogyasztása

T: adóterhelés

PTA: A csoport által fizetett adó összege

PTB: B csoport által fizetett adó összege

PTFA: a külföldön foglalkoztatott A csoport által fizetett adó összege

PTFB: a külföldön foglalkoztatott B csoport által fizetett adó összege

TRA%: A csoport részére nyújtott kormányzati transzfer

TRB%: B csoport részére nyújtott kormányzati transzfer

TRFA%: külföldön foglalkoztatott A csoport részére nyújtott kormányzati transzfer

TRFB%: külföldön foglalkoztatott B csoport részére nyújtott kormányzati transzfer

IA: A csoport jövedelme terhére megvalósított beruházási aránya

IB: B csoport jövedelme terhére megvalósított beruházási aránya

IFA: a külföldön foglalkoztatott A csoport jövedelme terhére megvalósított beruházási aránya

IFB: a külföldön foglalkoztatott B csoport jövedelme terhére megvalósított beruházási aránya

II: Beruházási igény

SA: A csoport megtakarítása

SB: B csoport megtakarítása

SFA: a külföldön foglalkoztatott A csoport megtakarítása

SFB: a külföldön foglalkoztatott B csoport megtakarítása

SST: megtakarítások összesen

Hitel_kin: hitelkínálat

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Decoupling from China: A Case Study of Electric Vehicles and Implications for Europe and the US

Zsófia NGUYEN¹

¹PhD Candidate in Economic, University of Sopron University degree (dr. univ.) 2017

KEYWORDS

- Electric Vehicles
- Globalization
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ABSTRACT

The electric vehicle sector has emerged as a critical component in the global shift towards sustainable mobility. However, the industry's reliance on Chinese supply chains and manufacturing capabilities presents a significant concern for many countries, particularly given the ongoing geopolitical tensions with increased tariffs. These tariffs represent protectionism, potentially causing inefficiencies and higher consumer costs, leading to significant delays in the reduction of carbon emissions, which many developed Western nations have committed themselves to. As a result, the concept of decoupling from China has gained traction, presenting both opportunities and challenges. This paper explores the feasibility and implications of decoupling from China in the EV sector. The paper found that if a complete decoupling from China in the EV sector were to happen, it would require significant investment, lead to increased costs, and potentially disrupt supply chains. Partial decoupling, maintaining some economic ties while investing in domestic capabilities, could mitigate risks. The paper suggests a balanced approach, collaborative initiatives between China, US and EU could be more effective.

JEL-codes: L62, H23, R41, Q58

Introduction

In the last decade, electric vehicles (EV) have become a critical transformation and innovation of the global automotive industry, with China emerging as a dominant player in the market, accounting for 60% of consumption and 45% of production in 2023. It is also the primary producer of lithium batteries, the main component in EVs, with 65-80% of global production (IEA, 2024). It should be noted that it is not only Chinese EV brands (BYD, Great Wall, SAIC, BAIC, Changan, Chery, Geely, XPeng, NIO) that produce EVs in China; many Western brands (Tesla, Ford, GM, BMW, VW, Mercedes,

¹ E-mail: zsafia.trang.nguyen@phd.uni-sopron.hu
MTMT: 10082053 | ORCID: 0009-0007-9533-3690

Audi, Renault, Jaguar Land Rover) also have EV plants within China, producing for the Chinese domestic market, but also for export. Internationalization has become a crucial aspect for all EV manufacturers in China, targeting key external consumer markets. So far, Chinese EVs have primarily entered international markets through exports. The growth in EV exports has played a significant role in reversing China's automotive trade balance; since mid-2022, vehicle exports have consistently outperformed imports. This trend was further accelerated by the export of Chinese-produced vehicles to Russia, particularly in light of the retreat of Western brands from this market following the invasion of Ukraine (Oliveira, 2024).

The primary destination market for Chinese EVs export is Europe, followed closely by Asia. In contrast, there is minimal penetration in the North American and Latin American markets, although growth is accelerating in Brazil (Oliveira, 2024). Recently, the EU imposed a provisional anti-subsidy tariff of up to 37.6% on EVs imported from China after an anti-subsidy investigation launched by the European Commission in October 2023 without a petition by domestic EV producers. Furthermore, Chinese EV brands are generally hesitant to export to the U.S. due to a 27.5% tariff on imported automobiles, which is also expected to rise to 100% through the new trade restriction (Zhou & Gao, 2024). Additionally, the U.S. government has signaled its intention to decouple from China, emphasizing this goal over efforts to reduce carbon dioxide emissions and other gases that contribute to global warming (Tobita & Hotta, 2023). Consequently, the Chinese EV industry faces a wave of unilateral trade restrictions as US and EU policymakers are set to impose further tariffs on Chinese EVs. From this trend, a crucial question arises: is it possible for Western automakers to decouple from China's supply chain in the EV sector?

The notion of decoupling from China's supply chain has gained traction in recent years, driven by concerns over trade tensions, intellectual property protection, and geopolitical risks (Farrell & Newman, 2020). However, the reality of decoupling is far more complicated, particularly in the EV sector where China has established a significant lead in terms of technological innovation, efficient production, at a low-cost base. This paper aims to investigate the implications of decoupling from China's supply chain in the EV sector, with a focus on the potential impact on US and EU policymakers. Specifically, it will examine the challenges and opportunities associated with diversifying supply chains outside of China, the potential consequences of imposing tariffs on Chinese EVs, the strategies that Western automakers can

adopt to remain competitive, and how the EU and the US can effectively balance their trade relationship with China while promoting its strategic interests, reducing dependence, and increasing competitiveness in the EV race.

The Emergence of China's Electric Vehicle Industry

In the early 2000s, China's car industry was struggling, focusing mainly on traditional internal combustion engine vehicles (ICE) without any domestic brands capable of competing with foreign automakers and potentially leading this domain. China recognized that it would never surpass the automakers from the US, Germany, and Japan in terms of innovation for ICE. Additionally, research on hybrid vehicles, where the batteries initially played a secondary role compared to the gasoline engine, was already pioneered by Japan. The Chinese government turned its attention to EVs as a new priority. This shift also aimed to address several issues, including severe air pollution and reliance on imported oil, while also aiding economic recovery post-2008 crisis. EV technology became a focal point in China's 10th Five-Year Plan (FYP) period 2001-2005, especially after Wan Gang – an automotive engineer with EV expertise who worked for Audi in Germany –, became the minister of science and technology in 2007. To encourage the growth of the EV industry, the government implemented supportive measures, such as offering \$29 billion in financial subsidies to automakers from 2009 to 2022, integrating EVs into public transportation, waiving license plate restrictions for EVs in cities like Beijing, and providing local government support to companies like BYD. The government support also included extending subsidies to foreign firms, such as Tesla, to strengthen the EV ecosystem. Lastly, it is important to mention that China has huge investments in building charging infrastructure across the country, making it more convenient for EV owners to recharge their vehicles and combat initial resistance to change from ICEs commonly referred as “range anxiety” (Yang, 2023).

With substantial government support, China's EV industry transitioned from the exploration stage to the demonstration stage during the 11th FYP (2006–2010). In this period, 2,600 plug-in EVs were put into operation, including 970 battery electric cars (BEV), 350 plug-in hybrid electric cars (HEV), 730 battery electric buses, 350 plug-in hybrid electric buses, and 200 battery electric special vehicles. During the 12th FYP (2011–2015), the Chi-

nese New Energy Vehicle (NEV) industry entered the market stage, progressing from the demonstration phase, with 494,200 plug-in EVs put into operation (Du et al., 2017). During the 13th FYP (2016–2020), the entire industrial chain of the EV industry was established and upgraded at the national level. In line with the expansion of the sector, financial subsidies from the government gradually declined while the technical entry barriers for the EV industry increased. Strong interventions were implemented to guide and promote the sustainable development of EVs, particularly focusing on technological innovation and improving energy efficiency (Wu et al., 2021).

As a result of these policies and investments, China has become the world's largest market for EVs, accounting for 60% of global EV sales in 2023. Most of the EVs sold in China are produced domestically. Additionally, China is the leading global producer of lithium batteries with 60% to 80% for cathode productions, which are essential components of EVs (IEA, 2024). With the battery typically accounting for about 40% of the cost of a new EV, China's focus on developing affordable technology in this field is now paying major dividends. Many Western EV makers initially favored lithium nickel manganese cobalt (NMC) batteries, which offer a longer range and higher performance.

In contrast, Chinese companies have prioritized lithium iron phosphate (LFP) technology, which is cheaper and more reliable. By focusing on improving LFP batteries, the Chinese firm CATL has become the leading global EV battery manufacturer, with control of more than a third of the global market. China's strength in battery production is bolstered by the good access it has secured to the raw materials used because of a long-term strategy of buying stakes in key mining companies for minerals such as lithium. It also controls the majority of the refinery capacity in the world when it comes to critical components. Factors such as these are contributing to the growing global dominance of China in EV batteries (Wang, 2024). The growth in the sector has not only provided sustained growth for China's EV industry but also positioned China as a leader in climate policy (Yang, 2023). These policies are part of the 14th FYP (2021-2025), which promotes collaboration between EV and battery manufacturers to integrate NEV production with recycling processes and to manage the entire lifecycle of re-used EV batteries, ensuring quality and responsible environmental disposal with the government offering incentives such as tax exemptions and loans (Zhou et al., 2023).

Current State of China and the West EV Industry

In recent years, the demand for EVs is rising as competition intensifies, leading to a decrease in price compared to non-electric vehicles, making them more affordable and accessible to the public. Notably, the second-hand EV market is also expanding, with prices falling quickly and becoming competitive with combustion engine equivalents. According to *Global EV Outlook 2024* from the International Energy Agency (IEA, 2024), in 2023, around 14 million EVs were sold globally, with most of the sales concentrated in China (60%), Europe (25%), and the United States (10%). In contrast, these markets accounted for around 65% of total car sales worldwide, showing that sales of EVs remain more geographically concentrated than those of conventional ones. Although EV sales in emerging economies have been slower than in major markets, growth accelerated in 2023, with Vietnam seeing around 15% of cars sold as electric and Thailand at 10%. The same study from IEA also states that the global share of EV sales is projected to increase to 35% by 2030, up from less than 25% in previous forecasts. China is expected to remain the largest market for EVs, followed by the US and the EU, which are anticipated to double their market shares and maintain their current positions. As China leverages its dominance in EV and battery production to foster a robust domestic EV industry. Chinese companies like CATL, BYD, and SAIC Motor are key players in the global EV market (Yang, 2023). From 2018 to 2023, exports of Chinese EVs experienced rapid growth, with 1,016% in both quantity and value. In 2023 alone, China's total exports of EVs increased by 70%, reaching a value of \$34.1 billion. The quality of these exports is also improving, as evidenced by higher unit prices and an increasing proportion of exports going to high-income countries such as the UK, or the Gulf States of Saudi Arabia, the UAE and Qatar. This growth has been fueled by a relaxation of joint venture requirements for EV manufacturers imposed by the Chinese government, as well as the development of higher-quality EVs by domestic manufacturers. However, Chinese EV exports to the United States did not see significant increases during this period due to high tariffs of 27.5% on automobiles imported from China (Coffin et al., 2024). The majority of EVs exported from China are destined for Western Europe and the UK due to high demand in the region, high per capita income, high local EV prices, low European customs tariffs (Oliveira, 2024). There are also substantial government and manufacturer subsidies regardless of its origin, in an attempt to reduce emissions and support EVs adoptions as seen in

many EU countries such as Germany provides up to €6,750 via its Umweltbonus scheme (Morrison et al., 2023), Spain's MOVES III program extends to €400 million to support EV adoption and charging installations and other member states offer purchase incentives, such as tax breaks and reduced toll fees, to make EVs more affordable (European Commission, 2025).

The second largest share of China's EV market is held by a foreign firm – the US-based Tesla, which accounted for 7.8% of the market last year. Western auto firms have historically operated in China through joint ventures, but since 2019, Tesla has had its own wholly-owned factory in Shanghai, which received national and local government support and now makes 150,000 cars a year. In the Chinese domestic market, Tesla primarily targets the high-end segment, while BYD's main focus is on more affordable cars such as the Seagull, billed as the world's cheapest electric car. Nonetheless, Tesla is in increasingly fierce competition with Chinese firms both in the international and local Chinese markets. In 2023, Tesla significantly cut prices for some of its Chinese models, as Geely successfully launched their premium brand called Zeeker in direct competition to Tesla's most popular Model 3 and Model Y products (Wang, 2024).

To understand the competitiveness of Chinese EV brands, a recent report by Rhodium Group (2024) gives the example of BYD's Seal U model that sells for €21,769 in China and €41,990 in the EU. Not only are Chinese automakers rapidly gaining shares of the European EV market (especially in the lower-priced segments), but they are making higher profits on their European sales. (Bukowski, 2024).

Table 1. Volkswagen and BYD model comparison in Germany and China (Price in EUR)

OEM	Model	Price in Germany	Price in China	German price premium relative to China	Battery kWh	Horsepower
Volkswagen	ID.4	46,335	31,011	49.4%	77	204
BYD	Seal U Comfort	41,990	21,769	92.9%	72	218
Volkswagen	ID.3	32,975	21,011	56.9%	58 (CN: 52.8)	204 (CN:170)
BYD	Atto 3 Comfort	37,990	17,923	112.0%	60.5	204

Source: Rhodium Group, 2024

Factors Promoting the Decoupling of EV

The aforementioned increases in tariffs leveraged against China-made EVs is part of a broader concern by the US and its European allies regarding China’s strategic industrial policies. In this context, both the EU and the US continue to reinforce expectations for EV legislation to align with their 2030 strategy and simultaneously encourage adding value and creating jobs across EV supply chains in their economies. The difference in US and European approaches to Chinese EVs reveals deep strategic divisions. The US is concerned about maintaining its technological edge and protecting domestic industries. It has embraced protectionism and tariffs to counter China’s rise. EU countries on the other hand remains cautious, recognizing the risks of alienating a major economic partner (Bukowski, 2024). In May 2024, the US increased tariffs on Chinese-made EVs from 25% to 100%; this follows its longstanding concern about China’s unfair trade practices (Zhou & Gao, 2024). Additionally, the US Defense Department has added Chinese battery manufacturer CATL to a list of companies it claims work with China’s military, further escalating tensions between the US and China. CATL responded by stating that it is not engaged in any military-related activities. While the designation does not involve an immediate ban on sales, it presents a significant a blow to the reputations of affected companies and signals a stark warning to US entities and firms about the risks of conducting business with

them. It could also add pressure on the US Treasury Department to sanction the companies. The purpose of the Chinese Military Companies (CMC) list is to communicate the Defense Department's opinions, which may guide other government departments. The most severe consequence for companies on the CMC list is a potential ban on US investments, but the final decision will rest with the reelected President Trump and his administration (Reuters, 2025). Therefore, it remains uncertain whether a new phase of stricter measures against China will emerge, particularly since Trump is historically known for initiating the trade war with China and increasing tariffs on goods and banning Huawei from the 5G network over national security concerns (Nguyen, 2022).

In line with the US, Canada has increased its import tariff on Chinese EVs from 6.1% to 100%, citing issues related to Chinese industrial policies and subsidies that lead to overcapacity and unfair competition. In July 2024, the EU imposed a provisional anti-subsidy tariff of up to 37.6% on EVs imported from China, following an anti-subsidy investigation initiated by the European Commission in October 2023, without any petition from domestic EV producers (Zhou & Gao, 2024). This decision has revealed a division among EU countries. The French government has argued for high tariffs, seeking to shield its robust but struggling domestic car industry from cheap Chinese imports. Conversely, German automakers, with large market shares in China and longstanding partnerships with Chinese firms, worry about a tit-for-tat retaliation. China has signaled its willingness to retaliate by threatening to raise tariffs on high performance ICE vehicles from 15% to 25%, a direct threat to BMW, Porsche and Mercedes' luxury vehicles. Other EU nations are similarly divided. BYD is already building factories in Hungary and Spain as part of their strategy of localizing production within the EU and thus circumventing the import tariffs (Bukowski, 2024). Furthermore, China has also filed a dispute against the EU's tariff at the World Trade Organization (Zhou & Gao, 2024). It is not clear the effect that such an increase will have on European consumers demand for China-produced EVs, but it is likely to slow down the fast penetration they were having on the wealthier Western European markets (Oliveira, 2024).

Discussion on Potential Consequences of Decoupling and Implications for Europe and the US

Comparing the US and EU approach towards China reflects the wide range of possible outcome in response to decoupling from China. The stark contrast between the 2 largest economies in process and outcomes underlines the enormous impact of the political system. The US, and EU have a complex relationship with China regarding EVs production, despite their differences, the US and EU share a common concern about China's overwhelming dominance in the EV and broader green technology space. The US has taken an aggressively protectionist, with blanket tariffs on Chinese EVs and related materials, reflecting a dual focus on protecting domestic industries and decoupling from China. In contrast, the EU has adopted a more calibrated approach, imposing provisional tariffs of 37.6% on Chinese EV imports following an anti-subsidy investigation. In both markets, demographic, social, and psychological influences shape consumer perceptions of EVs, contributing to significant heterogeneity in consumer preference. The differing tariffs and strategies of the US and EU contribute to tensions, pushing China to localize production within Europe, and find ways to keep its limited access to the US market, such as through the Geely-owned Volvo's production plant in South Carolina (The New York Times, 2025).

The implications of such tariffs extend beyond immediate economic impacts. The harm to China's EV industry could potentially lead to reduced competitiveness and innovation, affecting global supply chains and consumer access to affordable EVs. For the US and EU, the benefits may include supporting domestic EV manufacturing, creating jobs, and potentially enhancing energy security. However, from an economic theory perspective, these tariffs can be analyzed through the lens of protectionism. Additionally, the theory of comparative advantage suggests that countries should specialize in producing and exporting goods and services in which they have a comparative advantage, and import those in which others have an advantage (Findlay, 1991). Tariffs, however, distort this natural trade flow, potentially leading to inefficiencies and higher consumer costs. In the case of the US and EU, the potential harm from decoupling includes disrupting established supply chains, raising production costs, and potentially escalating trade tensions. The benefit lies in the protection of domestic industries, which could lead to job creation and technological advancements.

It's crucial for policymakers to carefully weigh these considerations. While there are valid concerns about China's trade practices, abrupt decoupling could lead to unintended consequences, such as market disruptions, increased global tensions, and a general deterioration of the global efforts to cut carbon emissions. A more balanced approach might involve engaging in dialogue with China to address trade imbalances, while also investing in domestic innovation and sustainability in the EV sector. Policymakers should also consider the potential for collaborative initiatives, such as joint research and development projects, which could foster technological advancements without the need for disruptive tariffs. Additionally, focusing on creating a level playing field through international agreements and regulations could be more effective than unilateral tariffs in addressing perceived trade distortions.

If the US and EU were to completely decouple from China in terms of EV and battery production, it would involve severing all economic ties and self-sufficiently developing domestic EV and battery manufacturing capabilities. This approach would require significant investment in research and development, infrastructure, and workforce training. While this could theoretically reduce dependence on China, it would likely lead to increased costs due to the high initial investment required. Moreover, the time needed to develop such capabilities could extend beyond the urgency of addressing current market demands and environmental goals. Both the US and EU have well-established automotive industries with advanced technology and a high degree of innovation. The EU also has a strong focus on sustainability and environmental regulations, which can be advantageous in the EV sector. Despite their advantages, the US and EU do rely on China for most aspects of EV production.

Partial decoupling could involve a hybrid approach, maintaining some economic ties with China while simultaneously investing in enhanced domestic capabilities. This would allow for the gradual reduction of reliance on Chinese manufacturing, potentially mitigating risks associated with supply chain vulnerabilities. However, this strategy would require careful management to balance the need for reduced dependence with the economic benefits of existing supply chains. Additionally, the partial nature of decoupling might not fully address concerns over distortions in global trade due to subsidies and overcapacity in China's EV industry.

In the scenario where decoupling is not feasible due to economic interdependencies, technological collaborations, or market dynamics, the focus would shift to diplomatic and policy-based strategies. This could involve strengthening international trade agreements and regulations to address trade

imbalances and unfair practices. Additionally, the EU and US could pursue targeted tariffs and subsidies for their domestic industries to foster growth and competitiveness without disrupting the entire supply chain. Diplomatic efforts to engage China in discussions on trade reforms and environmental standards would also be crucial.

Conclusion

In conclusion, while the US and EU have the capability to produce EVs without direct Chinese involvement, it would require significant investment and time to establish alternative supply chains. It's also important to note that China, with its dominant position in production as well as R&D and key component technologies, could potentially use these as leverage in trade negotiations. While the impulse to protect domestic industries and decouple from China is ongoing, policymakers must carefully consider the long-term implications of such actions. A balanced approach that combines strategic dialogue, domestic investment, and collaborative international efforts may offer the best path forward for the US and EU in navigating the complexities of global EV trade. While addressing trade imbalances and ensuring fair competition is crucial, a complete decoupling could impose substantial economic and social costs. In all scenarios, maintaining open communication channels with China for dialogue on trade practices and environmental standards is essential. This could help in finding a balanced approach that safeguards global trade interests while promoting sustainable development in the EV industry.

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Spatial sensitivity of national climate adaptation policies in Eastern-Central Europe

First results of national comparative studies

Attila Gergely SÜTŐ¹

¹Nemzetközi Kapcsolatok és Politikatudományi Doktori Iskola
BCE / CDI NKPTDI

KEYWORDS

- spatiality
- climate change
- strategic planning
- adaptation policy
- strategic planning tools

ABSTRACT

There is a strong link between climate adaptation and the geographic space: climate change impacts differ from region to region, and its spatial consequences require appropriate, region-specific adaptation responses. It is important to plan these measures in a spatially conscious way and to monitor their effectiveness, spatially varying impacts and adaptation results. The question arises whether spatial/territorial characteristics are adequately taken into account in adaptation policy activities, especially at national level, which spatial scale has so far received less attention in the literature than the local level. To investigate this topic, a new concept of spatial sensitivity and its applicability in adaptation policy is introduced and its role and extent in national adaptation planning and MRE activities in European countries is analysed by the research. The aim of the paper is to provide a brief overview of the research results to date, including the methodological background. The paper concludes with the first empirical results of the analysis for the Eastern-Central European region: that adaptation policy and planning are growing in importance in many countries, but the related monitoring/assessment activities and the emergence of spatial considerations in these and in planning itself are still in their early stages.

JEL-codes: Q5, Q54, Q58, R58

KULCSSZAVAK

- területiség
- éghajlatváltozás
- stratégiai tervezés
- alkalmazkodási politika
- tervezési eszközök

ABSZTRAKT

Nemzeti alkalmazkodási politikák klímaszemponú térérzékenysége Kelet-Közép-Európában. A nemzeti összehasonlító tanulmányok első eredményei. | Az éghajlati alkalmazkodás és a földrajzi tér között szoros kapcsolat áll fenn: az éghajlatváltozás térségenként eltérő hatásokkal jelentkezik, térbeli következményei megfelelő, térségspecifikus alkalmazkodási válaszokat követelnek. Fontos feladat ezen intézkedések térben tudatos tervezése,

¹ E-mail: suto@met.hu

MTMT: 10088328

valamint hatékonyságuk, a térben eltérő hatások és a helyileg eltérő alkalmazkodóképesség nyomon követése. Felmerül a kérdés, hogy a területi jellemzőket megfelelően figyelembe veszik-e az alkalmazkodási politikában, különösen nemzeti szinten, amely területi lépték eddig kisebb hangsúlyt kapott a helyi szinthez képest a szakirodalomban. A téma vizsgálatához egy új fogalom, a területi érzékenység fogalmát hozzuk létre, valamint annak alkalmazhatóságát, szerepét és mértékét elemezzük az európai országok nemzeti alkalmazkodási tervezési, monitoring és értékelési tevékenységeiben. A tanulmány célja, hogy rövid áttekintést adjon a kutatás eddigi eredményeiről, többek között a módszertani háttérrel. A tanulmány az elemzés első eredményeivel zárul a Kelet-Közép-európai régió kapcsán: az alkalmazkodási politika és tervezés súlya számos országban növekszik, de a kapcsolódó monitoring/értékelési tevékenységek és a térbeli szempontok megjelenése ezekben és magában a tervezésben még csak korai fázisban van.

JEL-kód: Q5, Q54, Q58, R58

Introduction

This study is the third part of a series of presentations/articles published in the framework of international conferences held by the Lámfalussy Faculty of the Sopron University. The first part presented a comprehensive literature review of European climate adaptation planning and monitoring/reporting/evaluation (MRE) activities (Sütő, 2023); suggesting that spatial viewpoints and special emphasis on geographical characteristics should be of key importance in the mentioned activities. The second study went through space interpretations and approaches of space-oriented disciplines and practical fields to create a new concept for spatial sensitivity in adaptation policy, as a basis for further empirical analyses (Sütő, 2024). According to these first two studies, it is clear that climate adaptation policy cannot be treated independently from the geographical space. Consequently, integration of geographical/spatial perspectives into adaptation policy activities are of key importance and raise the question: how and to what extent do these spatial considerations emerge in climate adaptation policy-related tools?

Climatic factors are ab ovo among the most important geographic endowments together with topographic, hydrographic, biogeographic or soil characteristics – they influence spatially different climate impacts and consequences. Several studies conclude that climate change and adaptation occur in the geographical space (Davidse et al., 2015; Sütő, 2023; Taylor, 2023). Planning and implementation of adaptation measures require adequate knowledge base about spatially different effects and search for regionally different adaptation responses. Spatially determined impacts are described often

by objective geographic dimensions, e.g. in the form of risk maps (Koks et al., 2014, Davidse et al., 2015). Climate risk and vulnerability assessments, as providers of these maps are basically spatial, monitoring relative spatial/territorial differences and indicating that spatial/territorial approach and the emphasis on geographical features, spatial differences play essential role in climate (adaptation) policy. Several Hungarian authors and articles deal with the methodological background of quantitative spatial climate vulnerability analyses (Pálvölgyi et al, 2010, Pálvölgyi et al, 2011) or assess the impact chain-based vulnerability of given sectors [e.g. Sütő & Fejes (2019, tourism), Pappné Vancsó et. al (2014, drought management), Pappné Vancsó et. al (2016, rural development), Uzzoli et. al (2019, human health), etc.].

Linkage between climate policy and spatial issues has started to be studied in the last two decades, but the total number of such literature-related items is still low. Majority of the few articles concentrates on mitigation [e.g. Gustaffson et al., 2009; McGloughlin & Sweeney, 2011; von Lucke, 2021]; or spatial/territorial differences and spatial specification in climate adaptation attitudes & awareness (e.g. Weckroth & Ala-Mantila, 2022, or from Hungary Bús et al., 2021, Bodor & Grünhut 2021, Kiss et al., 2021, Kiss et al, 2022). Directly adaptation's spatiality-focused articles are rare and rather case study-like (Jensen et al., 2013; Skryzhevskaya et al., 2015; Cobbinah & Adnaney (ed.), 2019; Berke et al., 2021; Yarnal., 2021). Larger proportion of the related studies concentrates on adaptation planning and MRE activities in general. These are studies from the grey literature (e.g. EEA, 2020; EEA, 2022), as technical reports introducing national level adaptation planning and MRE in Europe with the most crucial challenges and current processes. Beyond these evidence-base reports real scientific studies focused mostly on the regional (Heidrich et al, 2016; Wright et al, 2021; Ottaviani Aalmo, 2022; , Birchall et al, 2022) or the local level (Salvia et al, 2021 a; Salvia et al 2021 b; Reckien et al (2023). National level comprehensive studies are rare (e.g., Morgan et al, 2019; Woodroff & Regan, 2019; Leiter, 2021). Hungarian authors deals mostly with municipal or county level strategic analysis and planning in climate policy (e.g. Botos & Sütő, 2018; Kiss et al., 2018; Óvári et al, 2024).

Spatiality in adaptation is dealt with in a rather implicit form. Several authors deal with the role of geography as a spatial science in understanding climate change, climate adaptation and their spatiality (Randalls, 2017; Farbotko, 2018; Chang & Wi, 2018; Colven & Thomson, 2018; Taylor & O'Keefe, 2021); or analyse the role of adaptation and risk analysis in spatial

planning (Sapountzaki et al. 2010, Greiving & Schmidt-Thomé 2013, Storbjörk & Uggla, 2014). Others focus on the growing connection between urban planning and adaptation planning (Uittenbroek et Al., 2013; Birkmann et al, 2014; Burnette & Caldarice, 2018; Salamin, 2018) again others on the assessment of the relationship between environmental and climate policies and regional policy (Greiving & Fleischhauer, 2010 and 2012; Davidse et al., 2015, Weckroth & Ala-Mantila, 2022).

However, the importance of proper, spatially conscious adaptation planning, monitoring and evaluation; the role of spatial thinking and aspects do not appear directly in the reviewed literature items. Those few studies that concentrate on these spatial issues (Schuster, 2008; Swart et al, 2009; Greiving and Fleischhauer, 2010; Roggema, 2009; EEA, 2022) conclude that although some special characteristics/focuses can be identified in national adaptation strategies' situation analyses in the late 2000s – early 2010s, their addressed sectors and actions are quite similar. No geographical specificities are reflected neither by the objectives nor the type of actions of given national strategies (Swart et al, 2009; Greiving and Fleischhauer, 2010; EEA, 2022). These findings point unambiguously to the direction of a new research gap: the spatiality of adaptation policy instruments has not been studied in sufficient depth, especially at national level, from a scientific point of view (Sütő, 2023).

Objective of the article

As we saw it, climate adaptation and spatiality are strongly related concepts: special climatic factors of geographical places determine the geographically / regionally different effects of climate change. Long- medium and short term changes of the climatic factors occur in the reality of space and show significant spatial diversity between the different geographical locations, resulting in spatially different climate change impacts and consequences. Policy responses to these challenges could be appropriate and effective if these spatial/territorial aspects/differences are taken into account properly. My wider research plans to increase the capabilities of climate adaptation policies and strengthen further their potentials to tackle the geographic reality of the present and future implications of climate change.

To respond to the research gap identified by the literature review, the importance of the geographical space and spatial elements in climate adaptation, the wider research is to reveal the sensitivity to spatial dimensions of

national climate adaptation policies in European countries. It aims at finding out whether climate adaptation, as a strongly geographical space-oriented area put significant weight on these matters or not. To reveal this spatial sensitivity of policies it analyses and evaluates the role and degree of spatial content and sensitivity to spatial dimensions in national climate adaptation policy planning and MRE instruments, providing aspects capable of measuring this spatial sensitivity. The article itself introduces the empirical results of the first analysed group of European countries, Eastern-Central Europe.

Methodology

The essential element of the empirical work phase is the comparative document analysis, concentrating on existing national planning documents, such as national adaptation strategies (NAS), national adaptation programmes

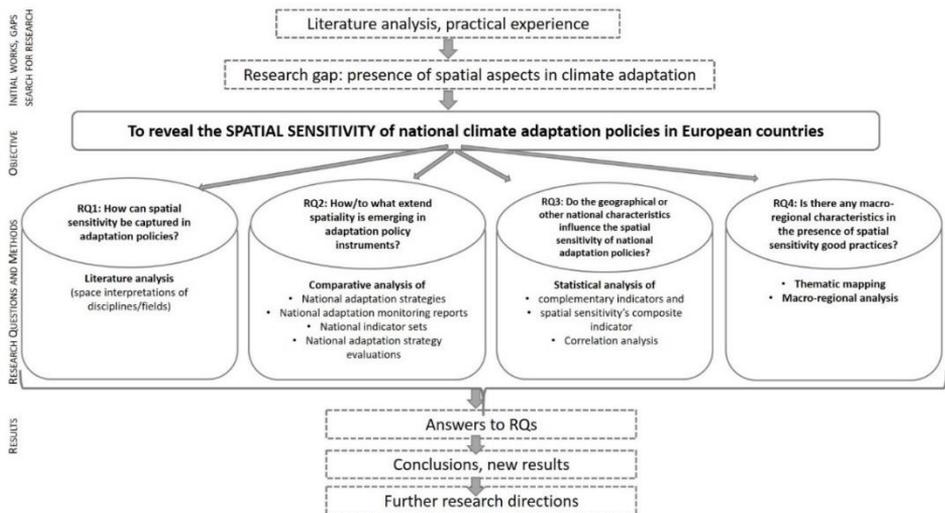


Figure 1: Structure and logic of the wider research.

Source: own editing.

(NAP), action plans, evaluation and monitoring materials); monitoring and evaluation reports, indicator sets and MRE systems. In the centrum of the analyses are the NAS documents². On the other hand, I also examine nati-

² Under the term NAS, similarly to Timo Leiter's 2021 analysis and using his umbrella definition, I understand national planning documents comprising both national adaptation

onal level monitoring methodological background documents, reports, evaluation concepts and products, indicator set descriptions elaborated or commissioned by national governmental organizations.

In countries having already implemented more than one adaptation planning cycle only those documents were analysed that are currently in force. Considering that adaptation is a relative new field (the community level strategic frameworks has been recently established and the national/regional/local regular planning cycles has begun only since the early 2010s in Europe) the research concentrates on the period of the last 1-1,5 decades, comparatively analysing results of the first MRE cycle.

In a third step, I try to identify the main influential factors of adaptation tools' spatial performance, through comparing the elaborated national spatial sensitivity composite indicators to other national social/economic/geographic/spatial administration-related indices. In the fourth step, macro regional determination is also sought in spatial sensitivity values of European national adaptation activities (*Figure 1*).

The concept and model of spatial sensitivity

To define the above-mentioned policy instruments' spatial content and the degree of spatiality within them, a new concept, namely spatial sensitivity of adaptation policy is introduced by the research. This model integrates the most important utilizable elements of the space interpretations and concepts of different scientific disciplines and practical fields into a complex definition as an appropriate basis for analysing spatiality's presence and weight in adaptation activities³ (Sütő, 2024).

Summarizing the usability of approaches of the examined disciplines, we can draw the conclusions in the form of an indicative definition for spatiality / spatial sensitivity in adaptation policy (*Figure 2* visualises this). We –

plans and national adaptation strategies. These can be either documents covering both mitigation and adaptation or strategies concentrating only on adaptation.

³ A wide variety of space interpretations of relevant disciplines and policy domains emerges before us. Out of these, the planned empirical analysis it concentrates mostly on absolute and objective space interpretations of natural sciences and environmental geography; on the relative approach of social and economic geography, regional geography, geopolitics, and regional studies; and on those disciplines that focus on (mostly internal) space concepts implicitly (political and administrative studies, and partly even the regional studies). On top of these even some practical fields' (regional development policy, strategic spatial and land use planning) spatial approaches and related concepts were also examined.

at least during this research – understand under the term “spatiality in policy activities” the conscious, constant and consequent taking of external and internal spatial elements and their characteristics, territorial/spatial differences, and spatial order into consideration within the absolute or relative space and the place-based approach in the examined activities, namely planning and MRE.

Consequently, we consider an adaptation policy activity spatially conscious/sensitive if it puts significant weight on these spatial aspects/dimensions both in their evidence seeking phases, during decision making (vision and objective planning and elaboration of measures), setting up indicator sets and conducting evaluations or establishing decision supporting systems. If these aspects are at least equal with the weight of the traditional sectoral approach (separated handling of different thematic fields parallel with each other) or even dominate it, then can we talk about a spatially oriented approach, or spatial sensitivity of these activities.

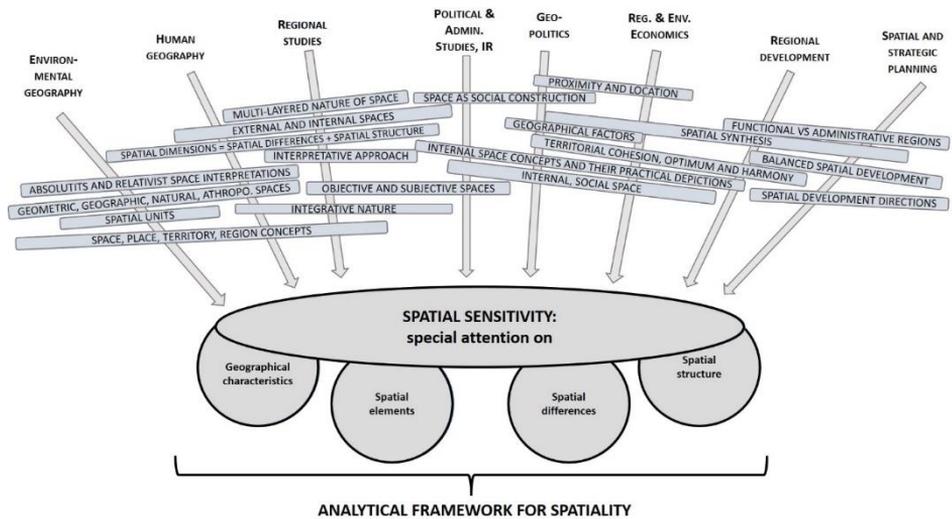


Figure 2: Main sources of the concept of adaptation’s spatial sensitivity in the research.

Source: own editing.

Delimitation of the analysed area

The geographical framework of the wider research is primarily Europe. More exactly the majority of the continent's countries (all EU countries + EEA states, completing the list with Western-Balkan states as countries that strongly strive for EU accession). From the former Central-European socialist bloc and Soviet successor states, I focus rather on the former group and leave the second out of the analysis due to their lesser focus on climate policy-related topics and the even more "low-priority development policy field" status of adaptation. The only exceptions are the Baltic states, which region, due to their historical and social roots are closer to the Central-European region than to the former Soviet-Union. The mini states (Lichtenstein, the Vatican, Andorra, Monaco, San Marino, with the exception of Luxemburg, which is somewhat bigger than the others) were also left out, because the main topic of the research, spatiality and spatial differences cannot be adequately interpreted at national level in such small countries.

During the analysis of spatial sensitivity of European national adaptation policies, an interesting issue is whether this spatial sensitivity is depending on the macro regional location of a given European country or not. To answer this question European macro regions must be delimited in the research. Grouping the analysed European countries this way, as a practical side effect, we also can split the empirical work phase into different sections, the first of which is concentrating on the topic of this article, Eastern-Central Europe.

The most frequent type of macro regions in the different books/articles are basically the traditional North/West/South Europe division, completed with Eastern Europe. The first three regions' delimitation is more or less clear and similar group of countries are classified into these regions in the different works, meanwhile the latter's is a bit tricky. Probáld after having overviewed the several nomenclatures, delimitations and the social, economic and geographic characteristics of European countries, grouped the states into 5 main regions (Western, Southern, Northern Europe and Eastern Europe and the Baltic states). The fourth group was split into 2 additional subgroups: Western-Central and Eastern-Central Europe. Regarding the latter Probáld said it comprises the Eastern part of Central- and South-Europe (the Balkan Peninsula without Greece) (Probáld et al., 2000). Similarly, Illés also collected the different history-, ethnography-, politics- and economics-oriented Eastern- and Central-European delimitations, especially emphasising the role of politics. He mentioned that some concepts even differentiate a third region between East and West, an area with special geopolitical position and unique

strategic challenges⁴. After 1990, the ex-satellite states of the Soviet Union compose this group, which countries often emphasised their differences from Balkan states then. (Illés, 2002).

If we are looking for practice-oriented delimitations, approaches of EU-level strategic documents/regional policy tools can be mentioned. The 2011 Territorial State and Perspectives of the European Union (TSP) document⁵, as the background document of the then actual Territorial Agenda of the EU dedicated an individual chapter for the spatial potentials and challenges of Europe, presenting Europe's four main macro regions facing special challenges (Figure 3). Beside Western, Southern and Northern Europe, the Eastern part of Central-Europe („the Central-Eastern”) was also identified. It included most of the then new (post-2004) EU Member States⁶ (TSP, 2011).

The EU's regional development policy has dealt with European macro regions since the middle of the 2000s (Illés, 2002). In the current programming period, transnational cooperation, coordinated by the Interreg B programme, allows for collaboration over larger transnational territories or around sea basins⁷ promoting better cooperation across countries within the designated regions. Out of the current 12 macro regions, the Central, the South-east and the Danube regions cover roughly the territory of Eastern-Central-Europe (ec.europa.eu).

The most up-to-date delimitation is that of the first European Climate Risk Assessment Report (EUCRA) that supports the identification of adaptation-related policy priorities. The EUCRA considers four subcontinental

⁴ One group of this approaches focuses on “Central-Europe” based on the German “Mitteleuropa” concept, under which they initially understood the eastern territories inhabited by German population, later the territories of the German and Austro-Hungarian empires, depicting the German orientation of Central Europe. The other main subgroup is called “Zwischeneuropa” or “In-between-Europe” concepts. These have weaker historical but stronger geopolitical roots. The essence of the idea strived for counterweighing the influence of German and Russian dominancy. The creation French-based cordon sanitaire of Petite Entente states after 1918 is a good example for this.

⁵ Presented at the Informal Meeting of Ministers responsible for Spatial Planning and Territorial Development on 19th May 2011 Gödöllő, Hungary

⁶ Regarding their characteristics, similar features emerged than in the studies of Probáld and Illés, completed with demographic, economic and settlement network-related development endowments.

⁷ In some programmes, even non-EU countries (third countries such as Iceland or Lichtenstein), enlargement and neighbourhood partner countries, and OCTs (The Overseas Countries and Territories) are also involved, with the aim of achieving stronger territorial integration.

regions (see *Figure 3*). The Baltic states in this delimitation belong to Northern Europe and all the West-Balkan to Southern Europe, otherwise the logic follow those of the above introduced ones (EEA, 2024).

Eastern-Central Europe, as we experience, is among the vulnerable parts of the continent. In the region highly vulnerable sectors (e.g., water management, agriculture, forestry, energy infrastructure, tourism) and vulnerable territories (e.g., mountainous areas, landlocked plains, urban agglomerations and even coastal zones) emerge. The first part of the empirical analysis deals with this group of states. In My delimitation of the region follows the mixture of the above-mentioned Eastern-Central European delimitations and the EU-CRA delimitation, practically completing the latter with the Baltic states and the three southern Slavic countries of the Carpathian-basin.

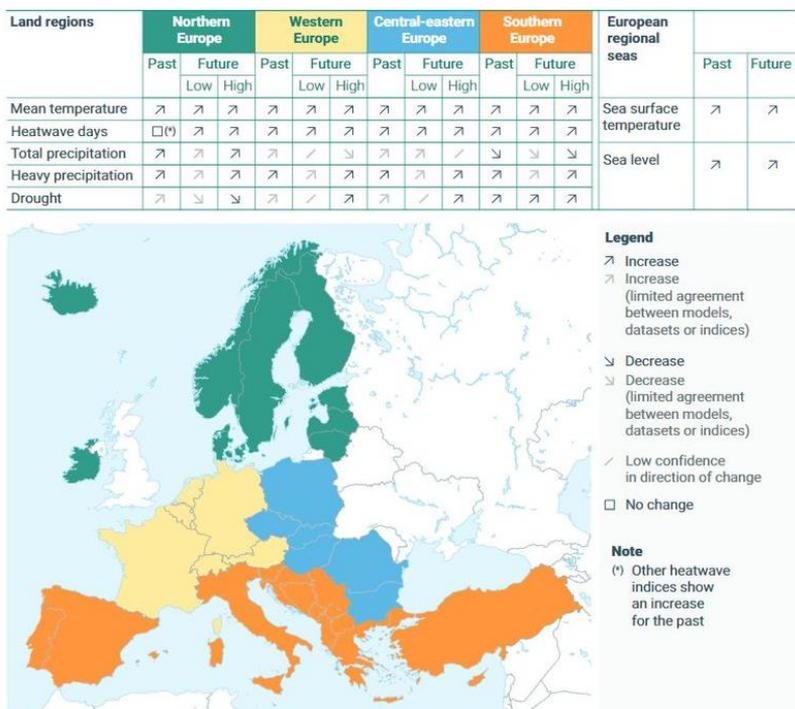


Figure 3: Observed and expected major climate risk factors in different European macro regions interpreted by the EUCRA.

Source: EUCRA, based on Copernicus climate change service (C3S)

Aspects of the comparative analysis of national adaptation policies' spatiality

The comparative assessment of the country-level adaptation policies' spatial sensitivity is based on a predefined analytical aspect system, with 9 main factors and 2-9 sub-factors under each factor. The comparisons takes a critical lead, not just the description of the national characteristics - the explicit system of analytical aspects serves this. The planned analytical aspects and sub aspects are as follows:

Weight and character of spatiality in climate adaptation policy in general is examined through the "space phraseology" (quantified emergence of space-related concepts in the documents' text) and the basic logic and structure of climate adaptation in a given country (are adaptation activities organised according to sectors or to territorial units/region types?).

Spatial levels of adaptation planning aspect assesses whether the NAS documents identify the main territorial levels of adaptation planning activities. We also searched for signs of propagation of adaptation planning at lower spatial (regional/local) levels in the NAS/NAP documents.

Spatial aspects are examined in evidence base-related work phases, exactly in the situation analyses and assessments (including SWOT analyses) of NAS/NAP documents. Here the basic logic (sectoral or spatial) of the situation analyses as well as degree of their spatial visualization (use of maps and regional figures/diagrams) is analysed. Spatial content is examined through the degree of appearance of region types, spatial units, spatial difference-searching logic and settlement-network related issues in the respective chapters' texts. The spatial planning focus is also interesting: to what extent do situation analyses/assessments deal with the connection between adaptation planning and spatial planning? The consideration of the given countries' position within Europe or their own macro region from adaptation point of view in the respective chapters were also examined.

Spatial aspects in objective systems are similarly in the focus of the empirical research. The basic logic (sectoral or spatial), the general spatial content and spatial visualisation of the adaptation visions and objective systems are analysed. Spatial content of specific and lower-level objectives (fields of intervention) and horizontal goals are analysed through the degree of appearance of region types, spatial units, spatial difference-searching logic and set-

tlement-network related issues. Emphasis on spatially oriented MRE activities within the objective system- and vision-planning is evaluated as well and the emergence of basic territorial cohesion-related concepts in these chapters.

Spatial aspects and content in adaptation actions is examined similarly to that of the objective system and vision. Degree of spatial aspects, spatial monitoring, and spatial planning focus of adaptation measures are part of this analytical aspect.

The *geopolitical content of adaptation planning* aspect examines the emergence of geographically climate-related risks (migration, potential competition for resources, etc.) as aspects for national security within the introduced challenges of NAS/NAP documents. The presence of strengthening macro regional / international co-operations between countries is also identified in some documents, meanwhile the appearance of the intention of exerting influence on other countries in the form of adaptation knowledge export or financial supports were also identified in some cases.

Traces of *spatiality in adaptation-related monitoring activities* are analysed through the identification of spatial levels of data connection and monitoring activities through the description of MRE activities in NAS/NAP documents or monitoring background materials. Where they exist, we try to identify spatial content of adaptation indicator sets. The presence of geo-information-based decision support system in adaptation activities, or the idea to develop such a systems is also examined.

Similarly to the previous main aspect, the *spatial aspects in adaptation related evaluations* identifies the degree of spatial focus/content in adaptation evaluation products as well as their spatial visualization. Where a system of evaluations exist, identification of the spatial levels are also examined.

The last aspect is based on planning hierarchy and concentrates on the *emergence of higher level spatial or adaptation objectives in national adaptation planning*. It follows the appearance of European-level adaptation directions (appearance of priorities of the actual EU Adaptation Strategy), European-level spatial directions (emergence of priorities of the actual Territorial Agenda of the EU) and finally the appearance of national spatial/regional development objectives within the NAS/NAP documents objective system.

As a next step, a complex spatial sensitivity indicator is calculated for each analysed country based on the enlisted aspects. For each sub-factor, a country gets a given value: 5 points in the best, 3 in the upper-middle, 1 in the lower-middle and 0 in the worst category. Attributed to each sub-factor the proper principles/rules of classification were defined in advance to avoid

subjectivity as much as possible. As examples, two main types of classification, a quantitative and a qualitative one are introduced below. In case of the “*space phraseology of the documents*” we analysed how a NAS uses space and other related concepts. If the concepts⁸ appear relatively frequently (with more than 400 mentioning), it goes into the best category; if the number of mentionings is between 399-150, it goes to the upper-middle, between 149 and 10 into the lower middle category; the weakest group is under 10 mentionings. As for the *spatial content of adaptation measures*, the best category means that a dedicated nominally spatial unit- or regional type-related or generally spatial logic-based group of measures is present among the actions. Upper-middle category means that a few separated (but not a group of) nominally spatial unit- or regional type-related or generally spatial logic-based measures emerge. In the lower-middle category only implicit territorial contents (e.g. monitoring system development targeting ecosystem mapping but reference to these mapping actions is weak or implicit in the text) appear. The lowest category means that no territorial implications can be observed among the measures. For the whole list of sub-aspects and the rules of the categories’ classification in each one, see the annex.

Results: spatial sensitivity of national adaptation policies in Eastern-Central Europe

The following chapter goes through the first Eastern-Central-European results of the empirical analysis. It is divided into subchapters according to different blocks of the analysis. Summarizing tables also help the understanding. In them, a particular colour scale was applied: dark grey indicates the best, medium-grey the upper-medium level and light grey the lower-medium level spatial performances. White cells indicate the lowest national performances in a given sub-aspect; diagonal hatching indicates the irrelevance of a sub-aspect in a given country (e.g. lack of vision, SWOT, etc. in a NAS/NAP document). At the end of the analysis spatiality (spatial sensitivity) of national adaptation policies has been measured by a composite indicator, calculated by adding the scores corresponding to the classification for each sub-criterion of a given country together. Best categories (dark grey cells) means

⁸ The examined concepts were: place, region, regional(ity), territory, territorial (ity), space, spatial(ity), geography, geographic, local, location.

5 points; upper-middle categories (medium-grey cells) 3; lower middle (light-grey cells) 1; meanwhile the lowest and irrelevant categories 0 point.

General information, general spatiality, spatial levels of adaptation

The first sub-aspects deal generally with adaptation strategies at national level in the given countries (*Figure 4*). Adaptation planning (mostly due to the urge from the first EU Adaptation Strategy) at national level is present in all analysed countries, in most of the cases in the form of a dedicated NAS and NAP. Croatia, Poland and Latvia have only strategies without action plan according to the accessible materials; meanwhile Lithuania applies an integrated mitigation-adaptation strategy.

In Hungary is the situation similar, but here the adaptation module of the integrated strategy can even be interpreted as a dedicated, separated NAS. The function of the documents are basically similar: the assignment of the highest hierarchical adaptation directions at national level, with defined vision, objectives, measures based on proper evidence base. Only Lithuania and Slovenia are exclusions with their legal and institutional framework documents.

Main aspect	Sub-aspect	CRO	CZH	EST	HUN	LAT	LIT	POL	ROM	SLK	SLN	BUL	SRB
Weight and character of spatiality in adaptation policy	<i>Space ontology of the document</i>	Dark grey	Dark grey	Light grey	Dark grey	Light grey	Light grey	Dark grey	Dark grey	Light grey	Light grey	Light grey	Dark grey
	<i>Spatial /sectoral character of adaptation policy</i>	Light grey											
Spatial levels of adaptation planning	<i>Spatial levels of adaptation planning</i>	Light grey	Dark grey	Light grey	Light grey	Light grey	Light grey	Light grey					
	<i>Propagation of adaptation planning at lower spatial levels</i>	Light grey	Light grey	Light grey	Dark grey	Light grey	Light grey	Dark grey	Light grey	Light grey	Light grey	Light grey	Light grey

Figure 4: General spatiality and appearance of spatial levels of adaptation planning in Eastern-Central European national adaptation strategies. Dark grey cells indicate the best performing countries, medium-grey the upper-medium, light grey the lower-medium and white cells the lowest national performances in a given sub-aspect. Source: own editing.

The *spatial phraseology of the documents* aspect concentrates on the presence of the space-related phrases in the documents. The highest values (more than 400 mentionings) are observed in Hungary, the Czech Republic, Serbia and Romania, meanwhile the group of followers consists of Croatia, Poland, Slovakia and Bulgaria (between 150 and 400 mentionings). The rather framework-like, general documents (Lithuania, Slovenia) performed weaker. Out of the mentioned countries Hungary is performing especially strong, all examined definitions get several mentionings. Other countries show outstanding results in given concepts (Romania: place and location; Serbia: territory, local; Czechia: region, territory/territoriality).

Emergence of adaptation activities at lower spatial levels and actual propagation of lower level adaptation planning are strong in Poland, Hungary and Romania and slightly weaker in Bulgaria and Estonia. This weak emphasis can be explained by the mostly unitary structure of the analysed country administrations. In Hungary, a specific sub goal mentions the need for elaboration of vulnerable regions' strategies; some action lines in the settlement development chapter mentions local strategy building; chapter V.2.2. directly urges the planning of local and county strategies. In Romania importance of national, regional and local policy makers' role is mentioned already by the Introduction, furthermore the introductory part of the objective system chapter talks about local CC planning's importance, and some sub-objectives and measures mention the topic, too⁹.

Spatial content in the evidence-base work phases

Situation analyses, SWOT chapters and (where it were applied) situation assessment chapters were examined as "evidence base work phases". The basic logic of the analysed document parts follows mainly a sectoral logic (*Figure 5*).

Some signs of spatial thinking is stronger in Hungary and Poland (Hungary's NAS is well equipped with maps and spatial vulnerability assessment results; Poland applies quasi-consequent spatial unit- or regional type mentionings in all sectoral situation analysis subchapters) but the majority performed weaker or showed the lack of spatial aspects. Concrete visualization

⁹ Sub-objective 7.1. directly urges local adaptation planning; 11.5. and 12. 3 sub-objectives too, in connection with tourism adaptation and industrial adaptation respectively. Measure 5.3.1. urges involvement of citizens in local planning; 3.4.4. propagates natural habitat management-oriented local planning. The second part of Chapter 8 consequently emphasises the importance of local planning (Local Adaptation Action Plans, tourism destination-related planning, connections with settlement planning were also emphasised).

was the strongest in Hungary (14 maps), the Czech Republic (12), Poland (9+ one regional table), Serbia (9) and Latvia (7) with relatively larger number of maps. Slovakia and Bulgaria follow these leaders a bit lagging behind.

Main aspect	Sub-aspect	CRO	CZH	EST	HUN	LAT	LIT	POL	ROM	SLK	SLN	BUL	SRB
Spatial aspects in adaptation related evidence base	Basic logic of the situation analyses						Diagonal hatching						
	Spatial visualization of the situation analyses		Dark grey		Dark grey			Dark grey		Medium grey		Dark grey	Dark grey
	Spatial contents of situation analyses		Medium grey				Diagonal hatching	Medium grey	Medium grey				Medium grey
	European position		Medium grey				Medium grey						Medium grey
	Spatial contents of SWOT	Diagonal hatching		Diagonal hatching									
	Spatial content of situation assessments	Diagonal hatching	Diagonal hatching	Diagonal hatching	Diagonal hatching			Diagonal hatching					
	Spatial planning focus		Medium grey	Dark grey		Dark grey							

Figure 5: Spatial content in the evidence-base work phases in Eastern-Central European national adaptation strategies.

Dark grey cells indicate the best performing countries, medium-grey the upper-medium, light grey the lower-medium and white cells the lowest national performances in a given sub-aspect; diagonal hatching indicates the irrelevance of a sub-aspect in a given country.

Source: own editing.

The *concrete spatial content* (mentioning of national level spatial vulnerability inequalities, nominating concrete territorial/spatial units, special geo-

graphic areas, region types, or settlement network elements, functional areas¹⁰ and their vulnerability characteristics) is medium level in the Hungarian, Estonian, Romanian, Polish, Czech and Serb NAS situation analyses. The Polish NAS includes consequent spatial content throughout the whole situation analysis, mixing sectoral and spatial logic, some subchapter is sectoral (energy, forestry, etc), some regional (mountain areas, coastal zones, urban areas & spatial development).

Spatial planning, as an important tool of adaptation or as a related field is mentioned particularly by Czechia and Serbia, in the form of dedicated chapters. Latvia put on the topic particularly great emphasis (one of the NAS's 6 main risk areas is "tourism and landscape planning"), as well as Estonia (the NAS situation analysis urges the taking into consideration of climate change and resilience aspects in spatial planning decisions, meanwhile land use and planning has a separated situation analysis chapter).

Consideration of their own geographic position within Europe gets weak emphasis in the documents generally. Only Lithuania performed in mediocre way with the consequent mentioning of its Baltic position throughout several points of the NAS. Estonia, Czechia, Bulgaria and Serbia show only weak signs of this kind of considerations in their climatology subchapters, the others even less. *SWOT analysis and situation assessment* chapters emerge only in two countries, Lithuania and Bulgaria, but the spatial content in these chapters is weak, anyhow.

All in all, regarding all sub-aspects, among the generally weak results, Serbia performed the best (13 points out of 35), followed by Czech Republic, Latvia Poland and Hungary (10-12).

Spatial content in the classic planning subchapters

The vision and the different hierarchical elements of the objective systems compose an important part of strategies, as the manifestations of actual planning activities. Regarding the *basic logic of visions*, 3 documents do not contain such chapters; the others do but only Romania mentions "areas" in general.

The *overall objectives* are always thematic (only Estonia's overall objective mentions explicitly regional and local levels); the specific objectives usually (the only exclusions are Croatia, Poland and Estonia). Especially good example is Croatia, whose objective system is a mixture of sectoral and spatial

¹⁰ Functional Urban Areas, cross-border territories, macro regions.

specific objectives¹¹. Poland also applies mixed types of objectives, out of which two (“Efficient adaptation in rural areas”; “Sustainable regional and local development”) are directly spatial. Coastal areas, mountain areas, urban zones and spatial planning are recurring topics through the entire objective system; however, their nominated presence is scarce, only appearing in the narrative descriptions of objectives. Estonia’s sub goals (=specific goals) are basically thematic, only one sub goal deals with regional types, but this at least directly. *The lower level objectives* (sub-objectives, fields of interventions, action lines, etc.) show stronger spatial content in the generally well performing Hungary and Poland, plus Latvia, Lithuania and Serbia. The other countries’ lower-level objectives touch spatiality weakly and implicitly, and Croatia even lacks this level of objectives. *Real horizontal objectives* are missing from the majority of documents: in these cases, we analysed the horizontal principles identified in the NAS documents. Croatia’s, Estonia’s and Slovenia’s guiding principles mentions the importance of spatial planning/regional development, while Lithuania nominates adaptation monitoring and geopolitical aspects as horizontally important activities/factors during adaptation.

The importance of spatial MRE is especially emphasised in the objective system of Croatia (the country’s NAS Priority #4 explicitly aims at strengthening management capacities with a networked monitoring and early warning system; while Priority #5 focuses even on geo-information-based monitoring activities and decision support), Hungary (in the country’s NAS the 4th specific objective explicitly aims MRE and geo-information system development and vulnerability assessment-related knowledge base development), Latvia (a dedicated NAS chapter and Appendix deal with MRE issues of adaptation policy) and Slovakia (specific objective #4 partly and sub-objective 4.6. directly deal with MRE issues, but not particularly spatial aspects of them; the NAP strategic priority #4 urges development of knowledge base, data collection, monitoring and research related to data dissemination and information). Out of the *basic territorial cohesion concepts* multilevel governance is present everywhere, meanwhile some countries (Estonia, Hungary¹²,

¹¹ It has two spatial objectives (#1 aims at sustainable regional and urban development; #2 focuses on rural areas, coasts and islands), the others thematic ones. Objective #3 is for energy development, objective #4 for monitoring and early warning system development, #5 for R&D). Objectives #4 and #5 even include implicit contents (#4: importance of local/regional level in risk management; #5: GIS-based monitoring development).

¹² The emphasis on integration of adaptation objectives into sectoral planning in Hungary’s NAS can be understood as a paraphrase of territorial optimum.

Main aspect	Sub-aspect	CRO	CZH	EST	HUN	LAT	LIT	POL	ROM	SLK	SLN	BUL	SRB
Spatial aspects in adaptation related objective systems	Basic logic of vision			Diagonal hatching				Diagonal hatching		Diagonal hatching			
	Spatial content of adaptation visions	Light grey	Light grey	Diagonal hatching		Light grey		Diagonal hatching	Medium grey	Diagonal hatching			
	Basic logic of objective system	Medium grey		Medium grey		Light grey	Light grey	Medium grey				Light grey	
	Spatial content of overall / strategic objectives	Dark grey	Light grey				Light grey	Dark grey		Light grey			Light grey
	Spatial content of lower-level objectives (fields of intervention)	Diagonal hatching	Light grey	Diagonal hatching	Medium grey								
	Spatiality's presence in horizontal goals	Medium grey	Light grey			Light grey	Light grey	Light grey				Medium grey	Diagonal hatching
	Spatial MRE focus of objective system- and vision-planning	Dark grey	Light grey	Light grey	Dark grey	Dark grey	Medium grey	Medium grey	Medium grey	Dark grey	Medium grey	Medium grey	Light grey
	Basic territorial cohesion concepts' emergence	Light grey		Medium grey	Medium grey	Light grey	Light grey	Dark grey	Medium grey	Light grey	Light grey	Light grey	Medium grey
	Spatial visualization of the vision /objective system	Diagonal hatching											

Figure 6: Spatial content in the visions and objective systems in Eastern-Central European national adaptation strategies.

Dark grey cells indicate the best performing countries, medium-grey the upper-medium, light grey the lower-medium and white cells the lowest national performances in a given sub-aspect; diagonal hatching indicates the irrelevance of a sub-aspect in a given country.

Source: own editing.

Poland¹³, Romania, Bulgaria) mention balanced sustainable territorial development, place-based approach or territorial optimum-searching nature of adaptation planning. All in all, regarding the visions and objective systems Poland (20 points out of 45) and Croatia (18 points) are leaders with a rather medium-level performance as we see; followed by the Baltic states (13-14 points) and Hungary (11) (*Figure 6*).

Spatial content in the adaptation actions

The *actual adaptation actions' spatiality* shows somehow more balanced picture than the previous aspects. Actual spatial content is present everywhere but usually implicitly, in the form of mentioning general region types (e.g. coastal areas, river valleys, mountainous areas, areas with water shortages, flood-prone areas), land use forms (e.g. forest areas, agricultural land) or some special areas (e.g. Baltic coast, Homokhátság) in the measures' texts or titles. None of the NAPs dedicate concrete group of actions for the topics. The concrete, nominally spatial unit- or region type-based measures are rare; strong implicit presence (mentionings in the action descriptions) is present in the Czech Republic, Poland, Slovakia, Croatia, Latvia and Romania. The others perform weaker. *Spatial MRE-focussed measures* show stronger presence in Croatia (where a whole priority deals with MRE issues¹⁴), Hungary (both its first and second National Climate Adaptation Action Plan dedicates one-one explicit measure for the topic, based on an MRE concept, as defined in the first Climate Change Action Plan), and Latvia (a dedicated group of 5 measures in NAP deals with MRE issues of adaptation policy), followed by Lithuania, Czech Republic and Poland. *Spatial planning-oriented measures* appear particularly in Croatia, where "Spatial planning and management" appears as a particular group of measures. The upper-medium category is filled by the three Baltic states, Poland, Slovakia and Bulgaria.

All in all, adaptation measures' spatiality show the strongest signs in Croatia (13 points out of 15) and Latvia (11), followed by Poland (9), Czechia, Hungary and Lithuania (7-7-7). The overall performance is good,

¹³ Poland, for example, urges integrated development strategies at different level and local integrated adaptation strategies are in harmony with the concept of territorial optimum/territorial synthesis.

¹⁴ Furthermore the NAS General measure OM-01 aims at increasing the level of knowledge and capacity for monitoring the impact of climate change, risk assessment and adaptation to climate change; meanwhile a dedicated measure (RP-01) aims at developing indicators measuring the effects of the implementation of the Adaptation Strategy.

compared it to other analytical aspects, considering the maximum available 15 points, and the mentioned examples (*Figure 7*).

Geopolitical content of the NAS/NAP documents

As opposed to the previous aspect, geopolitical content in the analysed NAS/NAP documents is uniformly weak. With the exclusion of Lithuania, the country that registers at least medium-level results in all three sub-aspects¹⁵, the other countries show mostly weak results or lacking geopolitical focus. Two other exclusions are Estonia¹⁶ and Slovenia¹⁷, which countries performed exceptionally well only in one sub-aspect (territorial cooperation in the field of adaptation) (*Figure 7*).

Spatiality in adaptation monitoring

Spatiality in adaptation monitoring activities is emerging rather weakly. MRE activities have started in the analysed countries and out of its pillars monitoring shows the strongest signs but no detailed information is available about their actual spatiality. Lithuania, Poland, Hungary and the Czech Republic shows strongest signs of MRE (actually, they are in the planning phase of their systems – however, results of these has not been available so far). For instance, Hungary’s climate strategy’s chapter V.4.5. is particularly about monitoring, introducing a special two-tier approach. The first Climate Change Action Plan aims the preparation, the second the setting up of a CC adaptation MRE system. The planned further development of the National Adaptation GeoInformation system (NAGiS) may be the basis of regional

¹⁵ Sub goal 37.11. concentrates on climate policy’s international connections, and mentions geopolitics even directly in 37.11.3.; paragraph #37.11.3.’s first part directly deals with anticipation and preparation for migratory pressures; its second part directly deals with bilateral and multilateral climate partnerships in mitigation and adaptation; meanwhile its third part directly deals with achievement of climate targets and damage loss mitigation and natural phenomena management in other countries especially in least developed ones.

¹⁶ In Estonia’s NAS Sub goal 6’s Measure 6.3. aims at participating in international mitigation and adaptation cooperation and in international climate policy development to share best practices and mitigate international climatic problems.

¹⁷ “Broader cooperation” specific objective mentions the importance of European and international cooperation processes in the field of adaptation; its 2.2. sub-objective “Proactive participation in European and international activities” mentions both international cooperation and geopolitical influence gathering.

vulnerability indicators and the planned MRE system could implement climate policy's MRE tasks, with territorial emphases. In Lithuania's climate policy framework the intention of such developments are mentioned among key horizontal goals¹⁸.

Regarding *actual indicator sets*, real spatial indicator collections are rare. Strong adaptation indicator sets with both impact/result and output indicators but without spatiality are planned in Croatia, the Czech Republic, Hungary¹⁹, Estonia, Poland and Serbia. Other countries applies either only output (Slovakia, Slovenia, and Bulgaria) or no indicators.

Though several countries are thinking of *development of GIS-based DS system is adaptation*, the only exclusion, where the intentions have already been implemented is Hungary, where the NAGiS has been operating and continuously developed since 2016 and has served since then as a basis of the national strategy and its action plans, the county- and settlement-level climate strategies and Sustainable Energy and Climate Action Plans. Serbia comes up in its NAS with an ecosystem-oriented GIS development idea²⁰, meanwhile Bulgaria, Slovenia and Poland also dedicate special actions for GIS development, but no information is available yet about the implementation of these ideas (*Figure 7*).

¹⁸ 33.7. and 36.4. sub goals directly aim at developing data and information collection to continuously monitor and assess climate risks, vulnerability and adaptation options in different sectors at different spatial levels (national, regional, local).

¹⁹ In the first and second Climate Change Action Plan output indicators and National Climate Change Strategy-related result indicators are enlisted, but these are not collected and spatially processed. No spatial content or breakdown is mentioned.

²⁰ The Biodiversity subchapter of the NAS Situation Analysis mentions “*The Republic of Serbia still has to implement an integrated functional national biodiversity geo-information system available to the wider scientific public and interested professionals, and consequently, the comprehensive monitoring and study of the climate change impact on biodiversity is limited. In addition, integrated lists of priority species, habitats and ecosystems for monitoring the climate change impacts on biodiversity still need to be developed*”.

Main aspect	Sub-aspect	CRO	CZH	EST	HUN	LAT	LIT	POL	ROM	SILK	SILN	BUL	SRB
Spatial aspects in adaptation related actions	<i>Spatial content of adaptation measures</i>	Medium-grey	Medium-grey	Light-grey	Light-grey	Light-grey	Light-grey	Medium-grey	Medium-grey	Medium-grey	Light-grey	Light-grey	Light-grey
	<i>Spatial monitoring focus of adaptation measures</i>	Dark-grey	Medium-grey	Light-grey	Dark-grey	Dark-grey	Medium-grey	Medium-grey	Light-grey	Light-grey	Light-grey	Light-grey	Medium-grey
	<i>Spatial planning focus of adaptation measures</i>	Dark-grey	Light-grey	Medium-grey	Light-grey	Light-grey	Medium-grey	Light-grey	Light-grey	Medium-grey	Light-grey	Light-grey	Medium-grey
Geopolitical content of adaptation planning	<i>The emergence of geographically climate related risks as aspects for national security</i>	Light-grey	Light-grey	Light-grey	Light-grey	Light-grey	Medium-grey	Light-grey	Light-grey	Light-grey	Light-grey	Light-grey	Light-grey
	<i>The emergence of strengthening macro regional/ international co-operations</i>	Light-grey	Light-grey	Dark-grey	Light-grey	Light-grey	Medium-grey	Light-grey	Light-grey	Medium-grey	Dark-grey	Light-grey	Light-grey
	<i>The emergence of strengthening macro regional/ international influence</i>	Light-grey	Light-grey	Light-grey	Medium-grey	Light-grey	Medium-grey	Light-grey	Light-grey	Light-grey	Light-grey	Light-grey	Light-grey
Spatiality in adaptation monitoring	<i>Spatial levels of data connection and monitoring activities</i>	Light-grey	Medium-grey	Light-grey	Medium-grey	Light-grey	Medium-grey	Medium-grey	Light-grey	Light-grey	Light-grey	Light-grey	Light-grey
	<i>Spatial content of indicator sets</i>	Medium-grey	Light-grey	Medium-grey	Dark-grey	Light-grey	Light-grey	Medium-grey	Light-grey	Light-grey	Light-grey	Light-grey	Medium-grey
	<i>Presence of GIS based DS system in planning</i>	Medium-grey	Light-grey	Light-grey	Dark-grey	Light-grey	Light-grey	Medium-grey	Light-grey	Light-grey	Medium-grey	Medium-grey	Medium-grey

Figure 7: Spatiality in adaptation actions of NAP documents, geopolitical content of adaptation documents and spatiality in monitoring of the Eastern-Central-European national adaptation activities.

Dark grey cells indicate the best performing countries, medium-grey the upper-medium, light grey the lower-medium and white cells the lowest national performances in a given sub-aspect; diagonal hatching indicates the irrelevance of a sub-aspect in a given country.

Source: own editing.

Spatiality in adaptation evaluation

Evaluations' spatiality is the worst performed aspect altogether within the complete comparative analytical system. Even in those countries where proper resources and/or emphasis are devoted at all for evaluation in adaptation, these activities are following a sectoral rather than spatial/territorial logic. The few examples that can be specially mentioned are the Czech Republic, the NAS of which mentions the strong visualization of the planned/implemented evaluations. Hungary similarly enlists in its NAS and NAP a detailed list of evaluation products but their spatiality is referred to only weakly. Similarly, the Serb NAS nominates several evaluation products, too, without any special spatial references, either. Concrete evaluation products are still lacking or are not yet available in the majority of the countries (*Figure 8*).

Altogether the monitoring and evaluation aspects see the best performances in Hungary (13 points out of 18) and the Czech Republic (11), followed by Poland, Croatia and Serbia (between 7-9 points). All countries perform better due to their higher monitoring points, the evaluation sub-aspects performed uniformly weaker.

Consideration of higher level spatial / adaptation objectives in adaptation planning

The last aspect examined the appearance of higher (EU and national) level adaptation policy and spatial development objectives in the analysed NAS documents. There is no country among the analysed ones that lacks references to these higher-level objectives totally, only the degree of consideration differs. Regarding adaptation, the then-actual EU Adaptation Strategy's priorities were examined, more exactly their appearance in the NASs²¹. The priorities of these were taken into consideration everywhere, mostly explicitly (Hungary, Lithuania, Romania, Bulgaria and Serbia dedicate particular coherence-analytical subchapters to the EU Adaptation Strategy, and name EU Adaptation Strategy-conform objectives/priorities, corresponding to all EU adaptation priorities). Even the second best performing countries reflect to most of the EU-level adaptation priorities (Latvia, Romania, Slovakia, Slovenia).

In case of the spatial development objectives, both the European and the respective national ones appear in the NAS documents, but not directly and

²¹ In case of older NAS documents the connection to the 2013 EU Adaptation Strategy, in case of current NAS documents to the 2021 version was analysed.

not entirely. The majority of the EU/national priorities appears in the NAS of Croatia, Estonia, Hungary, Poland and Romania or the minority of them in the other countries. Particularly good example is Hungary, where the then-fresh National Development and Regional Development Concept contained an energy and climate policy chapter, whose content was based on the relevant NAS parts as well. Sectoral action lines of the climate strategies also reflected the relevant national spatial development lines. Within this aspect, Hungary and Poland performed well (11-11 points), followed by Estonia, Lithuania, Bulgaria, Serbia and Romania (7-7 point out of 15) (*Figure 8*).

Main aspect	Sub-aspect	CRO	CZH	EST	HUN	LAT	LIT	POL	ROM	SLK	SLN	BUL	SRB
Spatial aspects in adaptation related evaluations	<i>The degree of spatial content in adaptation evaluation</i>	Light grey	Light grey	White	Light grey	Diagonal hatching	White	White	White	White	White	White	Light grey
	<i>Spatial visualization in adaptation evaluation</i>	Diagonal hatching	Medium grey	Medium grey	White	Diagonal hatching							
	<i>Spatial levels of evaluations</i>	Diagonal hatching	Light grey	White	Light grey	Diagonal hatching							
Consideration of higher level spatial / adaptation objectives in adaptation planning	<i>Consideration of national spatial objectives</i>	Light grey	Light grey	Medium grey	Medium grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey
	<i>Consideration of European spatial objectives</i>	Light grey	Light grey	Medium grey	Medium grey	Light grey	Light grey	Light grey	Medium grey	Light grey	Light grey	Light grey	Light grey
	<i>Consideration of European adaptation objectives</i>	Light grey	Light grey	Light grey	Dark grey	Medium grey	Dark grey	Dark grey	Dark grey	Medium grey	Medium grey	Dark grey	Dark grey

Figure 8: Spatiality in adaptation evaluation and appearance of higher level spatial / adaptation objectives in adaptation planning of the Eastern-Central-European countries.

Dark grey cells indicate the best performing countries, medium-grey the upper-medium, light grey the lower-medium and white cells the lowest national performances in a given sub-aspect; diagonal hatching indicates the irrelevance of a sub-aspect in a given country.

Source: own editing.

Influential factors of adaptation policies' spatiality

Summarizing the analytical sub aspects, Poland and Hungary stand out from the group of countries with respectively 77 and 68 point, followed by Croatia, Czechia, the Baltic states and Serbia (between 44 and 60). Altogether, these values indicate at best a mediocre or even weaker performance regarding the maximum available 175 points (*Figure 9*).

Interesting issue is whether which factors are the most influential for the spatial sensitivity values of the analysed countries. I collected some physical (size of the country, number of climate zones in a given country according to the EEA classification, urbanisation), economic (GDP/capita), social (HDI, education level), spatial governance- or adaptation policy-related (number of implemented adaptation cycles) indices to find out which have the strongest influence on spatial sensitivity (*Figure 9*).

country	Spatial sensitivity composite indicator (source: own calculation)	Size (km ²) (source: Eurostat)	number of climate zones (source: EEA)	GDP/pop (source: Eurostat)	HDI index (source: worldpopulatio onreview)	spatial governance (1 means unitary; 2 decentralised unitary; 3 regionalised unitary; 4 federal state. Source: ESPON)	urbanisation % (urban population / total population,) (source: World Bank- world development indicators)	population with tertiary education (%) (source: OECD)	number of finished adaptation planning cycles (source: EEA, own calculation)
<i>BUL</i>	40	111000	3	13270	0,8	1	76,701	26,7	1
<i>CRO</i>	49	88070	3	17500	0,88	1	58,575	24,8	0
<i>CZH</i>	47	78870	1	26670	0,9	2	74,552	23,5	1
<i>EST</i>	53	45340	1	27360	0,9	1	69,81	36	1
<i>HUN</i>	68	93030	1	17410	0,85	1	72,864	25,7	2
<i>LAT</i>	44	64570	1	20350	0,88	1	68,671	34	1
<i>LIT</i>	48	65290	1	23820	0,88	2	68,694	41	1
<i>POL</i>	77	312690	2	17350	0,88	3	62,18	33,2	1
<i>ROM</i>	39	238400	3	14920	0,83	1	54,672	16,1	2
<i>SLK</i>	33	49030	2	20000	0,81	2	54,027	29,8	2
<i>SLN</i>	29	20480	2	26980	0,93	1	56,088	25,8	1
<i>SRB</i>	45	88360	2	9070	0,81	1	57,113	23,3	1

Figure 9 Spatial sensitivity composite indicator values and other physical, social, economic and planning-related indicators of the analysed countries.

Source: own editing.

The correlation analysis of the chosen indices (*Figure 10*) with spatial sensitivity shows that mostly weaker-than-medium-level connections can be identified, with the exclusion of the size of the countries (stronger-than-medium connection) – unsurprisingly, bigger a given country is, more diverse its geography is and this fact will be reflected even in the spatiality of adaptation planning directions.

	spatial sensitivity	size	number of climate zones	GDP/pop	HDI	spatial governance	urbanisation	education	adapt. pl. cycles
<i>Spatial sensitivity</i>	1								
<i>Size</i>	0,539729	1							
<i>number of climate zones</i>	-0,30867	0,383941	1						
<i>GDP/pop</i>	-0,11919	-0,43976	-0,57812	1					
<i>HDI</i>	0,135877	-0,19798	-0,45583	0,814069	1				
<i>spatial governance</i>	0,430694	0,473101	-0,19002	0,17339	0,121973	1			
<i>urbanisation</i>	0,350626	-0,15679	-0,46856	0,213166	0,105064	-0,01387	1		
<i>education</i>	0,279213	-0,21926	-0,57832	0,434568	0,321008	0,383181	0,32408	1	
<i>adaptation pl. cycles</i>	-0,05434	0,154199	-0,12574	-0,11633	-0,43314	0,039253	-0,11409	-0,22913	1

Figure 10 Correlation matrix of spatial sensitivity index and its potential influential factors in Eastern-Central European national adaptation activities.

Source: own editing.

Surprisingly, the number of climate zones does not correspond with the country sizes and the spatial sensitivity of adaptation policies, due to the relative homogenous climate zonality of the bigger states (Poland, Romania, and Bulgaria) of the region. The second strongest (it is still only weaker-than-medium) connection is shown to spatial administrative structures – the more decentralised/federal a country is the stronger spatiality could be perceived in adaptation policy documents, but the strength of the connection is weak for now. Probably after the inclusion of bigger Western or Southern European countries (e.g. Germany, Italy, France or Spain) into the analysis, this connection will be linear and stronger.

Conclusions, limitations and further steps

According to both the literature and our everyday life experience climate change is among the top priority global challenges. To its impacts and consequences climate adaptation policy can find answers. Its instruments offer solutions for the spatially determined impacts. As opposed of the other pillar of climate policy, decarbonisation, adaptation itself especially linked to the geographical space, requires explicitly local/regional responses, which fact is reflected in the main spatial levels (local, subnational, national) of adaptation planning, monitoring and evaluation. Increasing number of literature items deal with these activities in Europe, but significantly fewer with spatiality’s role in adaptation policy. These findings point to the direction of a research gap: the presence/weight of geographical/spatial dimensions in national adaptation policy activities have not been examined yet neither from a scientific point of view nor in a comprehensive way.

To fill this gap, my planned wider research aims at examining the sensitivity of European national adaptation activities for spatial issues. Based on space interpretations of spatially oriented disciplines and practical fields a new concept of spatial sensitivity of adaptation policies is introduced and a comparative analysis of this sensitivity of European national adaptation documents is conducted, based on a single system of analytical criteria. The first section of analyses targeted Eastern-Central European countries from the Baltic states to the Carpathian Basin. We can observe that adaptation policy and planning are growing in importance in these countries, but the related monitoring/assessment activities and the emergence of spatial considerations in these and in planning itself are still in early stages. Hungary and Poland show the best performances, followed by the 3 Baltic states, Croatia, Czechia and Serbia. But overall, the picture is quite mosaic-like and diverse, almost every sub-aspect show different rankings. From the potentially available 175 point the best-performing countries, Poland and Hungary reached respectively 77 and 68 points – these are only mediocre performances at the best. If we compare the complex spatial sensitivity values of the countries with environmental, social, economic and administrative structure-related indicators, the strongest connections are with the size of the countries and the spatial administrative structures – these connections are expected to be even more stronger when all EU and EEA countries will be involved into the analyses, completing the comparative examinations as the next step. In the final phase, a conclusion could be drawn whether there is any macroregional determination in national spatial sensitivity of adaptation policies in Europe or not.

As the Introduction has already referred to it, neither the international nor the domestic literature has dealt directly with climate adaptation planning's and MRE activities' spatial performance. The existing studies on national, regional or municipal level climate adaptation activities concentrate rather on methodological challenges and barriers of these activities. The few available comparative studies on national climate adaptation strategies and/or MRE activities analyse only few countries in a case study-like form [Schuster (2008); Swart et al, (2009); Greiving and Fleischhauer, (2010)] or, although compare a larger number of countries with each other, they do that from a descriptive point of view [Leiter (2021), or the studies of EEA (2020, 2021)] and concentrate to a lesser extent or not on real spatial performance, let alone its quantification.

Naturally, the research (especially in its current phase) has numerous limitations. Although it intends to cover the majority of Europe at the end of the research process, currently this study concentrates only on the Eastern

part of Central Europe, resulting in insignificant differences between the countries regarding administrative structure, size, number of climate zones, social and economic indices etc. This similarity of countries in given aspects diminishes the explanatory force of the correlation analysis. To counterweight these weaknesses, in the next phases, other macro regions of the continent (Northern, Southern, Western Europe and the West Balkans) will be included in the analysis. The research, although applies (limited) quantitative methods, they are based only on results of document analyses. There are some additional information that could be obtained through soft methods (interviews, questionnaires, surveys), and it is in question yet, whether these time-consuming methodologies could occur within the time frame of the project. At the same time, the research's inclination to experimenting with quantification of adaptation planning's and MRE's spatiality is its novelty.

Overall spatial aspects emerge in the Eastern-Central European countries' adaptation activities but not consequently and not in an overwhelming weight. Several ways can be identified to improve this geographical/spatial orientation of national adaptation policy making and hopefully the wider research currently being conducted can participate to the strengthening this spatiality of adaptation policies with some suggestions.

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Annex

The list of analytical aspects, sub-aspects and principles/rules of classification

1. Weight and character of spatiality in adaptation policy

- **Space phraseology of the document**
 - How the Strategy use space and other does related concepts? If the strategy applies space and other concepts (place, region territory, spatiality, territoriality) relatively frequently (more than 400 mentioning), it goes into the best category; if the number of mentioning is between 399-150, it comes to the upper-middle, between 149 and 10 into the lower middle category; the weakest result is under 10 mentionings.
- **Territorial/sectoral character of adaptation policy**
 - Is the adaptation policy document behaving as a synthesizer of other sectors? Best category: the document follows a territorially oriented structure and synthesises different sectoral directions for given territorial units/region types, consequently, considering a territorial differences within the country both in the situation analysis/assessment parts and in the objective system; Upper-middle category: 1-2 territorial objectives and/or a territorial summarizing/synthesizing chapter in situation analysis, recurring implicit mentionings of territorial differences, structures Lower-middle category: basically sectoral character (situation analysis chapters, objectives, interventions) but some implicit mentionings of territorial differences, structures.. Lowest category: No territorial issues are detected in climate policy.

2. Spatial levels of adaptation planning

- **At what spatial levels is adaptation planning operating in the country?**
 - Best category: A dedicated strategy chapter / part deals with the issue of national, regional and local level adaptation tasks. . Upper-middle category: Both national and lower levels (regional, local) are mentioned by the strategy/legislation as levels of adaptation actions, activities. Lower-middle category: Only vague references are there to national and regional OR national and local level. Lowest category: Only national level is mentioned.

- **Does the national level strategy propagate adaptation planning at lower spatial levels?**
 - *Best category: Yes, explicitly (as a nominated objective/measure of the strategy). Upper-middle category: Yes, strong implicitly, suggesting in the texts of the objectives/measures. Lower-middle category: only sectoral planning/regional planning is urged at lower spatial levels. Lowest category: No propagation.*

3. Spatial aspects in adaptation-related evidence base

- **Basic logic of the situation analyses**
 - *Best category: It has special territorial logic, structured according to territorial units/region types Upper-middle category: It has a separated territorial chapter or concentrates on territorial differences throughout its entirety. Lower-middle category: no territorial chapter but all/majority of sectoral chapters mention even relevant spatial issues. Lowest category: It is structured exclusively by sectors.*
- **Spatial visualization of the situation analyses**
 - *Best category: the situation analysis subchapters contain several thematic maps, and regional data-related figures in connection with each sector (altogether more than 5); Upper-middle category: the situation analysis subchapters contain 3-5 thematic maps/regional tables or figures. Lower-middle category: the subchapters contain 1-2 thematic maps/ figures of regional data. Lowest category: there are no thematic maps in the situation analysis subchapters.*
- **Spatial contents of situation analyses** (Does it mention national level territorial vulnerability inequalities, nominates concrete territorial/spatial units? Does it mention special geographic areas' or settlement network elements, functional areas (FUAs, CBCs, macro regions) vulnerability characteristics? Does it mention general territorial logic, spatial approach, focusing on spatial mapping, spatial differences, vulnerability characteristics?)
 - *Best category: All situation analysis subchapter deal consequently with the above mentioned topics with great emphasis. Upper-middle category: some situation analysis subchapter deal consequently with the above mentioned topics. Lower-middle category: only scattered presence of territorial/spatial references in few subchapters. Lowest category: it does not mention any of these.*
- **Consideration of European positions regarding the climatic challenges**
 - *Best category: A special, dedicated subchapter deals with the topic of climate impacts in the respective macro region and the theme is recurring throughout the whole strategy. Upper-middle category: A part of a subchapter deals with the macro regional situation of CC, the climatic chapters has a related part. Macrorregional position is a recurring topic in the document. Lower-middle category: There is global or European outlook maybe with maps, but special macro regional emphasis is lesser: Only references or scattered mentioning about macro regional situation. Lowest category: no European or macro regional outlook at all.*
- **Spatial contents of SWOT** (emergence of national level territorial vulnerability inequalities, nominates concrete territorial/spatial units special geographic areas' or settlement network elements, functional areas (FUAs, CBCs, macro regions) vulnerability characteristics, general territorial logic, spatial approach, focusing on spatial mapping, spatial differences)
 - *Best category: the SWOT mentions all of these topics and with more than one examples in each cases; Upper-middle category: it mentions 2 types. Lower-middle category: It mentions only 1 type. Lowest category: it does not mention any of these.*
- **Spatial content of situation assessments** (Emergence of national level territorial vulnerability inequalities, nominates concrete territorial/spatial units special geographic areas' or settlement network elements, functional areas (FUAs, CBCs, macro regions) vulnerability characteristics, general territorial logic, spatial approach, focusing on spatial mapping, spatial differences)
 - *Best category: It mentions all of these topics and with more than one examples in each cases; Upper-middle category: it mentions 2 types. Lower-middle category: It mentions only 1 type. Lowest category: it does not mention any of these.*
- **Spatial planning focus**
 - *Best category: The situation analysis dedicates a special chapter/subchapter to the introduction of spatial planning's role in adaptation. Upper-middle category: the situation analysis mentions spatial planning in one or more subchapters as an important activity. Lower middle category: only weak reference to spatial planning can be detected (e.g. spatial contexts of some regional/settlement type's CC-related problems are mentioned or coherence with national spatial planning is introduced). Lowest category: it does not mention anything regarding the issue.*

4. Spatial aspects in adaptation related objective systems

- **Basic logic of vision**
 - Best category: the Vision chapter is structured in a spatial logic (according to spatial units/territorial types). Upper-middle category: Within the Vision a separated part/paragraph is dedicated for special spatial aspects. Lower-middle category: it mentions spatial issues/places implicitly (emphasizing diversity or different spatial levels). Lowest category: It is structured exclusively by sectors/themes.
- **Spatial content of adaptation visions**
 - Best category: the Vision explicitly mentions special geographic areas' or settlement network elements, functional areas (FUAs, CBCs, macro regions) vulnerability characteristics, general territorial logic, spatial approach, focusing on spatial mapping, spatial differences, Upper-middle category: it mentions only 1-2 type of the enlisted aspects. Lower-middle category: it mentions territorial logic, spatial approach but only vaguely (emphasizing diversity in a given sector; or tasks of different spatial levels). Lowest category: it does not mention any of these.
- **Basic logic of objective system**
 - Best category: The objective system is structured according to spatial units/territorial types. Upper-middle category: It has one or more special, explicitly territorial objectives. Lower-middle category: all sectoral objectives mention even relevant spatial sub-objectives. Lowest category: the whole system is structured exclusively by sectors.
- **Spatial content of overall / strategic objectives**
 - Best category: more objective targets at given territorial unit / regional type / generally deals with spatial differences/structures Upper-middle category: at least one objective targets at given territorial unit / regional type / generally deals with spatial differences/structures.. Lower-middle category: among the objectives one or more refers to decrease of national level spatial vulnerability inequalities/spatial structures. Lowest category: they do not mention any of these.
- **Spatial content of lower-level objectives (fields of intervention)**
 - Best category: among the lower-level objectives several objectives target at given territorial unit / regional type / generally deals with spatial differences/structures even in their title; Upper-middle category: a few objective target at given territorial unit / regional type / generally deals with spatial differences/structures even in their title. Lower-middle category: only the objective's texts mention territorial units / regional types. Lowest category: they do not mention any of these.
- **Spatiality's presence in horizontal goals (e.g., principles of sustainable land use)**
 - Best category: More special horizontal goal/goals deal(s) nominates territorial issues (use of territorial logic, focusing attention on regional vulnerability and resilience, taking into consideration territorial diversity, propagation of place-based approach). Upper-middle category: Only one special horizontal goal deals with territorial issues implicitly. Lower-middle categories: only related principles emerge (subsidiarity, decentralization, multilevel governance, etc.). Lowest category: no horizontal topic emerges.
- **Spatial MRE focus of objective system- and vision-planning**
 - Best category: among the objectives and vision paragraphs a higher-level objective and/or a Vision paragraph nominate the importance of national or regional MRE development in adaptation. Upper-middle category: one objective/Vision sentence deal with the MRE aspects directly. Lower-middle category: only weak references emerge to sectoral MRE issues. Lowest category: they do not mention any of these.
- **Basic territorial concepts' emergence (territorial cohesion, territorial capital, territorial harmony, territorially balanced development, territorial optimum, place-based approach)**
 - Best category: the vision and the objective system's text mentions at least 4 out of the 6 concepts. Upper-middle category: the objective system's text mentions only 2-3 of the enlisted aspects. Lower-middle category: only 1 of the enlisted aspects are mentioned. Lowest category: the objective system's text does not mention any of these.
- **Spatial visualization of the vision /objective system**
 - Best category: the vision chapter and/or the objective system chapters contain more figures (cognitive objective maps, graphs, figures about spatial directions of adaptation interventions, photographs) in connection with the intended goal or the localization of the objectives; Upper-middle category: the above chapters contain 2-3 visual elements about spatiality; regional examples. Lower-middle category: the above chapters contain 1 visual elements about spatiality; regional examples. Lowest category: there are no thematic maps in the vision chapter and/or the objective system chapters.

5. Spatial aspects in adaptation related actions

- **Spatial content of adaptation measures**
 - Best category: Nominally spatial unit- or regional type-related or generally spatial logic-based group of measures are present among the actions. Upper-middle category: Several nominally spatial unit- or regional type-related or generally spatial logic-based measures emerge. Lower-middle category: only few nominally spatial unit- or regional type-related or generally spatial logic-based measures or just implicit territorial contents (e.g. monitoring system building targeting mapping of ecosystems, but reference to these mapping actions is weak or implicit). Lowest category: No territorial implications can be measured.
- **Spatial planning focus of adaptation measures**
 - Best category: A dedicated group of actions deals with spatial planning's role in adaptation. Upper-middle category: one or few actions deal nominally with spatial planning's role in adaptation. Lower-middle category: only implicit reference to the topic. Lowest category: no action mentions anything regarding the issue.
- **MRE focus of adaptation measures**
 - Best category: a dedicated group of actions deals with spatial MRE issues, system building in adaptation. Upper-middle category: dedicated action or strong implicit reference in an action's or actions' text to the need for adaptation MRE activities. Lower-middle categories: only weak implicit reference to the need for sectoral MRE activities. Lowest category: no action mentions anything regarding the issue.

6. Geopolitical content of adaptation planning

- **The emergence of geographically climate related risks as aspects for national security (e.g., migration, water reserves, and cross-border weather events).**
 - Best category: explicit, nominated reference to the issue among the objectives/measures' titles or in the form of a situation analysis chapter; Upper-middle category: explicit reference for the issue in the document in the description of objectives/measures or in the situation analysis; Lower-middle categories: implicit reference to the issue in the document in the description of objectives/measures or in the situation analysis; Lowest category: no reference to the topic.
- **The emergence of strengthening macro regional / international co-operations through adaptation in strategies.**
 - Best category: explicit, nominated reference to the issue among the objectives/measures' titles or in the form of a situation analysis chapter; Upper-middle category: explicit reference for the issue in the document in the description of objectives/measures or in the situation analysis; Lower-middle categories: implicit reference to the issue in the document in the description of objectives/measures or in the situation analysis; Lowest category: no reference to the topic.
- **The emergence of strengthening macro regional / international influence through adaptation in strategies.**
 - Best category: explicit, nominated reference to the issue among the objectives/measures titles or in the form of a situation analysis chapter; Upper-middle category: explicit reference for the issue in the document in the description of objectives/measures or in the situation analysis; Lower-middle categories: implicit reference to the issue in the document in the description of objectives/measures or in the situation analysis; Lowest category: no reference to the topic.

7. Spatiality in adaptation monitoring

- **Spatial levels of data connection and monitoring/reporting activities.**
 - On what territorial levels does adaptation MR in the country? Does it concentrate / from which levels does MR obtain data? Best category: There is a functioning monitoring system in adaptation, using lowest-possible level territorial data in the adaptation indicator system. Upper-middle category: MR system is planned in adaptation, in the form of an action or objective, with spatial data use. Lower-middle category: MR system is planned in adaptation, but no words of lower-than-national-level territorial data in the adaptation indicator system. Lowest category: no MR system in adaptation anyway.
- **Spatial content of indicator sets.**
 - Emergence / weight of territorial approach in adaptation monitoring systems. Best category: There are impact/result and output indicator sets, concentrating on special geographic areas/regions/administrative units. Upper-middle category: There are impact/result indicators, but no territorial breakdown can be identified nor any geographic/regional specification. Lower-middle category: only output indicators are gathered in the indicator system. Worst category: no indicator system is present in the country.

- **Presence of GIS based DS system in planning:** existence of climate policy related GIS in the country and its utilization in adaptation planning and MRE.
 - *Best category:* there is a functioning GIS-based adaptation-oriented multi-thematic GIS-based DS tool(s) in the country. *Upper-middle category:* adaptation oriented thematic GIS-based DS tool's establishment is planned in the country in the form of an action or objective. *Lower-middle categories:* adaptation website is functioning /planned but without signs of GIS system. *Lowest category:* neither thematic GIS-based DS tools nor CC adaptation websites are present in the country.

8. Spatial aspects in adaptation related evaluations

- **The degree of spatial content in adaptation evaluations:** emergence / weight of geographically oriented reports.
 - *Best category:* emergence of explicitly even in their title geographically/spatially oriented evaluation products, rich in territorial chapters, analytical aspects, evaluation questions *Upper-middle category:* emergence of reports with partly geographic, spatial content (use of territorial chapters, analytical aspects, evaluation, lower but existing emphasis on territorial differences in evaluations). *Lower-middle categories:* large number of adaptation evaluation products, established system but no territorial content. *Lowest category:* only the NAS/NAP aims the setting up of an evaluation system or elaboration of products but no evaluation products in practice yet.
- **Spatial visualization in adaptation evaluation:** the degree of graphic solutions' use to present territorial differences, characteristics in evaluations and reports.
 - *Best category:* consequent and frequent emergence of explicitly geographically oriented maps or diagrams, info graphs in the evaluation product(s). *Upper-middle category:* only scarce use of geographically oriented maps or diagrams info graphs. *Lower-middle category:* only diagrams indicating territorial issues emerge in the document. *Lowest category:* no use of these tools are present.
- **Spatial levels of evaluations: the emergence of different territorial levels among the regular and ad-hoc evaluation products**
 - *Best category:* consequent, regular emergence of explicitly territorially oriented evaluation reports in adaptation at subnational and local levels, and the NAS/NAP refer to these. *Upper-middle category:* only ad-hoc emergence of explicitly territorially oriented evaluation reports in adaptation at subnational and local levels, and the NAS/NAP refer to these. *Lower-middle category:* only national level evaluations exist. *Lowest category:* the NAS/NAP plan to elaborate evaluation reports at lower spatial levels, but no evaluation products in practice yet.

9. Consideration of higher-level adaptation and spatial/territorial objectives in adaptation planning

- **Consideration of national spatial/regional development objectives** (goals & objectives of national territorial/spatial strategic documents) **in adaptation planning.**
 - *Best category:* all or almost all national territorial objectives emerge explicitly in nominated form in the documents' vision/objective system/measures. *Upper-middle category:* strong implicit presence of national territorial objectives: majority of objectives/priorities of the national territorial development directions identified in National Spatial Development Concepts is present among the NAS objectives/measures. *Lower-middle categories:* weak implicit presence of national territorial objectives: only a minority of objectives/priorities of the national territorial development directions identified in National Spatial Development Concepts is present among the NAS objectives/measures. *Lowest category:* They do not emerge.
- **Consideration of European spatial development objectives** (cohesion policy goals) **in adaptation planning.**
 - *Best category:* all or almost all European territorial objectives from the actual TA emerge explicitly in nominated form in the documents' vision/objective system/measures. *Upper-middle category:* strong implicit presence of European territorial objectives, majority of objectives/priorities of European territorial development directions identified in the then actual Territorial Agenda of the EU is present among the NAS objectives/measures. *Lower-middle categories:* weak implicit presence of European territorial objectives only a minority of objectives/priorities of European territorial development directions identified in the then actual Territorial Agenda of the EU is present among the NAS objectives/measures. *Lowest category:* They do not emerge.
- **Consideration of European adaptation objectives** (EU Adaptation Strategy's goals) **in adaptation planning**
 - *Best category:* European adaptation objectives identified in the EU Adaptation Strategy emerge explicitly in nominated form in the documents' vision/objective system/measures. *Upper-middle category:* strong implicit presence of European adaptation objectives: majority of European adaptation objectives identified in the EU Adaptation Strategy is present among the NAS objectives/measures. *Lower-middle categories:* weak implicit presence of European adaptation objectives: minority of European adaptation objectives identified in the EU Adaptation Strategy is present among the NAS objectives/measures. *Lowest category:* They do not emerge.

Pénzügyi tudatosság és kultúra: Tanulságok egy primer kutatás alapján

SZEBERÉNYI András¹ – TISZA Márk Marcell²

¹PhD., főiskolai tanár, Budapesti Metropolitan Egyetem
Marketing és Kommunikáció Intézet

²BA hallgató, Budapesti Metropolitan Egyetem Kommunikáció és médiatudomány

KEYWORDS

- financial awareness
- financial literacy
- sustainable finance
- financial decision

ABSTRACT

Financial Awareness and Culture: Lessons from a Primary Research Study
| In today's world, money plays a vital role in everyday life, requiring individuals to make both simple and complex financial decisions regularly. Everyone is involved in this process, from teenagers managing pocket money to adults choosing payment methods. This study explores how respondents acquire financial knowledge, with whom they prefer to discuss financial matters, and what goals they set. A survey-based primary research involving 361 participants was conducted. Two hypotheses were tested: (H1) respondents primarily gain information from the internet and prefer discussing finances with experts; (H2) one of their main financial goals is to build up precautionary savings as a form of financial security. The results indicate a significant relationship between internet use and financial awareness; however, family remains the dominant context for financial communication. Most participants have defined financial goals, especially regarding savings and retirement planning. The study underscores the importance of financial education programs and highlights opportunities to further enhance financial literacy and awareness in society.

JEL-codes: G41, G50, G53

KULCSSZAVAK

- pénzügyi tudatosság
- pénzügyi kultúra
- fenntartható pénzügy
- pénzügyi döntés

ABSZTRAKT

Modern világunk egyik lételeme a pénz, így minden egyes nap szükség van arra, hogy egyszerű vagy összetettebb pénzügyi döntéseket hozzunk. E döntések meghozatalában mindannyian érintettek vagyunk, akár zsebpénzt beszedő tinédzserek, akár banki fizetési módot választó felnőttek. A tanulmány célja annak vizsgálata, hogy a megkérdezettek milyen csatornákon keresztül szerzik pénzügyi ismereteiket, kivel beszélnek szívesen saját pénzügyeikről, illetve milyen célokat tűznek ki. Kérdőíves primer kutatásunk során összesen 361 főt kérdeztünk meg. A kutatásra vonatkozóan két hipotézist fogalmaztunk meg: (H1) a válaszadók leginkább az internetről tájékozódnak, és szakértőkkel

¹ E-mail: aszeberenyi@metropolitan.hu | MTMT: 10051048 | ORCID: 0000-0002-1387-0350

beszélnek pénzügyeikről; (H2) egyik fontosabb céljuk, hogy biztonsági pénzügyi megtakarítást képezzenek. Az eredmények alapján az internethasználat és a tudatosság között szignifikáns kapcsolat mutatható ki, azonban a kommunikáció terén a családi kör dominál. A válaszadók döntő része rendelkezik pénzügyi célokkal, különösen a biztonsági megtakarítás és nyugdíjcélú tervezés terén. A tanulmány rávilágít az edukációs programok fontosságára, valamint a pénzügyi tudatosság további fejlesztésének lehetőségeire.

JEL-kód: G41, G50, G5358

Bevezetés

Magyarországon konkrét kezdeményezések vannak a pénzügyi kultúra és tudatosság „szabályainak” megismertetésére és a meglévő tudás mélyítésére. A kultúra kialakításában sok piaci szereplőnek alapvető szerepe van. A pénzügyi kultúrát a Magyar Nemzeti Bank (MNB) is fontosnak tartja, az egyik legsikeresebb ilyen kezdeményezés a „Pénz7” nevű program, amikor a meghívott és/vagy önkéntes előadók általános iskolákban és középiskolákban előre megadott témákban tartanak a diákoknak ismeretterjesztő előadásokat és interaktív foglalkoztató órákat a pénzügyekkel kapcsolatban (Pénz7, 2024). A tanulmány alapvető problémafelvetése, hogy a pénzügyi kultúra és a tudatosság még gyerekcipőben jár Magyarországon, aminek fejlesztésén pénzügyi szakembereknek, tanároknak, a Bankszövetségnek (és a bankoknak), valamint az MNB-nek összefogásban kell dolgoznia. Nemcsak az iskolákban szükséges elkezdni foglalkozni ezzel a témával/kérdéskörrel, hanem otthon, a háztartásokban, és a szülőknek is ismeretterjesztő anyagokkal és oktatási módszerekkel szükséges elmagyarázniuk a pénzügyi tudatosság alapjait, hogy ezzel is kialakuljon egyfajta kultúra, amit tovább tudnak adni a gyermekeiknek nevelési céllal (Remsei, 2011). További problémaként azonosítható – előzetes tapasztalatok és kutatások alapján –, hogy az ügyfelek gyakran nem ismerik a különbséget a bankkártya és a bankszámla között. Ez megmutatkozik abban, hogy véleményük szerint, amikor megkapják a fizetésüket akkor helytelenül úgy mondják, hogy „*a kártyámra érkezik a fizetésem*”. Itt állunk egy digitális „forradalom” kapujánál, ahol a pénzügyi fintech cégek egyre nagyobb lépésben fejlesztik az innovatív megoldásokat a pénzügyek kezelésére és sokan csak hallomásból tudnak ezekről.

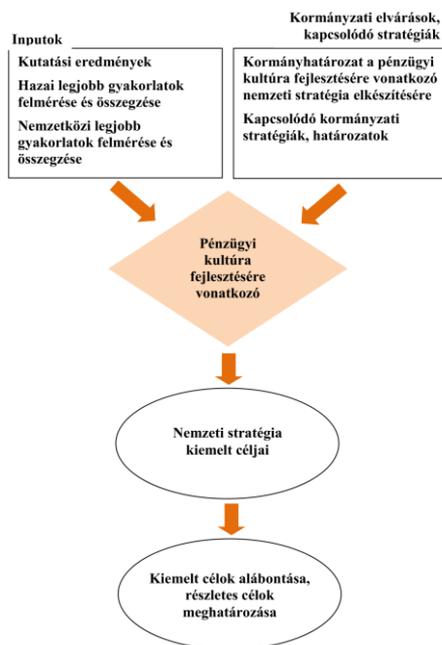
A pénzügyi kultúra fejlődése Magyarországon

A mindennapi életünkben már nem tudjuk kikerülni a pénz fogalmát, ezáltal pénzügyi döntéseket kell hoznunk. Pénzügyi döntést hozhat egy tinédzser is, amikor a szüleitől kapott zsebpénzt kell beosztania az iskolában vagy a vágyott dolog eléréséhez gyűjtenie kell; a boltban, amikor megkérdezik tőlünk, hogy mivel fizetünk – készpénz vagy bankkártya, sőt, hamarosan érkezik a QR kódos (Quick Response-kód) fizetés is –, ez is már a mindennapi döntéseink része (Fáykiss et al., 2023). Döntéseket hozunk a fizetésünkről, a megtakarításainkról, a kiadásainkról, a befektetéseinkről vagy akár egy utazásról is. A döntéseink lehetnek tudatosak és nem tudatosak – minden döntés mögött valamilyen információ áll, kérdés, hogy ezen információkat honnan kapjuk, mi hogyan értelmezzük, azt hogyan dolgozzuk fel (Szőke & Tóth, 2023). A pénzügyeinkkel kapcsolatos döntéseinkhez szükségünk van a bennünk kialakult pénzügyi kultúrára. Például, hogy több banki ajánlat közül tudunk-e dönteni, össze tudunk-e hasonlítani ajánlatokat és lehetőségeket bizonyos szempontok alapján. Egyre nagyobb körben, egyre elterjedtebb skálán mozog azon pénzügyi termékek összessége, melyek egyre komplexebbek, ugyanis a digitalizáció és a megváltozott bankolási szokások felülírhatják idővel a hagyományos bankolást. Ezeket a változásokat a digitalizáció gyors előretörése és a mesterséges intelligencia megjelenése tovább gyorsítja (Csiszárík-Kocsir, 2021; 2022). A legmodernebb és leggyorsabb megoldás a mobilapplikációk tudásának terjedése. Az információk sokasága miatt a használók tudása csak megkésve igazodik a változásokhoz, ugyanis, aki nem bankban dolgozik, kevésbé szerez tudomást a bank innovációiról. Ebben kulcsszerepe van a hitelintézetnek, a marketing osztálynak és a banki ügyintézőknek, tanácsadóknak, akik edukálják az ügyfeleket.

Érdemes röviden megemlíteni a pénzügyi kultúrával kapcsolatos tudatosság és döntések fejlődésének egyik kiinduló pontját, amely a 2008-as gazdasági világválság után kezdett kibontakozni. Mondhatni, hogy az egész világ elismerte, hogy a pénzügyi tudatosságot és döntéseket javítani szükséges, sokkal szélesebb ismeretekre van szükség a pénzügyek tekintetében. A megfelelően elsajátított pénzügyi tudatosság és kultúra segíthet abban, hogy egy háztartás a pénzügyeiből – melybe beletartoznak a bevételek és kiadások – a legtöbbet hozza ki, tehát vagy javítsa a helyzetét, vagy kezdjen el egy pénzügyi terv alapján működni a mindennapokban és építkezni a jövőt figyelembe véve. Az oktatásnak és nevelésnek rendkívül fontos szerepe van ebben (Né-

meth-Lékó, 2020), mivel a 2008-as válság egyik oka (többek között) a lakosság pénzügyi ismereteinek hiánya volt. A banki szerződéskötések során is előfordult számtalan téves és hiányos tájékoztatás, mely az ügyfél eladósodását okozta a nem megfelelő szabályozói környezet és az ügyfelek féktelen hitelfelvétele miatt. Gondoljunk a devizahitelekre, ahol az ügyfél olyan árfolyamkockázatot vállalt, amiről a hitel felvételekor egy múltbéli árfolyamról kapott tájékoztatást. A kockázati tájékoztatót minden devizahiteles ügyfél aláírta, és amikor látta, hogy a forint hitel drágább, a legtöbb esetben nem volt kérdés, hogy melyik hiteltípust válassza. A devizahitelek leggyakoribb devizaneme az euro (EUR), japán yen (JPY) és svájci frank (CHF) volt, mely devizanemekből a bank váltotta át az ügyfélnek forintba a hitelösszeget a hitel folyósításakor, és forintban is kérte a törlesztést az éppen aktuális deviza árfolyam szerint. A bank ezzel a devizaváltás árfolyamkockázatát áthárította az ügyfélre. Amikor a forint elkezdett leértékelődni az előzőekben említett devizákkal szemben (főleg az euró és a svájci frank), akkor kezdett több család bajba kerülni, mert a háztartás jövedelme nem nőtt olyan ütemben, mint a törlesztőrészlet. Akkor még nem létezett adósságfék-szabály, mely ma már jelentős biztonságot nyújt a hitelintézetek és az ügyfelek számára is (Kovács & Szóka, 2020). Később viszont 2015. január 1-jétől az MNB életbe léptette az adósságfék-rendelet részeként az adósságfék szabályozást, amely a forint alapú szerződéseket érinti. A jövedelemarányos törlesztőrészlet mutató (JTM) a hitelfelvételkor maximalizálja az ügyfelek rendszeres jövedelmének meghatározott arányában elvállalható törlesztési terheit, így csökkentve az ügyfelek túlzott eladósodásának kockázatát (Magyar Nemzeti Bank, 2023). A gazdasági krízisek időről-időre rádöbentették az embereket, gazdasági szakértőket és vállalatokat (Tóth et al., 2022, 2023), hogy nagy jelentősége van a pénzügyi ismereteknek és a megfelelő szakemberek jelenlétének, akik ezen ismereteket mélyíthetik és a pénzügyi kérdésekben segíthetnek az ügyfeleknek. A válság óta több kezdeményezés is útnak indult. Állami szabályozás is megjelent, valamint a hitelintézetek is felismerték, hogy a pénzügyileg edukált ügyfél akár rövid, akár hosszú távon nekik is kedvező, mivel így tudatos döntéseket fognak hozni a banki ügyeikkel kapcsolatban. A tudatos, és az utóbbi évekre jellemzően most már fenntarthatónak is minősülő pénzügyi döntések tekintetében élen jár például a Raiffeisen Bank, ahol a legtöbb nagyobb fiókban már úgynevezett „meeter greeter” gyakornok kolléga áll az ügyfelek rendelkezésére, aki edukálja az ügyfeleket a pénztár helyett a befizetős ATM (Automated Teller Machine) vagy a banki internetbank használatára, amennyiben az adott kérés elintézhető akár két kattintással. Továbbá,

a legtöbb banknál már elérhető az a megoldás, ami lehetővé teszi az ügynevezett fedezetlen hitelek (személyi kölcsön, hitelkártya és folyószámla-hitelkeret) banki applikáción keresztül történő igénylését is. A célja ezeknek, hogy papírmentesen és emberi beavatkozás nélkül fussanak be az igénylések a bankhoz. A pénzügyi tudatosság növelésére már született elfogadott módszertan, amely a különböző kutatási eredmények feldolgozásától kezdve, a hazai és nemzetközi legjobb gyakorlatok bemutatásán át több olyan stratégiát is magában foglal, amely egységesen a pénzügyi kultúra fejlesztésére vonatkozik (1. ábra).



1. ábra: Alkalmazott módszertani felépítés a pénzügyi tudatosság fejlesztésére

Forrás: Pénzügyi tudatosság fejlesztésének stratégiája, Magyarország Kormánya, 2019., 8. o.

Az 1. ábra alapján meghatározott nemzeti stratégiai, valamint a kiemelt célok egyértelműen rámutatnak tehát, hogy pénzügyi szakemberekre nagy szükség van. A célok további támogatására pedig elindult egy Pénzügyi Oktatási Program, a Pénz7 programsorozat, melyhez a magyar iskolák 2015-ben csatlakoztak, ezzel egyidejűleg pedig az iskolákban is megjelentek a pénzügyi jellegű órák és előadások. Az MNB több pályázatot is meghirdetett a témával kapcsolatban, hogy emelje a pénzügyi kultúráját. A kormány 2016 novemberében

rében kiemelte a 2045/2016. Korm. határozatában, hogy a pénzügyi tudatosságot fejleszteni szükséges, ezzel egyidejűleg pedig kormányzati szinten közpolitikai célként fogalmazódott meg a hazai lakosság pénzügyi tudatosságának növelése is. A nemzetgazdaság működéséhez elengedhetetlenek a pénzügyileg tudatos polgárok. A kormány fontos célként határozta meg a lakosság pénzügyi tudatosságának fejlesztését, aminek következtében elkészült egy 7 évet felölelő stratégia (2017-től 2023-ig). A stratégia tartalmazza az eddig elért eredményeket, programokat és ezekre építkezve adja meg a további célkitűzéseket. Ezek teljes mértékben a magyar igényekre lettek kidolgozva. Kiemelt prioritás egy pénzügyileg tudatos generáció felnevelése (Harangozó, 2015). Egy megfelelő pénzügyi tudással és attitűddel rendelkező lakosság nevelése a végső cél, amely adott esetben elősegítheti a pénzügyi rendszer stabil, egészséges működését, valamint Magyarország eredményességét és hatékonyságát (Kovács & Szóka, 2020). Mindenképpen kiemelendő a Z generáció pénzügyi tudatossága, illetve szokásainak vizsgálata, mivel ők sokat tartózkodnak a virtuális térben, online médiafogyasztásuk több órára tehető, mobiltelefonjuk az ő külön világuk. Máshogy állnak az anyagi függetlenséghez, nem igazán vágnak rá, tárgyak helyett szolgáltatásokat vesznek igénybe. Szívesen adnak pénzügyi tanácsokat leginkább családjuknak, partnerüknek vagy barátjuknak, még akkor is, ha bevallásuk szerint átlagos pénzügyi ismeretekkel rendelkeznek (Csiszárík-Kocsir & Garai-Fodor, 2018; Hoschek & Szóka, 2024).

A PÉNZ7 programsorozat célja

A Pénz7 (2024) egy pénzügyi tudatosságot és pénzügyi tervezést népszerűsítő oktatási program, amely Magyarországon működik. Célja, hogy felhívja a figyelmet a pénzügyi ismeretek fontosságára és segítsen az embereknek jobban megérteni a pénzügyek világát. A Pénz7 különböző interaktív workshopokat, tréningeket, valamint online tananyagokat kínál, hogy segítse az embereket abban, hogy hatékonyabban kezeljék pénzügyeiket és jobb pénzügyi döntéseket hozzanak. Az Európai Pénzügyi Tudatosság Hét (European Money Week) keretében Európa szerte közel 30 országban zajló Pénz7 eseménysorozat számos különböző fórumon jelenik meg, kezdve szakmai programoktól az iskolákban szervezett speciális eseményeken át egészen játékos versenyekig. A Magyar Bankszövetség és a Pénziránytű Alapítvány 2015 és 2016 között kezdték el a Pénz7-et, melynek főszervezője az Emberi Erőforrások Minisztériuma (EMMI) volt. A kezdeti évek után az EMMI vállalta a projektgazda szerepét, és beillesztette a programot a tanév hivatalos

rendszerébe is. A Pénz7 további célja még, hogy lehetőleg minél fiatalabb korban támogassa a pénzügyek iránt érdeklődő diákok tudásának bővítését, és felhívja a figyelmüket a pénzügyi tudatosság fontosságára. Magyarországon példaértékű összefogás jött létre az Európai Pénzügyi Tudatosság Héthez kapcsolódó „Pénz7” eseménysorozat megvalósítására, amit támogat a Nemzetgazdasági Minisztérium és a Junior Achievement Alapítvány. Az iskolai részvétel évről évre növekszik, a folyamatosan bővülő program mostanra már 200.000 diákot és 1.200 iskolát érint. A résztvevő diákok széles körű tudást szerezhetnek pénzügyek és vállalkozói ismeretek terén a számos interaktív kísérőprogram és játékos tananyag révén (Pénzügyminisztérium, 2015).

Magyarország a Pénz7 program (2024) és az Organization for Economic Co-operation and Development (OECD-INFE, 2020) által koordinált nemzetközi összehasonlító elemzés szerint a pénzügyi tudatosság terén pozitív eredményeket ért el. Hazánk az ilyen jellegű fejlesztéseknek köszönhetően a 4. helyet érte el a programban részt vevő országok között. Bár a pénzügyi ismeretek terén kimagasló teljesítményt mutat, további erőfeszítések szükségesek a pénzügyi tudatosság gyakorlati alkalmazásának fejlesztésére. A fentebb említett kutatások azt mutatják, hogy Magyarországon a pénzügyi műveltséget mérő mutatók értéke közelít az átlaghoz és a legjobb eredményeket a pénzügyi ismeretek területén értük el. Fontos továbbá az ilyen területeken történő folyamatos fejlődés, hogy a pénzügyi tudatosság növekedjen és stabilizálódjon az országban. Az elemzés alapján Magyarországon a pozitív pénzügyi ismeretek terén tapasztalt előrelépés sajnos még nem járt kéz a kézben kedvező pénzügyi magatartásformák kialakulásával. A pénzügyi magatartás tekintetében hazánk az utolsó negyedben helyezkedik el a Pénz7 programban részt vevő országok nemzetközi összehasonlításában. Bár tapasztalható néhány javulás, például a háztartási költségvetés készítőinek aránya emelkedett és a megtakarítási hajlandóság is stabil maradt, mégis van hová fejlődni. Kiemelendő, hogy a magyar eredmények elmaradnak a nemzetközi normáktól a bevételek és kiadások nyomon követése, a pénzügyi termékek összehasonlítása, valamint a független pénzügyi tanácsadás terén. A folyamatos tudatosság- és magatartásfejlesztés kiemelt fontosságú lenne a további eredmények javítása érdekében.

Az OECD-INFE (2020) kutatása szerint a magyar válaszadók pénzügyi attitűdben kissé felülmúlják a részt vevő országok átlagát, a 39 ország között a 17. helyen állnak. Az eredmények alapján látszik, hogy az életkor növeke-

désével egyre felelősebbé válik az attitűd, a nők hajlamosabbak takarékoskodni, mint a férfiak és a magasabb iskolai végzettség is meghatározó tényező. A magyar kutatás egyértelműen kimutatta, hogy a hosszú távú és jól felépített pénzügyi oktatási és ismeretterjesztési programok pozitív hatással vannak. A magas pénzügyi tudás és jó eredmény a hosszú távú, állami intézmények, oktatási tárca, jegybank és a Pénziránytű Alapítvány által folytatott, együttműködő pénzügyi tudás terjesztésének köszönhető. Bár vannak biztató trendek, további fejlesztési lehetőségek rejlenek a pénzügyi kultúra területén. A jelenlegi tudás gyakorlati alkalmazása és más tényezők (motiváció, tervszerűség, körültekintés) további fejlesztést igényelnek (Pénz7, 2024).

Anyag és módszer

A tanulmány megírásának első szakaszában a pénzügyi kultúra magyarországi fejlődésének bemutatását tűztük ki célul, majd ezt követően rávilágítottunk arra, hogy miként fejleszthető a pénzügyi kultúra és tudatosság. A szakterülethez kapcsolódó tudományos források elemzésével rávilágítottunk arra, hogy miként fejleszthető a pénzügyi kultúra és tudatosság Magyarországon.

Primer kutatásként egy reprezentatívnak nem tekinthető, 25 kérdésből álló online kérdőíves megkérdezést alkalmaztunk, amelyet 375 fő töltött ki, viszont a helytelen kitöltések kiszűrése után, végül csak 361 fő válaszait tudtuk értékelni. A kérdőívet 14–65 év között bárki kitölthette, mivel 14 éves kortól már lehetőség van bankszámlát nyitni törvényes képviselő jelenlétében, illetve a 65. életév jelenleg a hatályos nyugdíjkorhatár. A 14 éves kor fölötti fiatal korosztály a zsebpénz beosztásával elkezdheti kialakítani a saját maga kultúráját a pénzügyekben, a nyugdíjkorhatár betöltése pedig azért lehet fontos esemény, mert valakinek ugyan még távlati, de felmerülhet kérdésként, hogy az állami nyugdíj elegendő lesz-e ahhoz az életszínvonalhoz, amit az adott életszakaszában megszokott. Jelen jogszabály szerint ugyanis minden befizetett nyugdíjcélú megtakarítás után (éves szinten) 20%-os adójóváírás érvényesíthető a következő évi személyi jövedelemadó (SZJA) bevallásban. Az aktuális állami szabályozás szerint az alábbi három típusba sorolható megtakarítás minősül nyugdíjcélúnak: Önkéntes nyugdíjpénztár (röviden: ÖNYP), nyugdíjbiztosítás, Nyugdíj-Előtakarékossági Számla (röviden: NYESZ).

Megjegyzendő, hogy a visszaigényelhető adójóváírás kerete 150.000 Ft, mely közösen értendő az ÖNYP és Egészségpénztári befizetések 20%-ára, azonban a visszaigénylés egy összegben csakis az egyik pénztári számlára

történhet. Ezen kívül a NYESZ számlára történt befizetések 20%-ára külön 100.000 Ft keret vonatkozik. Továbbá a nyugdíjbiztosítások is önálló kerettel rendelkeznek, melynek mértéke 130.000 Ft és itt is a befizetések 20%-a érteendő. Amennyiben többféle termékre is szeretnénk adóvisszatérítést igényelni, akkor az egységes maximális keret 280.000 Ft.

A terjedelmi korlátok miatt jelen tanulmányban, a kérdőívünkre kapott válaszok esetében csak a pénzügyi tudatosságra vonatkozó eredményeket mutatjuk be.

A primer kutatáshoz kapcsolódóan az alábbi hipotéziseket fogalmaztuk meg:

1. *Hipotézis: A kutatásban résztvevők leginkább az internetről szereznek pénzügyekkel kapcsolatos tájékoztatást, valamint kizárólag banki ügyintézővel vagy pénzügyi tanácsadóval hajlandóak beszélni magán pénzügyeikről.*
2. *Hipotézis: A kutatásban résztvevők egyik fontosabb pénzügyi célja, hogy biztonsági megtakarítást képezzenek.*

A hipotézisek vizsgálatára kétféle statisztikai módszert alkalmaztunk, a változótipusok jellegétől függően. A nominális és ordinális kategóriaváltozók közötti függetlenségek vizsgálatához Pearson-féle khi-négyszet (χ^2) próbát használtunk, ami esetében a kimutatott kapcsolatok szignifikanciáját 0,05-nél kisebb p-érték esetén tekintettük elfogadhatónak.

A khi-négyszet próbák esetében az összefüggések erősségének megítéléséhez *Cramér-féle V* mutatót alkalmaztunk, amelyet az alábbi kategóriák szerint értékeltünk:

- *Gyenge kapcsolat:* $0,00 \leq V < 0,10$
- *Közepes kapcsolat:* $0,10 \leq V < 0,30$
- *Erős kapcsolat:* $0,30 \leq V \leq 1,00$

A kvantitatív változók közötti kapcsolatok elemzésére Pearson-féle korrelációs együtthatót (r) használtunk. Az értelmezés során a következő határértékek alapján kategorizáltuk a kapcsolat erősségét:

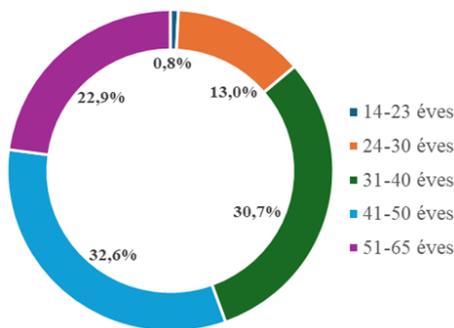
- *Gyenge kapcsolat:* $0,00 \leq |r| < 0,30$
- *Közepes kapcsolat:* $0,30 \leq |r| < 0,50$
- *Erős kapcsolat:* $0,50 \leq |r| \leq 1,00$

Az adatfeldolgozást és a statisztikai elemzéseket az IBM SPSS Statistics 27 programcsomag segítségével végeztük el.

A kutatáshoz kapcsolódó demográfiai adatok bemutatása

A kérdőív kitöltésére 2024 februárjától április végéig volt lehetősége a kitöltőknek. A kitöltők az online közösségi média felületeken – úgymint Facebook, Instagram, LinkedIn – érthették el a kérdőívet. A nembeli megoszlás esetében a válaszadók 59,7%-a volt nő, és 40,3% férfi, ami főként annak tudható be, hogy a nők vélhetően nagyobb kitöltési hajlandósággal rendelkeznek.

A 2. ábrán látható a kérdőívet kitöltők életkorra vonatkozó megoszlása, amely esetében öt különböző kategóriát határoztunk meg. A kategóriákat arányosan határoztuk le életkorok szintjén, hogy a kitöltések száma ne torzítsa az eredményeket.



2. ábra: A kérdőívet kitöltők életkorra vonatkozó megoszlása (%)

Forrás: Saját szerkesztésű ábra primer kutatás alapján, 2024, n=361

A 2. ábra eredményei alapján megállapítható, hogy a korcsoport megoszlása bár változatos, de mind a megadott öt korcsoportból voltak kitöltők. A legtöbb kitöltő a 31–40 éves (30,7%) és a 41–50 éves (32,6%) korosztályból volt. A legkisebb számban (0,8%) a 14–23 éves korosztály szerepelt a kitöltők között. Ennek oka lehet, hogy a Z generáció már sokkal kevésbé aktív a Facebookon a korábbi évekhez képest, illetve sokuk nem használja még a LinkedIn platformot.

A válaszadók iskolai végzettségét tekintve mindenki rendelkezik legalább érettségivel, 27,6%-uk felsőfokú szakirányú végzettséggel, 32,2%-uk pedig alapkülső diplomával.

Foglalkozást tekintve a kitöltők 68,6%-a szellemi alkalmazott és nettó bért/jövedelem oldalról vizsgálva a kérdőívet, a kitöltők majdnem 50%-a keres 350.001 és 600.000 Ft között, ennél magasabb keresettel pedig 36,8%-uk rendelkezik. Ebből feltételezhetjük, hogy ezek már azon jövedelmek, ahol van lehetőség megtakarítás indítására és/vagy hitel felvételére, így a havi bevétel-kiadás megtervezése tudatos, vagy legalábbis van rá igény.

Az 1. táblázat foglalja össze, hogy a demográfiai háttérváltozók – úgy mint nem, életkor, iskolai végzettség, jövedelem – milyen statisztikailag szignifikáns kapcsolatot mutatnak a különböző pénzügyi attitűdökkel, célkitűzésekkel és kommunikációs szokásokkal. Az elemzések során khi-négyzet próbát alkalmaztunk, amelyet Cramér-féle V mutatóval egészítettünk ki a kapcsolatok erősségének bemutatására. Az így kapott eredmények segítségével mutatjuk be, hogy mely tényezők járulnak hozzá a pénzügyi tudatosság vagy a kommunikációs preferenciák alakulásához.

Az első változópár, a *nem és a kommunikációs attitűd* közötti kapcsolat ($\chi^2= 9,842$; $p= 0,020$; $V= 0,098$) gyenge, de statisztikailag szignifikáns kapcsolatot mutat, vagyis a válaszadók nemi hovatartozása befolyásolja, mivel hajlandóak pénzügyeikről beszélni. Ugyanakkor a kapcsolat gyenge jellege miatt ez a H1 hipotézis kommunikációs részének csak részleges alátámasztását szolgálja. Az *életkor és a biztonsági megtakarítás célkitűzése* között közepes ($\chi^2= 12,115$; $p= 0,016$; $V= 0,183$) erősségű, szignifikáns kapcsolat áll fenn, ami hozzájárul a második hipotézis alátámasztásához, miszerint a megtakarítás egy fontosabb cél. Ez a kapcsolat azt mutatja, hogy az idősebb válaszadók körében nagyobb arányban fordul elő biztonsági tartalék képzése, ami a tapasztalat, felelősség és élethelyzet változásával magyarázható. Az első hipotézishez kapcsolódó *iskolai végzettség és tájékozódás forrása* közötti kapcsolat szintén statisztikailag szignifikáns, de gyenge ($\chi^2= 8,421$; $p= 0,038$; $V= 0,087$). Ez arra utal, hogy bár az iskolai végzettség hatással van arra, milyen csatornákon tájékozódik valaki, a különbségek nem feltétlenül relevánsak. A második hipotézishez kapcsolódó változópár – a *jövedelem és a hitel visszafizetés, mint cél* – közepes kapcsolatot mutat ($\chi^2= 10,977$; $p= 0,012$; $V= 0,162$), tehát az alacsonyabb jövedelműek számára gyakoribb a hiteltörlesztés, mint egyfajta prioritás. Ez az eredmény a hipotézis kiegészítő háttereként értelmezhető, és támogatja azt a megállapítást, hogy a jövedelmi szint hatással van a pénzügyi célstruktúrákra. A legszorosabb összefüggés, illetve legerősebb statisztikai kapcsolat a *kommunikációs attitűd és tudatossági önértékelés* között mutatkozott ($\chi^2= 15,487$; $p= 0,001$; $V= 0,312$), ami a

válaszadókra vonatkozóan azt jelenti, hogy akik magasabb tudatossági szintet jelöltek meg, nyitottabban kommunikálnak pénzügyi kérdésekről is. Ez az eredmény közvetlenül megerősíti a H1 hipotézis második részét, amely szerint a pénzügyekről való beszéd szorosan összefügg a tudatosság szintjével.

1. táblázat: Khi-négyzet próba és Cramér-féle V mutatók eredményei a demográfiai és pénzügyi attitűdváltozók között

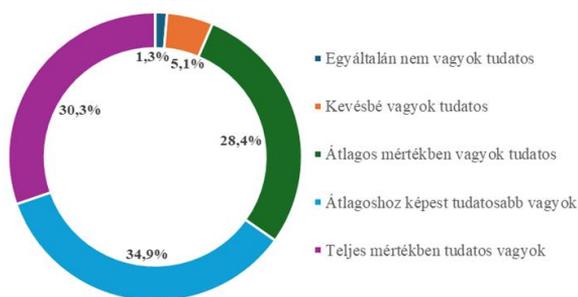
Változópárok	χ^2 érték	df	p-érték	Cramér V	Kapcsolat erőssége	Kapcsolati tényező megállapítása és kapcsolódó hipotézis
Nem és Kommunikációs attitűd	9,842	3	0,020	0,098	Gyenge	(H1) A férfiak és nők kommunikációs preferenciái eltérnek: a férfiak hajlamosabbak nyíltan beszélni pénzügyeikről, de ez a statisztikai összefüggés nem túl erős.
Életkor és Biztonsági megtakarítás célkitűzése	12,115	4	0,016	0,183	Közepes	(H2) Az idősebb korosztályok nagyobb arányban rendelkeznek biztonsági tartalékkal, megállapítható továbbá, hogy a kor előrehaladtával nő a pénzügyi előrelátás.
Iskolai végzettség és Tájékozódás forrása	8,421	3	0,038	0,087	Gyenge	(H1) Az iskolai végzettség hatással van arra, hogy ki milyen csatornát választ a pénzügyi információkhoz, de az eltérés nem markáns.
Jövedelem és Hitel visszafizetés, mint cél	10,977	3	0,012	0,162	Közepes	(H2) Az alacsonyabb jövedelműek körében gyakoribb, hogy pénzügyi célként a hitel visszafizetése jelenik meg.
Kommunikációs attitűd és Tudatossági önértékelés	15,487	2	0,001	0,312	Erős	(H1) Azok, akik magasabb pénzügyi tudatosságról számoltak be, nyitottabban kommunikálnak a pénzügyi kommunikációra is. Ez a legerősebb kapcsolat a vizsgált változók között.

Forrás: Saját szerkesztésű táblázat primer kutatás alapján, 2024

A statisztikai összefüggésvizsgálatok segítenek rávilágítani arra, hogy a válaszadók viselkedése és döntései számos demográfiai tényezőtől függhetnek. A khi-négyzet próbák és Cramér-féle V mutatók alkalmazásával kimutatott összefüggések, még ha több esetben gyengék is, hozzájárulnak a hipotézisek értelmezéséhez, és alátámasztják az egyéni attitűdök komplexitását. A kérdőív specifikus elemeire vonatkozó megállapításainkat a kutatási eredmények fejezetben mutatjuk be, nagy hangsúlyt fektetve a pénzügyi tudatosságra, tájékozódásra, célkitűzésekre és a döntéshozatallal kapcsolatos válaszokra.

A kutatás eredményei

A kérdőív elején olyan kérdéseket tettünk fel, amelyek a pénzügyi tudatosság témaköréhez kapcsolódó alapvető jártasságra, tapasztalatra, és a termékismeretre vonatkoztak. A kérdőív első kérdése során arra voltunk kíváncsiak, hogy vajon a kitöltők mennyire tartják magukat pénzügyileg tudatosnak. Az erre vonatkozó eredmények a 3. ábrán láthatók.



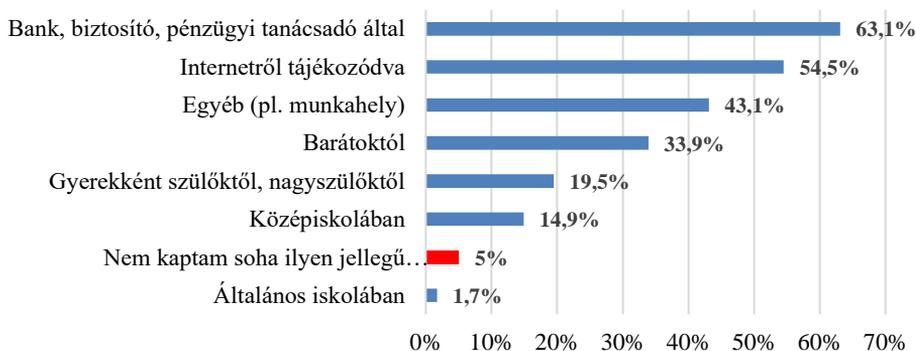
3. ábra: A kérdőívet kitöltők pénzügyi tudatossága saját véleményük szerint (%)

Forrás: Saját szerkesztésű ábra primer kutatás alapján, 2024, n=361

A 3. ábra eredményei szerint a megkérdezett emberek többsége az átlagoshoz képest tudatosabbnak (34,9%), illetve teljes mértékben tudatosnak (30,3%) tartja magát. A kérdőívünkben szereplő további kérdésekre kapott válaszok alapján megállapítható – ezen ábrához kapcsolódóan –, hogy az edukációs programok jelentősen közrejátszanak abban, hogy a válaszadók 93,6%-a legalább átlagos mértékben tekinthető tudatosnak a pénzügyeire vonatkozó cselekvéseiben. Mindösszesen a kitöltők csak 5,1%-a volt az, aki kevésbé tudatos, ha a pénzügyeit érintő költségeiről, tetteiről van szó. Érdekes eredmény-

nek tekinthető az a viszonylag kicsi (1,3%) bázisa a kitöltőknek, akik egyáltalán nem tudatosak a pénzügyeikre vonatkozóan. Megkérdezésünk során rákérdeztünk ezek okaira is, így esetükben kiderült, hogy az okok között szerepel például az, hogy nem tudják, hogyan kell félretenni, nem tudják jól beosztani a bevételüket, vagy gyakran tapasztalnak olyan váratlan pénzügyi kiadásokat, ami miatt nem tudnak tudatosan tervezni a rövid- és hosszú távú pénzügyi tevékenységeikkel.

A következő kérdés arra irányult, hogy a felmérésben résztvevők hol kapták meg a felvilágosítást az alapvető pénzügyekkel kapcsolatban. Ennél a kérdésnél hét különböző kategóriát különböztettünk meg egymástól, illetve az egyéb opcióban lehetősége volt kiegészítenie a kitöltőknek saját kategóriával is – ebben az esetben csak a munkahelyet vettük releváns opciónak, a többi említés valamilyen formában kapcsolható volt az általunk meghatározott kategóriákhoz. A felvilágosítás-oktatás csatornáihoz való tájékozódás eredményeit a 4. ábrán mutatjuk be.



Megjegyzés: Több válasz is megjelölhető volt!

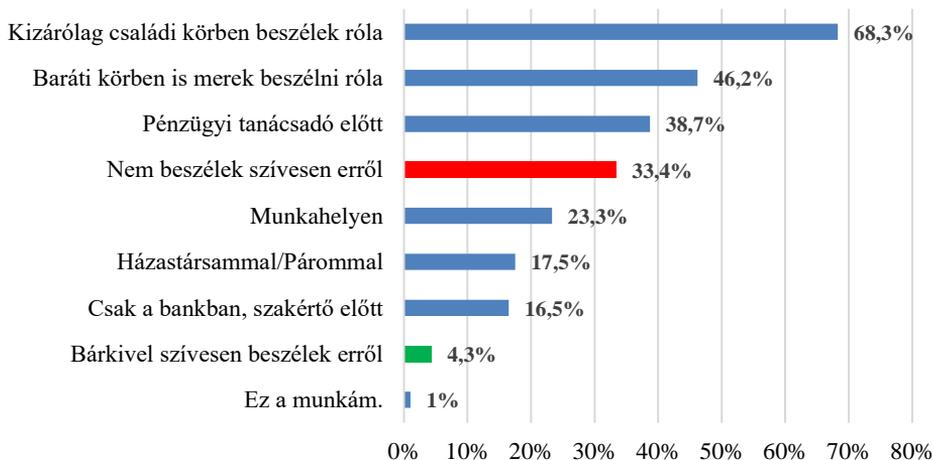
4. ábra: Az alapvető pénzügyekkel kapcsolatos felvilágosítás-oktatás csatornáinak aránya (%)

Forrás: Saját szerkesztésű ábra primer kutatás alapján, 2024, n=361

A 4. ábra eredményei kapcsolódnak az első hipotézisünk első részéhez, amely szerint a résztvevők leginkább az internetről szereznek pénzügyekkel kapcsolatos tájékoztatást. Ez hamisnak bizonyult, mivel a legtöbb kitöltő (63,1%-uk) leginkább bankoktól, biztosítóktól, vagy pedig pénzügyi tanácsadóktól kér felvilágosítást vagy tájékoztatást. Az eredmények rávilágítanak továbbá, hogy a kutatásban résztvevők 19,5%-a családtagoktól (szülőktől, nagyszülőktől) kap segítséget a pénzügyeik tekintetében. A szakemberek után viszont a legtöbben (54,5%) internetről próbálnak minél több oktatóanyagot keresni, illetve tájékozódni. A munkahelyek tekintetében mintegy

43,1%-uk kap pénzügyekkel kapcsolatos felvilágosítást, barátoktól 33,9%-uk kap hasonló oktatást, míg középiskolában már csak 14,9%-uk volt érintett ilyen jellegű felvilágosításban. További érdekes eredménynek tekinthető, hogy a megkérdezettek 5%-a soha nem kapott pénzügyekkel kapcsolatos oktatást vagy felvilágosítást, amely kapcsolódik a 3. ábra eredményeihez is, azon megkérdezettek esetében, akik egyáltalán nem tudatosak a pénzügyeiket illetően. Alapvető statisztikai kapcsolatokat is vizsgáltunk a nembeli megoszlás, az életkor, a tudatosság szintjei, valamint az oktatási csatornák között, viszont 5%-os szignifikancia szint esetén nem volt igazolható kapcsolat a csoportok és a kategóriák között.

Mivel a magyar kultúrában a pénzügyekről való beszélgetés sokszor érzékeny témának tekinthető, így arra is kíváncsiak voltunk, hogy a megkérdezettek milyen kommunikációs csatornán nyílnak meg leginkább, illetve hol merik leginkább felvállalni a pénzügyekkel kapcsolatos véleményüket, ismereteiket. Az ezzel kapcsolatos eredmények az 5. ábrán láthatóak.



Megjegyzés: Több válasz is megjelölhető volt!

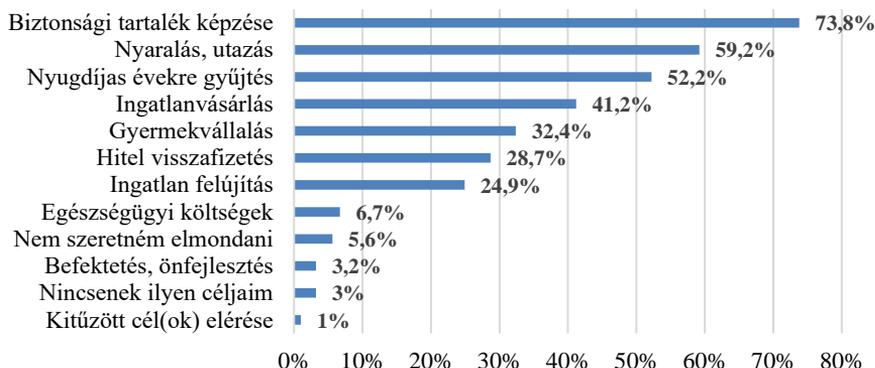
5. ábra: A kitöltők pénzügyi szokásai kommunikációs csatornák szintjén (%)

Forrás: Saját szerkesztésű ábra primer kutatás alapján, 2024, n=361

Az 5. ábra eredményei alapján nem egyértelműen állíthatjuk azt, hogy a megkérdezettek pozitív hozzáállással rendelkeznenek a pénzügyi szokásaikról való kommunikáció esetében. Az első hipotézisünk második felében azt feltételeztük, hogy a megkérdezettek kizárólag ügyintézővel, vagy pénzügyi tanácsadóval hajlandóak beszélni saját pénzügyeikről. Ennek a hipotézisnek – átvitt értelemben – köze van a magyar mentalitáshoz is, miszerint a saját

pénzügyeikről továbbra sem beszélnek szívesen, főleg nem idegenek előtt. Ezt jól alátámasztja a kutatásunk eredménye is, mivel még mindig 33,4%-a a kitöltőknek nem szívesen beszél pénzügyeit érintő témákról (szinte senkinek), illetve csak 16,5%-uk mer beszélni kizárólag bankban, szakértő előtt. Emiatt a hipotézisünk második részét sem sikerült bizonyítanunk, mivel a kapott eredmények szerint a kutatásban résztvevők többsége (68,3%) legszívesebben csak családi körben beszél saját pénzügyeit érintő témákról. Következésképpen felmerülhet az, hogy hiányzik az alapvető bizalom, ami a pénzügyekkel kapcsolatban – általánosságban véve – felmerülhet a kitöltőkben. Úgy érzik, hogy ez a fajta bizalmi légkör leginkább csak a családon belül van meg. Véleményünk szerint ez a viselkedés részben pszichológiai, részben pedig kulturális okokra vezethető vissza. Az emberek valószínűsíthetően zavarban érzik magukat, vagy félnek a pénzügyi helyzetük megosztásától. Az emberek gyakran szégyellik ezt, mivel nem szeretnék, hogy mások megtudják pénzügyi helyzetüket vagy (saját maguk által rossznak ítélt) döntéseiket. A bizonytalanság, a túlzott adósság vagy az anyagi nehézségek szintén okozhatnak szégyenérzetet vagy félelmet. Sokaknak hiányzik a megfelelő tudás vagy önbizalom a pénzügyekről való beszédhez. Úgy érezhetik, hogy nem értenek eléggé a témához, így inkább kerülik a pénzügyi témájú diskurzust. Felmerülhet további szempontként, hogy az emberek gyakran nem érzik magukat elég szakértőnek a pénzügyek terén, így inkább kerülik a pénzügyi kérdések tárgyalását szakemberekkel, még inkább a banki alkalmazottakkal. Ezen tényezők együttes hatása magyarázhatja, hogy miért nem szívesen beszél az emberek egy jelentős része pénzügyeiről és miért preferálják kevésbé nyilvános, illetve szakértő előtti pénzügyi kommunikációt. Az ilyen attitűdök átalakításához fokozott figyelemre és esetleges pszichológiai, szakértői támogatásra, valamint pénzügyi oktatásra is szükség lenne. Érdekességképpen még kiemelendő, hogy a megkérdezettek 4,3%-a bármilyen körülmények között, bárkivel hajlandó beszélni saját pénzügyeiről, amely viszont pont az előzetes elemzést támasztja alá, vagyis, hogy ők azok a kitöltők, akik rendelkeznek elegendő tudással, tapasztalattal vagy bizalommal ahhoz, hogy bátran merjenek beszélni ezekről.

A 6. ábrán látható eredményekre vonatkozóan azt a kérdést tettük fel, hogy a kitöltőknek vannak-e rövid- és hosszú távú céljai, és ha igen, akkor melyek ezek.



Megjegyzés: Több válasz is megjelölhető volt!

6. ábra: Kitűzött rövid- és hosszú távú pénzügyi célok (%)

Forrás: Saját szerkesztésű ábra primer kutatás alapján, 2024, n=361

A 6. ábrához szorosan kapcsolódnak a 2. táblázatban bemutatott korrelációs együtthatók eredményei is, amelyek a különböző pénzügyi attitűdökre és célokra fókuszálnak.

A 6. ábra és a 2. táblázat eredményei összhangban állnak a második hipotézissel, miszerint a válaszadók elsődleges célja a biztonsági megtakarítás kialakítása. A Pearson-féle korrelációs együtthatók alapján közepes kapcsolat mutatható ki az internetes tájékozódás és a pénzügyi tudatosság között ($r=0,342$), valamint a banki tanácsadóval való konzultáció és a biztonsági megtakarítás között ($r=0,389$). Ezek az összefüggések jól illeszkednek a 6. ábra azon eredményéhez, hogy a kitöltők közel háromnegyede kiemelten fontosnak tartja a megtakarítás képzését. A jövedelem és a pénzügyi célok száma között szintén közepes ($r=0,453$) kapcsolatot találtunk, ami arra utal, hogy magasabb jövedelmi szint mellett többféle pénzügyi célkitűzés jelenik meg. A családi kommunikáció és a tudatosság ($r=0,271$), valamint az internetes tájékozódás és a megtakarítás ($r=0,296$) közötti gyengébb, de szignifikáns összefüggések azt sugallják, hogy bár nem minden háttértenező bír ugyanolyan erős hatásúval, az együttes jelenlétük mégis komplex pénzügyi attitűdrendszer alakít ki. Ezek az eredmények a H1 és H2 hipotézisek validálását támogatják, különösen a pénzügyi tudatosság és a hosszú távú célstruktúrák vonatkozásában.

2. táblázat: Pearson-féle korrelációs együtthatók eredményei a különböző pénzügyi attitűdök és célok között

Vizsgált változópaárok	r érték	Kapcsolat erőssége	Szignifikancia (p -érték)	Kapcsolati tényező megállapítása és kapcsolódó hipotézis
Internetes tájékozódás és Pénzügyi tudatosság	0,342	Közepes	0,000	(H1) A közepes erősségű kapcsolat szerint azok, akik az interneten tájékozódnak, nagyobb eséllyel tartják magukat tudatosnak. Ez a kapcsolat megerősíti, hogy az online elérhető információk (pl. pénzügyi blogok, cikkek, videók) valós hatással vannak az önértékelésre és a pénzügyi attitűdre. Bár a tanulmányban elsődlegesen a banki tájékoztatást emeltük ki, az internet szerepe mégis hangsúlyos, és kapcsolódik a pénzügyi tudatossághoz.
Internetes tájékozódás és Biztonsági megtakarítás	0,296	Gyenge	0,004	(H2) A gyenge, de szignifikáns kapcsolat azt jelzi, hogy az interneten tájékozódók nagyobb eséllyel rendelkeznek megtakarítási céllal, valószínűleg azért, mert ezek az információforrások hangsúlyozzák a pénzügyi felkészültséget leginkább. A kutatás során nem közvetlenül vizsgáltuk ezt az összefüggést, azonban a szignifikáns kapcsolat utólagos értelmezése alapján megállapítható a relevancia.
Családi kommunikáció és Pénzügyi tudatosság	0,271	Gyenge	0,009	(H1) Ez a gyenge, de szignifikáns kapcsolat arra utal, hogy a családi pénzügyi diskurzusok hozzájárulnak a tudatosság valamilyen szintű fejlesztéséhez. Megállapítható továbbá, hogy ezek a diskurzusok bár fontosok, de nem kizárólagos forrásai a pénzügyi attitűdnek.
Banki / pénzügyi tanácsadó és Biztonsági megtakarítás	0,389	Közepes	0,000	(H2) A közepes erősségű szignifikáns kapcsolat azt mutatja, hogy akik tanácsadótól kapnak információt, gyakrabban törekednek tudatos megtakarításra. Ez validálja a második hipotézis második felét, és kiemeli a szakértői edukáció szerepét is.
Iskolai végzettség és Pénzügyi tudatosság	0,327	Közepes	0,001	(H1) A közepes erősségű szignifikáns kapcsolat szerint a magasabb iskolai végzettség magasabb önértékelt tudatossággal jár együtt, ami a formális oktatás pénzügyi edukációs szerepét támasztja alá.
Jövedelem és Pénzügyi célok száma	0,453	Közepes	0,000	(H2) Ez a közepes erősségű szignifikáns kapcsolat arra mutat rá, hogy a magasabb jövedelemmel rendelkezők többféle pénzügyi célt is meg tudnak valósítani, így ez a fajta anyagi biztonság lehetőséget teremt a hosszú távú tervezésre is.

Forrás: Saját szerkesztésű táblázat primer kutatás alapján, 2024

Összefoglalás

A pénzügyi tudatosság és kultúra szintje napjainkban egyre fontosabb kérdésként jelenik meg, különösen a gazdasági környezet változékonysága miatt. A primer kutatás célja a pénzügyi tájékozódási csatornák, a pénzügyi kommunikációs preferenciák és a hosszú távú pénzügyi célok vizsgálata volt, különös tekintettel a demográfiai változók szerepére. A kérdőíves kutatás során kapott válaszok lehetőséget biztosítottak arra, hogy képet kapjunk arról, milyen tényezők befolyásolják a pénzügyi döntéshozatalt, valamint, hogy mely csatornákon keresztül és kivel osztják meg pénzügyeiket a válaszadók.

A kutatás során két hipotézis került megfogalmazásra: Az első hipotézis szerint a válaszadók leginkább internetes forrásokból tájékozódnak pénzügyi kérdésekben, és elsősorban banki tanácsadóval vagy pénzügyi szakértővel hajlandók megosztani magán pénzügyeiket. A második hipotézis szerint a válaszadók egyik fontosabb pénzügyi célja a biztonsági megtakarítás kialakítása.

A statisztikai eredmények összefüggő elemzése és a korrelációs vizsgálatok alapján az első hipotézist csak részlegesen sikerült alátámasztani, azért, mert bár valóban sokan tájékozódnak az internetről, mégis a kommunikáció inkább családi környezetben történik.

A második hipotézis igazoltnak tekinthető, mivel a válaszadók többsége valóban a biztonsági tartalék képzését tekinti egyik céljának, de további célként megjelent még a nyaralás, utazás és a nyugdíjas évekre való gyűjtés is.

A Pearson-féle korrelációs együtthatók és a khi-négyzet próbák Cramér-féle V mutatóval kiegészített értékei alapján elmondható, hogy a demográfiai tényezők és pénzügyi attitűdök között többnyire gyenge és közepes erősségű, de statisztikailag szignifikáns kapcsolatok mutathatók ki. Kiemelendő, hogy a pénzügyi tudatosság önértékelése és a kommunikációs attitűd között erős kapcsolat áll fenn. Emellett az is megfigyelhető, hogy a magasabb jövedelemmel rendelkezők többféle pénzügyi célt fogalmaznak meg, míg az alacsonyabb jövedelemszinten élők körében a hitel visszafizetése jelenik meg prioritásként.

A kutatás eredményei alapján megállapítható, hogy a pénzügyi tudatosságot nem lehet csupán egyetlen tényező – például végzettség vagy jövedelem – mentén értelmezni, hanem egy komplex, sokváltozós attitűdstruktúráként kell kezelni. A válaszadók döntéseit a demográfiai sajátosságok mellett az információszerzési szokások, a kommunikációs hajlandóság és a hosszú

távú célok együttesen alakítják. A kapott eredmények gyakorlati hasznosíthatóságát tekintve fontos, hogy az edukációs programokat célzottabban, élethelyzethez illeszkedően dolgozzuk ki, illetve, hogy a pénzügyi tudatosság fejlesztése során figyelembe vegyük a személyes preferenciák, a családi szocializáció és a digitális tér szerepét is.

A jövőbeni kutatásaink esetében érdemesnek tartjuk, hogy az edukációs programok hatékonyságát longitudinális módon is vizsgáljuk, illetve, hogy a pénzügyi magatartásformák mélyebb feltárása érdekében kvalitatív megközelítést is alkalmazunk.

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Ghosting in Business Contexts: An Approach to Operationalization

Laureana TEICHERT¹

¹PhD student at the University of Sopron, Hungary
FOM – Hochschule für Oekonomie und Management, Germany

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- Talent Acquisition
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- Operationalisation

ABSTRACT

Ghosting, originally known as an interpersonal phenomenon, has spread to professional contexts, particularly in recruitment processes. Companies are faced with the challenge of candidate ghosting, where applicants break off contact without prior indication or explanation of reasons. While the phenomenon is present in the public debate, there is a lack of scientific research from the perspective of companies. This review takes a systematic approach to operationalising candidate ghosting in recruitment processes in order to analyse existing methodological concepts and develop a suitable research design. Using a literature review and a four-stage assessment approach, existing studies are analysed in terms of their generalisability, their focus on company processes and their ability to identify candidates' ghosting tendencies. The results show that previous research is often focused on candidate perspectives and rarely provides company-relevant recommendations for action. Based on the identified research gaps, an optimal methodological design is proposed that utilises quantitative approaches and relies on company accessible data. This review contributes to better prediction and prevention of candidate ghosting in recruitment processes and supports companies in developing targeted recruitment strategies.

JEL-codes: D81, M50, M51

Introduction to ghosting in vocational environments

Ghosting is a modern behavioural phenomenon that occurs not only in private but also in professional settings (Vagas & Misko, 2018). Ghosting originated in the interpersonal field of dating and describes the termination of contact between two parties involved in some kind of relationship (Koessler,

¹ E-mail: TeichertLaureanaAnnaErika@phd.uni-sopron.hu
MTMT: 10094298 | ORCID: 0009-0007-0459-9611

2018). One party breaks off contact without giving any prior notice or explanation. There is no response to attempts at contact. Ghosted parties are left in uncertainty about the situation (Kay & Cortice, 2022). The name of this trend comes from the described behaviour; one of the parties disappears ‘like a ghost’ (Freedman et al., 2019; Osbert-Pociecha & Bielinska, 2019). As indicated by Mela (2025), ghosting behaviour is linked to an attachment style that people develop during childhood and show in adulthood. People who experience ghosting can adapt their attachment style to act in the future with more caution and less dependence on others.

Since 2018, the trend has also spread to professional contexts. Due to a surplus of vacancies, ghosting could shift from the company side to the candidate side (Olten, 2021). Labour markets are developing in terms of both internationalisation and power shifts. Today, most labour markets face a diminishing number of suitable candidates, not only due to a lack of young talent, but also due to competition not only from within the country, but also on an international and global level. These two factors have led to a power shift in labour markets. It is no longer employers and companies who can choose which candidate to hire. Rather, it is the candidates who can choose which offer to accept. The shrinking pool of candidates leads to a surplus of open positions. Candidates often receive more than one job offer and can choose from a number of alternatives. This renders the need to maintain contact with less favoured potential employers redundant. Contact is only maintained with the employer who is chosen as the preferred one. Other companies wait for an answer that is unlikely to come. While some research reveals that candidates are concerned about the consequences of ghosting potential employers (Lewis, 2019(b); Threlkeld, 2021), this concern is not significant enough to prevent them from doing so. Ghosting is used instead of rejecting the offer. Changes in the labour market put candidates in a position where they can engage in ghosting behaviour (Olten, 2021; Dannhäuser, 2015; Osbert-Pociecha & Bielinska, 2019).

This leads to another aspect of ghosting behaviour that has to be considered: Changing perspectives on work life. While older generations, such as the generation of baby boomers, consider work to be a means of earning a living and a way of life. Younger generations see it as a complement to their lifestyle and personality. A job is no longer just about earning money; it has to suit personal beliefs, an overall lifestyle and a proper work-life balance. Raised in an era of consumption, excess and self-realisation, work is no longer the most important part of life. A job must complement the aspects of

life that are considered the most important for the individual. This perspective means that people handle job offers with less care than they did decades ago. Companies are no longer potential future employers. If companies do not receive a reply, they do not fit individual preferences, needs or lifestyles and are therefore not considered further. This renders maintaining contact redundant (Majka, 2024).

Another factor to consider is that, while communication via social media and technology has made it easier to get in touch with people all over the world, it has also made it easier to suddenly end this contact. As Schokkenbroek et al. (2025) explain, ghosting occurred even before communication was mostly handled via social media, and before the term ‘ghosting’ was defined. Not responding to letters was also a form of ghosting. As most people now handle their communications via technological devices and social media channels during the day, technology plays a significant role in ghosting. This form of communication makes it easier to ghost someone because it is easier to interrupt than a face-to-face personal relationship. Therefore, the intensity of the relationship is another aspect to consider. Relationships that are maintained via technology and social media are often not very strong, intense or personal. Since there are often fewer commonalities that could strengthen commitment, it is easier to terminate contact and end the relationship. Technology and social media can be seen as significant drivers of ghosting in any kind of relationship (Schokkenbroek, 2025).

Ghosting has increased since the development of online dating apps. Virtual communication gives online dating the character of online shopping. Online profiles are designed like products (Aretz, 2017). The sheer number of options obscures the person behind the profile and reduces the ability to make decisions. People are categorised on the basis of ‘price comparisons’ (Zöllner, 2019). Recruitment has clear parallels with online dating. Professional networks offer companies the opportunity to contact candidates worldwide. Candidates have access to job offers worldwide and are keen to find the ‘perfect match’. Companies are faced with empty candidate markets and international competition. If candidates are not interested or their interest wanes, they leave the recruitment process through ghosting (Pugh, 2022; Gurchiek, 2018). Ghosting is draining financial, human and emotional resources. Recruiters and hiring managers are frustrated by the trend of no-shows (Kumar & Narayana, 2019).

The problem is that there is an information asymmetry in recruitment processes (Spence, 1973). Companies have to rely on information generated through available channels or provided by candidates. Potential employees

may also be pursuing personal goals, such as ghosting in recruitment processes, of which companies are unaware. This leads to problems such as adverse selection, the selection of mismatched profiles due to lack of information, and moral hazard, candidates who are not interested in another job and only want to test their market value (Carr & Brower, 1996).

Recruitment departments should be enabled to tailor recruiting activities to target groups and address the identified problem of candidate ghosting in recruitment processes. The relevance of candidate ghosting to organisations is not the number of cases, but the impact of a ghosting incidence on business processes. 64% of recruiters say they are not prepared for candidate ghosting. Therefore, companies need to be empowered to implement adapted recruiting practices (Kumar & Narayana, 2019).

The topic is known in public discourse, but has been underrepresented in academic discourse (LeFebvre, 2017). The following approach to operationalisation is concerned with examining the methodological research designs of previous studies. The aim of this review is to analyse how a research design needs to be set up in order to provide research findings that support organisational processes to address the problem of candidate ghosting. As the research landscape should develop in a specific direction to not only generate insights, but also knowledge that can be applied by companies, the research landscape is analysed in terms of existing methodological concepts. A concept for an ideal research design is then generated, which would fill the described gap in the research landscape.

Methodology

The aim of this review is to identify research on ghosting in the professional environment that provides a methodological concept that serves organisational processes and the recognition of candidates' ghosting tendencies in recruitment processes from the company side. As well, this systematic review works towards generating an approach on operationalisation to identify respective factors that would predict candidates' ghosting tendencies to prevent candidate ghosting in recruitment processes. This operationalisation approach is based on a literature review that examines the academic discourse with reference to the Scopus listing (Paul et al., 2021).

A four-category assessment is used to systematically narrow down existing methodological concepts that serve the purpose of the review. The

first step is to locate studies that focus on ghosting in a professional setting. The next step is to examine whether the methodology of the selected research focuses on a research design that serves generalisation, also in terms of the potential application and use of the respective research findings. Furthermore, it is investigated whether the selected research provides a methodological approach that targets the company perspective of candidate ghosting in recruitment processes. It is also investigated whether the applied research design of the selected studies contributes to the identification of factors that predict candidate ghosting tendencies.

The aim is to find out whether there is a research design that deals with the measurement and identification of candidate ghosting tendencies in recruitment processes and could be used to set up preventive recruitment activities to mitigate and prevent candidate ghosting in recruitment processes. After analysing existing research regarding the described aim, based on this knowledge an approach on operationalisation is generated.

Definition of the Review Question

Previous research on ghosting in the professional environment is sparse, especially if the focus is limited to the company perspective in recruitment processes (Kumar & Narayana, 2019). The research landscape provides a broad understanding of ghosting in the professional environment. Although candidate ghosting is a choice made by candidates and endangers company processes, there is little research that would support organisational processes to prevent candidate ghosting by adapting recruitment activities to optimise recruitment processes for both sides, candidates and organisations.

Candidate ghosting is a problematic situation that can't be solved once it has occurred. Therefore, candidate ghosting needs to be prevented before it occurs (Lyons et al., 2024). Consequently, asked has to be if there is an existing research design that identifies factors that predict candidate ghosting tendencies in recruitment processes? After analysing the research landscape focusing on the reviews aim the second review question follows: What aspects have to be included in a research design to aim at the prevention of candidate ghosting in recruitment processes?

Inclusion and Exclusion Criteria

Included studies examine ghosting in professional settings. Selected studies must be primary research. The research must also be freely available. The focus of the included research must be on ghosting in a vocational setting, either from the candidate's or the organisation's point of view. The last inclusion criterion requires that the study provides sufficient information about the methodological approach to decide whether the research serves the underlying review question and dedicated aim. This excludes research that focuses on ghosting in private settings, secondary research and research that does not provide sufficient information on the methodological background used. If the research meets all the established inclusion criteria, the research is considered to be included in the review (Dekkers et al., 2022).

Search Strategy

The search period is not further limited as the phenomenon of ghosting has recently emerged in professional settings. Articles published in scientific journals were considered for inclusion. The Scopus listing is used as a reference. First, Google Scholar is searched for suitable research. Next, the bibliographies of the selected research were searched for further relevant articles and studies. Other resources are considered if they are referenced by the selected research. In order to find relevant articles, several search terms related to ghosting were examined (Paul et al., 2021).

Research Selection Process

A total of 415 records were identified during the selection process. Non-academic articles and dissertations were excluded (Herjanto et al., 2016; Islam & Amin, 2022). Reports that addressed ghosting in contexts other than professional settings were also excluded. A total of 51 articles were assessed for relevance based on titles and abstracts. Articles that did not report on research were excluded. 19 reports were identified for retrieval. The content of the research was reviewed in more detail. Studies that did not report primary research were excluded. A total of 10 reports were assessed for eligibility. Three articles had to be excluded due to insufficient information on the re-

search design. In addition, three non-academic studies had to be included because they were referred to in the selected studies. Finally, 10 studies fulfilled the inclusion criteria, listed in following Table 1.

Study	Author	Year	Research Focus
What causes workplace ghosting?	Delgado	2018	Acceptance of ghosting
Understanding of Ghosting in re-education of human resources in organization	Vagas & Misko	2018	Evaluation of the Global Indicator of Ghosting to predict employees' ghosting tendencies
The Ghosting Guide: An Inside Look at Why Job Seekers Disappear; Ghosting unmasked: Listen to the Voices Behind the Epidemic; Employer Ghosting: A Troubling Workplace Trend	Lewis, Threlkeld	2019, 2021	Candidates' reasons for ghosting; Impact of Covid-19 on ghosting behaviour
Ghosting w polskich Przedsiębiorstwach – perspektywa kandydata/pracownika. Wyzwania dla rekrutacji	Osbert-Pociecha & Bielinska	2019	Candidates' reasons for ghosting
Ghosting Behavior Of Job Applicants: An Analysis Of Factors Driving The Behavior	Kumar & Narayana	2019	Factors affecting ghosting
Ghosting as a Manifestation of Inversion on the Polish Labor Market	Osbert-Pociecha & Bielinska	2021	Perceptions of ghosting
Slip Out the Back Jack: Why Applicants Ghost Potential Employers	Karl et al.	2021	Factors affecting ghosting
When Candidates and Recruiters Vanish: Indeed's Ghosting in Hiring Report	Indeed Survey with Censuswide	2023	Ghosting trends 2023
Ghosting from the workplace: The impact of feedback (or lack thereof) on applicants' psychological needs satisfaction	Wood et al.	2023	Impact of company-side ghosting on psychological needs satisfaction of candidates
The vanishing applicant: Uncovering aberrant antecedents to ghosting behaviour	Lyons et al.	2024	Effect of the dark triad, self-control and fear of missing out on ghosting

Table 1. Selected Research

Source: Delgado, 2018; Vagas & Misko, 2018; Lewis(a), 2019; Lewis(b), 2019; Threlkeld, 2021; Osbert-Pociecha & Bielinska, 2021; Karl et al., 2021; Indeed Survey with Censuswide, 2023; Wood et al., 2023; Lyons et al., 2024

Examination of Selected Research

The selected studies are reviewed in order of year of publication. A four-category assessment is used to efficiently narrow down the information that is relevant to and serves the purpose of the review. The examination of the selected studies focuses on the following four aspects: ghosting in the professional environment, a methodological concept focussing on a research design that serves generalisation also with regard to the potential application and use of the respective research results, a methodological concept aiming at the company perspective of candidate ghosting in recruitment processes, a research design that works towards the identification of factors that predict candidate ghosting tendencies. The purpose of the following review is not to assess the quality and contribution of the selected research in general, but to identify the value it brings to the specific objective of this particular review.

Candidates' assessment of ghosting behaviour by Delgado

The study “What Causes Workplace Ghosting?” by Delgado (2018) focuses on ghosting in the professional environment from the candidate’s perspective. Candidates withdraw from recruitment processes without explanation or prior notice. Ghosting is defined as ‘workplace ghosting’ and describes the failure of communication. A total of 507 full-time employees were interviewed about their experiences of ghosting. The data was collected through questionnaires and analysed using frequency and content analysis. Although the data was collected from the candidate’s side and from the candidate’s perspective, the study is addressed to the company side, especially to recruiters, to use the research results as an indication of how to handle ghosting in recruitment processes. The research contributes to the general understanding of this social trend in professional settings, but the results of the study do not provide a methodological basis for generalisation. The research is also not designed to identify factors that would predict ghosting tendencies (Delgado, 2018).

Ghosting in company-internal contexts by Vagas & Misko

The research “Understanding of ghosting in re-education of organisation” by Vagas and Misko (2018) deals with the situation of internal ghosting by employees. Ghosting is defined as a negative phenomenon in the workplace. The

survey comprised 202 participants. The study includes a quantitative research design and is designed to draw general conclusions for organisational processes. The aim of the research is to verify the methodology of the Global Indicator of Ghosting (GIG), which predicts the probability of a particular employee engaging in ghosting behaviour. The GIG could also be applied to recruitment processes. It consists of twelve items for self-assessment. The GIG itself was used for data collection. The data collected was analysed using statistical test procedures. The overall research design is dedicated to the company perspective and organisational processes. The research design also aims to identify factors that could predict ghosting tendencies in employees and candidates (Vagas & Misko, 2018).

Reasons to ghost a company by Lewis & Threlkeld (Indeed)

Indeed's research consists of three successive studies. The first study, "The Ghosting Guide: An Inside Look at Why Job Seekers Disappear", by Lewis(a) (2019), looks at the reasons why candidates ghost companies. It surveyed 4,000 jobseekers and 900 employers who had either been ghosted or engaged in ghosting behaviour. Data was collected through the submission of questionnaires and subsequent analysis of frequency and content. The research aims to shed light on the backgrounds and reasons for ghosting in recruitment processes and to contribute to a general understanding and holistic concept of the phenomenon in professional settings (Lewis(a), 2019).

The second part, "Ghosting Unmasked: Listen to the Voices Behind the Epidemic", by Lewis(b) (2019), delves deeper into the reasons for candidate ghosting. Data was collected by sending questionnaires to 250 jobseekers who shared their experiences of why they ghosted. The data was analysed using content analysis (Lewis(b), 2019).

The final section of the research "Employer Ghosting: A Troubling Workplace Trend", by Threlkeld (2021), highlights the impact of Covid-19 on ghosting behaviour in the workplace. 500 employers and 500 jobseekers were surveyed. The data collected was analysed using frequency analysis (Threlkeld, 2021). Indeed's research focuses on improving the general understanding of and the reasons for ghosting, but does not provide a research design that aims to generalise the research findings. The results of the research will be used to further the understanding of the phenomenon and its development during Covid-19. In addition, while data has been collected at the company level, the studies do not identify factors that would predict ghosting tendencies in candidates (Lewis(a), 2019; Lewis(b), 2019; Threlkeld, 2021).

***Younger generations engaging in ghosting
by Osbert-Pociecha & Bielinska***

“Ghosting w polskich przedsiębiorstwach – perspektywa kandydata/pracownika. Wyzwania dla rekrutacji”, a research by Osbert-Pociecha and Bielinska (2019), focuses on ghosting in the professional environment of the Polish labour market and examines ghosting as a challenge for companies. The study is aimed at human resource and recruitment professionals. A total of 101 participants were surveyed by sharing their experiences of ghosting cases through questionnaires. The sample does not meet the criteria of representativeness and the research design is not designed to produce research results that could form the basis for drawing generalised conclusions applicable to other areas and processes. The study examines the candidate perspective, leaving aside the company perspective, as well as the identification of factors that would predict candidate ghosting tendencies. The research works towards an advanced general understanding of ghosting in professional environments (Osbert-Pociecha & Bielinska, 2019).

***Factors on company side that affect ghosting
behaviour by Kumar & Narayana***

The research by Kumar and Narayana (2019), “Ghosting Behaviour Of Job Applicants: An Analysis Of Factors Driving The Behaviour”, focuses on the company perspective of ghosting in the professional environment. The research aims to identify factors from the company perspective that predict ghosting tendencies in candidates. 110 questionnaires were returned and analysed using statistical test procedures to determine which factors are statistically significant for candidate ghosting behaviour. The research focuses exclusively on the company’s perspective of the phenomenon, aiming to identify factors that will help companies to be aware of ghosting tendencies in advance and to be able to manage ghosting behaviour of candidates in recruitment processes. This study meets all aspects of the four-category assessment. The research aims to support organisations in predicting ghosting tendencies in candidates and in taking appropriate preventative action to deal with this behaviour (Kumar & Narayana, 2019).

Perceptions of ghosting behaviour on candidate side by Osbert-Pociecha & Bielinska

The follow-up study by Osbert-Pociecha and Bielinska (2021), “Ghosting as a Manifestation of Inversion on the Polish Labour Market”, aims to provide a better understanding of ghosting in occupational settings on the Polish labour market. The study examines the hypothesis that ghosting is becoming more widespread. The research concept consists of a two-wave design in which questionnaires were sent to 84 employers and 714 candidates, asking about their perceptions of ghosting. The research aims to identify antecedents, conditions and scales of ghosting behaviour. The data collected was analysed using frequency analysis. As the sample does not meet the criterion of representativeness, these results can’t be used for generalisation. The study also focuses on the company perspective of ghosting, but aims to identify predictors of ghosting on the candidate side. Although the research design and results are aimed at organisational processes to take action in advance and set up preventative recruitment activities, the results can’t be applied to other areas or processes due to the lack of representativeness (Osbert-Pociecha & Bielinska, 2021).

Factors on candidate side affecting ghosting behaviour by Karl et al.

The study by Karl et al. (2021), “Slip Out the Back Jack: Why Applicants Ghost Potential Employers”, integrates the theory of signalling, which deals with the case of an information asymmetry between two involved parties. It is referred to the recruitment process. The research aims to identify factors that predict ghosting tendencies on the candidate side. The sample consists of 246 undergraduate students from a medium-sized US university who received questionnaires with fictitious situations about an invitation to a job interview. The data were then subjected to statistical tests to determine the generalisability of the research findings. The research addresses the company side, but collects data only from the candidate side. The aim of the study was to investigate which factors in candidates serve as statistically significant predictors of ghosting behaviour in recruitment processes (Karl et al., 2021).

Ghosting trends in 2023 by Indeed with Censuswide

Indeed's second survey is in cooperation with Censuswide. "When Candidates and Recruiters Vanish: Indeed's Ghosting in Hiring Report" explores the development of ghosting in the workplace and international ghosting trends through 2023, with a particular focus on the UK, US and Canada. 4,516 jobseekers and 4,517 employers were surveyed and asked to share their experiences of ghosting. The research aims to provide a comprehensive and holistic understanding of the issue in terms of the international dimension of ghosting in the workplace. The data collected was subjected to content and frequency analysis and supports the relevance of the issue, but not the generalisability in terms of application of the results generated, nor the identification of factors that would predict ghosting behaviour of candidates in recruitment processes (Indeed with Censuswide, 2023).

Influence of lacking feedback on ghosting behaviour by Wood et al.

The study "Ghosting from the workplace: The impact of feedback (or lack thereof) on applicants psychological needs satisfaction" by Wood et al. (2023) examines the impact of feedback from recruiters on the psychological condition of applicants. The aim of the study is to understand the influence of companies' ghosting behaviour on candidates. 554 participants completed simulated online job applications. The data collected was subjected to statistical testing procedures to support the generalisability of the research design and findings. However, the results and the research itself are not dedicated to the company perspective or to identifying factors that would predict candidate ghosting tendencies. The study is concerned with understanding the consequences of ghosting from the company side, leaving aside the case of candidate ghosting (Wood et al., 2023).

Dispositional character traits affecting ghosting behaviour by Lyons et al.

The research "The vanishing applicant: Uncovering aberrant antecedents to ghosting behaviour" by Lyons et al. (2024) examines candidate character traits that might predict ghosting behaviour. In particular, the dark triad (Machiavellianism, narcissism, psychopathy), self-control, and fear of missing out in

candidates are examined for their correlation with ghosting behaviour. The aim of the study is to identify personality traits that predict the likelihood of candidates engaging in ghosting behaviour. 314 participants completed questionnaires with corresponding item scales on these traits. The collected data were analysed using moderated regression. General conclusions can be drawn from the research findings. The research aims at clarifying factors in candidates that would predict ghosting behaviour, but is not oriented towards the companies' perspective on recruitment processes (Lyons et al., 2024).

Quality Assessment

When analysing selected research, it was important to note that it is not the objective of the studies that is decisive for the evaluation within the four-category assessment, but the actual study design. Some studies are aimed at human resources and recruitment professionals, while other studies are designed to provide insight but not to identify ghosting tendencies in candidates in order to prevent ghosting. The stated aim of the research does not always correspond to the aim and specifications of this review, so the research landscape cannot be analysed according to the aim stated in the selected research. In order to avoid misinterpretation in the context of this review, the four-category assessment has been applied and a rating system has been set up that serves the purpose of the review.

It is also difficult to separate ghosting into its different types. As the research landscape is not yet fully developed, ghosting in the professional environment was included holistically in the search strategy. The four-category assessment was applied to limit the scope of the review. In order to include all studies and possibilities, the search strategy limited ghosting to the professional environment only. The four-category assessment reviews the selected research in more detail and focuses on studies that adopt and support the company perspective in order to include only studies that are relevant to the aim of the review.

Synthesis

The preliminary review presents the selected studies using a four-category assessment. Only half of the selected studies use a research design that would allow the generalisability of the study results. A few studies use a quantitative

research design. The fewest studies focus on the company's perspective on ghosting, most studies focus on the candidate's side and perspective. Although some of the research addresses the company side as well as human resource and recruitment professionals, the data collection does not focus on information available to companies during the recruitment process.

Only one study includes all four required factors and only two studies focus on the company side and perspective of the phenomenon. There is research that aims to identify factors that predict candidates' ghosting behaviour, but this research does not always include the company perspective in the study design. The following Table 2 summarises the review of selected research, taking into account the four-category assessment:

Research	Ghosting in vocational settings	Generalisability of research design and results	Focus on the company perspective on recruiting processes	Factors that would predict ghosting tendencies in candidates	Total
Delgado (2018)	X	—	—	—	1
Vagas & Misko (2018)	X	X	X	—	3
Lewis & Threlkeld (2019)	X	—	—	—	1
Osbert-Pociecha & Bielinska (2019)	X	—	—	—	1
Kumar & Narayana (2019)	X	X	X	X	4
Osbert-Pociecha & Bielinska (2021)	X	—	—	—	1
Karl et al. (2021)	X	X	—	X	3
Indeed with Censuswide (2023)	X	—	—	—	1
Wood et al. (2023)	X	X	—	—	2
Lyons et al. (2024)	X	X	—	X	3

Table 2. Rating - Four-category assessment

Source: Delgado, 2018; Vagas & Misko, 2018; Lewis(a), 2019; Lewis(b), 2019; Threlkeld, 2021; Osbert-Pociecha & Bielinska, 2021; Karl et al., 2021; Indeed Survey with Censuswide, 2023; Wood et al., 2023; Lyons et al., 2024

Review Results

The evaluation of the four-category assessment shows the weighting and thus the relevance of the included studies to the outcome of the review. The studies according to Delgado, Lewis, Threlkeld, Osbert-Pociecha and Bielinska

(2019, 2021), Indeed with Censuswide and Wood et al. fulfil one or two criteria of the four-category assessment and are therefore not relevant for the assessment of the review. The studies by Vagas and Misko, Kumar and Narayana, Karl et al., and Lyons et al. meet three to four criteria of the four-category assessment and are therefore included in the analysis of the review. The following Table 3 shows the detailed evaluation of these studies.

Research	Kumar & Narayana (2019)	Vagas & Misko (2018)	Karl et al. (2021)	Lyons et al. (2024)
Weighting	4	3	3	3
Research focus	Candidate ghosting in professional settings in the Indian labour market	Employee ghosting in company-internal contexts	Candidate ghosting in corporate contexts	Candidate ghosting in professional settings
Research design	Quantitative	Quantitative	Quantitative	Quantitative
Research results	Generalisable and comparable	Generalisable and further applicable	Generalisable	Generalisable
Data type	Primary data for analysis and secondary data for conclusions	Primary data	Primary data	Primary data
Survey tool	Online survey via Google forms	Global Indicator of Ghosting	In person during class time	Online survey via crowdsourcing platform Profilic Academic
Survey method	Structured questionnaires	Questionnaires with twelve items for self-assessment	Case and questionnaires	Questionnaires with item scales
Final sample size	110	202	246	314
Sampling technique	Non-probability convenience sampling technique, quality criteria	Quality criteria	Quality criteria	Random sampling by voluntary participation, quality criteria
Data source	Companies	Employees	Students	Full-time employees

Data analysis method	Statistical test procedures of percentage analysis, chi-square test, cross tabulation, frequency analysis	Statistical test procedures of factor analysis with varimax rotation, Mann-Whitney-U-test	Statistical test procedure of variance analysis	Statistical test procedure of moderated regression
Data analysis factors	Companies' industrial background, company size, company location, occurrence of ghosting, functional area, position level, educational background, years of experience	Different scenarios of communication behaviour: Ignoring colleagues, stopping communication, refusal without explanation, not responding, interrupting communication, ceasing interest, not responding after several contact attempts, terminating any kind of communication, answering to messages after a long time	Different scenarios for interview invitation: candidate's knowledge of the company and recruiter's communication level, candidate's attraction to the company and company's interest in the candidate, conscientiousness, helicopter parenting, ghosting	Candidates' character traits: machiavellianism, psychopathy, narcissism, fear of missing out, self-control
Research objective	Factors that predict candidate ghosting behaviour collected at companies and therefore generating results, that match organisational processes	Method to predict ghosting tendencies by analysing the employees' behavioural tendencies	Deep insights into the psychological backgrounds of candidates with ghosting tendencies to foster understanding	Deep insights into the psychological backgrounds of candidates with ghosting tendencies

Table 3. Analysis – Research Design

Source: Vagas & Misko, 2018; Kumar & Narayana, 2019; Karl et al., 2021; Lyons et al., 2024

In summary, the four studies analysed provide guidance on how to set up a data analysis methodology to make ghosting in research generalisable, thus preparing it for application in practice. However, only the study by Kumar and Narayana provides guidance on how to collect data that focuses on the company perspective, thus ensuring that the research findings are accessible and applicable to companies in the recruitment process.

Discussion and implications for future research

The following discussion looks at the strengths and weaknesses of the review, as well as a further methodological approach that outlines a research design focusing on the company perspective on candidate ghosting.

It should be noted that there has been little research on ghosting in the professional environment to date (LeFebvre, 2017). Since 2018, the phenomenon has been studied specifically from an academic perspective (Vagas & Misko, 2018). Coming back to the first review question (Is there an existing research design that identifies factors that predict candidate ghosting tendencies in recruitment processes?), in particular studies on ghosting in a professional context that focus on the company perspective are rare. The evaluation is therefore based on a few studies that meet the requirements of the review. Similarly, the operationalisation approach must be guided by the one study that deals with the company perspective and add elements from other studies.

In order not to rely solely on the research and its orientation, the four-category assessment was set up to filter out exactly those studies that meet the aim of the review. This means that the studies can be analysed purely on the basis of their research design. It was also clearly defined which elements of ghosting were included. The limitation to ghosting in the professional environment was broadly defined in order to provide a holistic approach and not to exclude any relevant studies. Nevertheless, the phenomenon was limited to studies in the professional environment.

In consideration of the second review question (What aspects have to be included in a research design to aim at the prevention of candidate ghosting in recruitment processes?), this review is followed by an operationalisation approach to help companies make decisions in the recruitment process and set up preventative measures to avoid candidate ghosting.

The analysis of the research design of the highest ranked studies provides an indication of a suitable research design for further studies. The analysis is based on the factors provided in the methodological design of the selected

studies. The study by Kumar and Narayana (2019) is used as a guideline for setting up a suitable research design. A future research design should support the company's perspective on the phenomenon of candidate ghosting to ensure further applicability and improvement of recruitment processes. The factors that have a statistically significant probability of predicting ghosting tendencies in candidates need to be identified. A future research design, that should be conducted within the academic discourse to expand this field of research, could be defined as follows:

Approach on operationalisation of candidate ghosting in recruitment processes		
Research design	Research focus	Ghosting in vocational settings In particular: Candidate ghosting in recruiting processes
	Research aim	Identification of factors that predict candidates' ghosting tendencies in recruitment processes
	Research objective	Identification of factors attributed to the candidates that predict ghosting tendencies These factors have to be available to companies from the beginning of recruitment processes
	Research design	Implementation of a quantitative research concept
	Research results	Research results have to aim at generalisability, comparability, and the further application to organisational processes
Survey	Survey tool	Online survey
	Survey method	Questionnaires ideally with item scales to examine ghosting
	Sample size	At least 200-300 participants
Data	Sampling technique	The sample has to meet the quality criteria for quantitative research
	Data type	Primary data should be used for analysis Secondary data can be used for explanation or drawing conclusions
	Data source	Data should be collected from companies
	Data analysis method	Statistical test procedures that identify significant dependencies and interrelations as variance analysis or moderated regression
	Data analysis factors	At least following factors should be part of the analysis: companies' industrial background, company size, company location, occurrence of ghosting, candidates' functional area, candidates' position level, candidates' educational background, candidates' years of professional experience, recruiter's communication level, companies' interest in the candidate

Table 4. Approach on operationalisation

Source: Vagas & Misko, 2018; Kumar & Narayana, 2019; Karl et al., 2021; Lyons et al., 2024

The paucity of research shows that there is an urgent need for further research in this area. In particular, the fact that the review is guided by only one study shows that research on ghosting in the professional environment is particularly necessary from a company perspective. The problem should not arise in the first place, but should be dealt with preventively from the outset. It is therefore necessary to produce research findings that support the business perspective. These results must be based on data that is not only accessible to companies in the recruitment process, but also applicable to the prevention of candidate ghosting in the recruitment process.

The research approach described should therefore be taken up and implemented in the academic environment, as this type of research has been lacking in the specific field. In general, there is a need for more detailed research on ghosting in the professional environment that not only provides insight into the phenomenon, but also provides further knowledge.

In the future, recruitment has to consider candidates as stakeholders rather than just applicants. It is therefore necessary not only to take candidates through the process, but also to work on their experience and journey. Currently, recruitment processes tend to be the same for all candidates, despite the fact that different candidates have different needs and preferences. The candidate experience should be considered in the same way as the customer experience. Candidates should be considered as different target groups, each with their own specific needs. If companies are aware of tendencies towards candidate ghosting, they should not stigmatise certain candidate groups, but rather adjust the candidate journey to provide an optimised experience tailored to the specific need for more elaborate touchpoints.

In general, this review's approach hints at a field that is widely used in customer contexts, but not in candidate contexts. In a data-driven era, the use of data and data-based knowledge should be elaborated upon. Currently, candidate data is evaluated through screening processes and interviews. In addition, the available data should be analysed in terms of its content, patterns, and candidates' needs and preferences. Data must be analysed using a more quantitative research method.

In particular, the field of candidate ghosting should evolve to use available data to gain insights about candidates and optimise the candidate experience, in the same way that customer data is used to adjust the customer experience. In the near future, research should focus on generating data to help companies prevent candidate ghosting. Therefore, data analysis should concentrate on the data available to companies to help mitigate candidate ghosting within organisational processes.

Further development of the research landscape should build on this basis and investigate candidate target groups in more detail. This should include identifying the aspects that differentiate different target groups and determining the preferences and needs of these groups, considering not only candidate ghosting, but also other behavioural trends. In the distant future, the research landscape should evolve to consider and handle candidates as customers, providing data that can be used to tailor recruitment activities to target groups, supporting candidates in line with their preferences without pressuring them to adhere to company processes.

In the future, research on ghosting in professional settings must develop beyond merely revealing the reasons and background of candidate ghosting, and instead provide knowledge and data that changes the perspective of candidates from applicants to stakeholders, who should be treated accordingly.

Conclusion

The review has shown that there is only one study that fully supports the organisational perspective on ghosting in the workplace. It has also been shown that there is research that examines factors that predict ghosting behaviour, but the research designs do not support application in organisational processes.

In order to develop a research approach that is fully focused on the organisational perspective to support the identification of ghosting tendencies in recruitment processes, elements of different studies need to be combined to generate a more specified research design. The research landscape on ghosting in the professional environment is not well developed. Research has mainly focused on generating insights and knowledge about the phenomenon, but not on generating an approach that supports the prevention of candidate ghosting in recruitment processes.

By combining different elements of several studies, a research approach was created that helps to identify candidate ghosting tendencies and to prevent ghosting behaviour in recruitment processes. This research approach aims to prevent the problem in advance and to optimise the recruitment process for both sides, as not only are companies aware of ghosting tendencies in advance, but they can also treat candidates according to their specific needs and tailor measures to target groups.

The review shows that such a research approach needs to be quantitative, investigate factors related to ghosting behaviour, and collect data from companies to ensure that the generated results are applicable to organisational processes and provide a database built on information available to companies. An appropriate research design needs to be applied in the academic discourse.

Interest Declarations

The author did not receive support from any organization for the submitted systematic review.

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Data Availability Statement

Research included in the systematic review is publicly accessible.

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Impact of Digital Twins on Sustainability of SMEs: A Systematic Literature Review

WITTMANN, Magdalena¹ – DIETERT, Tilko² – DIÓSSI, Katalin³

¹PhD student, University of Sopron, Alexandre Lamfalussy Faculty of Economics, István Széchenyi Economics and Management Doctoral School

²Professor, FOM – University of Applied Sciences for Economics and Management in Frankfurt am Main, Germany

³PhD, Assistant Professor, University of Sopron

KEYWORDS

- Digital Twins
- Sustainability
- SMEs
- Systematic Literature Review

ABSTRACT

This systematic literature review (SLR) investigates the impact of Digital Twins (DTs) on the environmental, economic, and social dimensions of sustainability in small and medium-sized enterprises (SMEs). SMEs, making up about 90% of global businesses, face challenges in adopting sustainable practices due to limited resources. DTs, as virtual representations of physical systems, provide opportunities for SMEs to optimize processes and achieve sustainability goals. Using the PRISMA methodology, a structured search was conducted, targeting peer-reviewed articles published between 2015 and 2024. The findings show that DTs enable cost reductions, improved resource efficiency, and enhanced working conditions. However, high initial costs and technical complexity pose significant barriers for SMEs. The review also highlights gaps in long-term studies on ecological benefits and socio-economic impacts. The study concludes that while DTs offer considerable potential for advancing sustainability in SMEs, strategic implementation and support mechanisms are essential for overcoming existing challenges.

JEL-codes: L25, L26, L60, M15, O33, Q56

KULCSSZAVAK

- Digitális ikrek
- fenntarthatóság
- KKV-k
- szisztematikus szakirodalmi áttekintés

ABSZTRAKT

A digitális ikrek hatása a kis- és középvállalkozások fenntarthatósági teljesítményére: szisztematikus szakirodalmi áttekintés | Ez a szisztematikus szakirodalmi áttekintés (SLR) a digitális ikrek (DT) hatását vizsgálja a fenntarthatóság környezeti, gazdasági és társadalmi dimenzióira a kis- és középvállalkozásokban (kkv-k). A globális vállalkozások mintegy 90%-át kitevő kkv-k a korlátozott erőforrások miatt kihívásokkal szembesülnek a

¹ E-mail: wittmann.magdalena@gmail.com | MTMT: 10096660 | ORCID: 0009-0008-1109-3843

² E-mail: tilko.dietert@fom.de | MTMT: 10098703

³ E-mail: diossi.katalin@uni-sopron.hu | MTMT: 10088154 | ORCID: 0009-0000-9426-00542

fenntartható gyakorlatok átvételében. A DT-k, mint a fizikai rendszerek virtuális reprezentációi, lehetőséget nyújtanak a kkv-k számára a folyamatok optimalizálására és a fenntarthatósági célok elérésére. A PRISMA módszertan alkalmazásával strukturált keresést végeztünk, amely a 2015 és 2024 között megjelent, lektorált cikkekre irányult.

Az eredmények azt mutatják, hogy a DT-k lehetővé teszik a költségsökkentést, az erőforrás-hatékonyság javítását és a munkakörülmények javítását. A magas kezdeti költségek és a technikai összetettség azonban jelentős akadályokat jelentenek a kkv-k számára. Az áttekintés rávilágít az ökológiai előnyökre és a társadalmi-gazdasági hatásokra vonatkozó hosszú távú tanulmányok hiányosságaira is. A tanulmány arra a következtetésre jut, hogy bár a DT-k jelentős lehetőségeket kínálnak a kkv-k fenntarthatóságának előmozdítására, a stratégiai végrehajtás és a támogatási mechanizmusok elengedhetlenek a meglévő kihívások leküzdéséhez.

JEL-kód: L25, L26, L60, M15, O33, Q56

Introduction

Achieving sustainability goals is especially challenging for small and medium-sized enterprises (SMEs), which make up about 90% of the world's companies and contribute significantly to global value creation (Chen et al., 2022). According to Marshall (1999), SMEs are believed to contribute around 60% of carbon dioxide emissions. SMEs are also responsible for 60% to 70% of industrial pollution worldwide (Calogirou et al., 2010). SMEs often have limited financial, technical and human resources, which makes it difficult for them to adopt sustainable technologies and processes (Bigliardi & Galati, 2017). At the same time, they are under pressure from stakeholders and regulators to make their production processes more sustainable (Baah et al., 2021; Ernst et al., 2022). In this context, an increasing number of blog posts, advertisements and examples from various companies are emerging online, that claim that digital technologies offer promising opportunities for SMEs to achieve their sustainability goals (Altintop, 2020; Bundesnetzagentur, 2024; European DIGITAL SME Alliance, 2024).

The aim of this systematic literature review (SLR) is to give a structured overview of the existing scientific contributions on the influence of Digital Twins (DTs) on the ecological, economic and social sustainability of SMEs and provide a solid foundation for future research and practical applications. The following central research question was chosen to serve this objective:

What is the current state of literature regarding the economic, environmental and social impact of Digital Twins on SMEs?

To answer the research question, a SLR was carried out in the scientific databases SCOPUS, Web of Science (WoS) and IEEE Xplore according to the SALSA framework model.

This paper is structured in six sections, as outlined in *Figure 1*:



Figure 1 – Structure of the Paper

Source: Own illustration (2024)

In Section 1, the paper outlines the importance of sustainability for SMEs, the challenges they encounter, and the transformative potential of DTs. It establishes the research objectives and formulates the central research question. Section 2 provides a concise theoretical background on SMEs, the dimensions of sustainability, and DTs. Section 3 describes the SLR methodology, emphasizing the SALSA framework and PRISMA protocol. Section 4 presents the review findings, focusing on the economic, environmental, and social impacts of DTs on SMEs, while synthesising and analysing results, identifying patterns, and addressing research gaps. Section 5 concludes key insights and highlights contributions.

Research Background

The following chapter provides a brief overview of the three most important research areas: SMEs, sustainability and Digital Twins.

Small and Medium-sized Enterprises

SMEs are defined based on a combination of criteria, including employee count, revenue, and organizational structure, with the specific thresholds varying globally. In the European Union, SMEs are categorized as enterprises with less than 250 employees and an annual turnover below €50 million or an annual balance sheet total less than €43 million (European Commission,

2003). SMEs represent about 90% of global enterprises, contributing to economic growth, job creation, and innovation (Chen et al., 2022).

Sustainability in a Corporate Context

As shown in *Figure 2*, Corporate sustainability entails balancing economic growth, environmental stewardship, and social responsibility, known as the Triple Bottom Line (TBL) (Elkington, 2004).



Figure 2 – Three Pillars of Sustainability

Source: Own illustration, based on Elkington (2004)

Environmental Sustainability focuses on reducing ecological footprints by minimizing waste, emissions, and resource consumption (World Commission on Environment and Development, 1987). Economic sustainability pertains to the financial viability and competitiveness of production processes. It involves cost reduction, efficiency improvements, and innovation to maintain profitability over time (Dyllick & Hockerts, 2002). Social Sustainability relates to the well-being of employees and communities. It encompasses fair labour practices, workplace safety, and community engagement (McKenzie, 2004). According to Marshall (1999), SMEs are estimated to contribute approximately 60% of carbon dioxide emissions. They are also responsible for 60% to 70% of industrial pollution worldwide (Calogirou et al., 2010). SMEs often face constraints in financial, technical, and human resources, which makes it challenging for them to adopt sustainable technologies and processes (Bigliardi & Galati, 2017).

Compared to large corporations, SMEs often face limited financial, technical and human resources, which makes it difficult for them to adopt sustainable technologies and processes (Bigliardi & Galati, 2017).

Digital Twins: Definition and Development

The term Digital Twin was first introduced by Michael Grieves in 2003 and describes a virtual representation of a physical object or system that reflects its properties and behaviour in real or near real time. DTs enable bidirectional communication between the physical and digital worlds, whereby data from the real system is transferred to the virtual model and vice versa. This technology is based on the integration of sensor technology, data analysis and simulation techniques to enable a comprehensive understanding and optimised control of systems (M. Grieves & Vickers, 2017).

DTs generally contribute to sustainability by offering economic, environmental, and social benefits within the TBL framework (Kamble et al., 2022).

Research Design and Methodology

A Systematic Literature Review is acknowledged as a fundamental element of the systematic review process. This methodology offers several advantages that are crucial for answering the underlying research question. An SLR provides an overview of the current state of research, and the conclusions to be drawn from it, including identified research gaps (Feak & Swales, 2009; Tranfield et al., 2003). SLRs enhance transparency, reproducibility, and bias minimization, ensuring valid results and a solid basis for future studies (Kitchenham & Charters, 2007; Petticrew & Roberts, 2006). This is particularly important in a dynamic and rapidly growing field of research such as DTs, where the quality and relevance of the literature can vary greatly. Furthermore, an SLR allows for the integration of different perspectives on the economic, environmental and social impact of DTs on SMEs, leading to a more holistic understanding of the topic. By considering the literature from different disciplines and contexts, patterns and knowledge gaps can be identified that are relevant for further research (Fink, 2010).

In order to minimize subjectivity and to ensure a structured research process, the literature review follows the four steps of the SALSA framework model, developed by Grant and Booth (2009) shown in *Figure 3*:

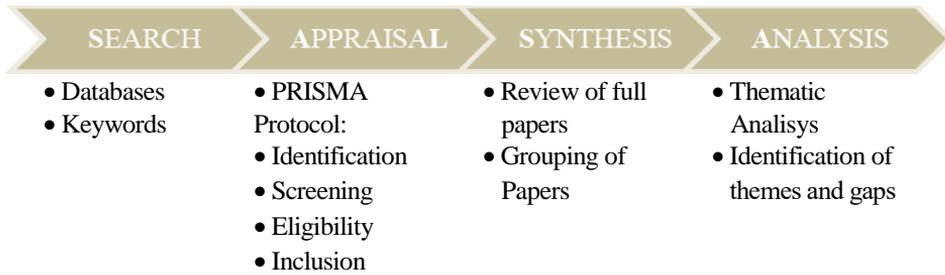


Figure 3 – SALSA Framework Model

Source: Own illustration, based on Grant and Booth (2009)

In the initial search phase, relevant literature is comprehensively identified using well-known databases, to gather a wide range of materials on the topic. The appraisal phase then critically evaluates the quality and relevance of these sources to ensure only credible studies are included, excluding unreliable research. Following established practices (Bathaei & Štreimikienė, 2023), this paper employs the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol at the appraisal stage within the SALSA framework. PRISMA ensures transparent and reproducible documentation of decisions regarding study selection and evaluation. The evaluation proceeds in four steps: In the identification step, all sources are identified using a keyword search. In the screening step, inclusion and exclusion criteria are defined and the subsequently identified papers are reviewed according to title and abstract. Duplicates are then removed. In step 3, the eligibility step, the documents identified in step 2 are compared in terms of their content for relevance to the research question. In the last step, the documents that have now been identified as final are used for the synthesis phase in the SALSA process (Moher et al., 2009). In the synthesis phase, the information from the appraised studies is combined and organized to highlight patterns, themes, and insights. It involves integrating findings from multiple studies to provide a cohesive understanding of the topic.

The final analysis stage involves interpreting the synthesized data, extracting conclusions, and answering the research questions to allow for an in-depth understanding of the implications, gaps, and trends in the literature, providing a basis for further research or practical applications.

Research Results

The systematic application of the SALSA framework provides the results outlined in the following chapters.

Search

A structured literature search was conducted to systematically investigate the current state of research on the research question defining key terms and synonyms to ensure comprehensive coverage.

Search Terms and Keywords

To cover the central topics of the research question, the primary search terms ‘Digital Twins’, ‘Sustainability’, ‘SMEs’ were defined. To capture the influence of DTs on the dimensions of sustainability more precisely, secondary terms were defined to describe the specific aspects of sustainability: To analyse the economic influence of DTs, terms such as ‘economic*’, ‘economic impact’, ‘cost reduction’, ‘productivity’ and ‘operational efficiency’ were used.

For the environmental dimension of sustainability, terms such as ‘ecologic*’, ‘environment*’, ‘sustainable development’, ‘environmental impact’, ‘resource efficiency’, ‘energy efficiency’ and ‘carbon footprint’ were applied. To capture the social dimension, terms such as ‘social impact’, ‘workforce’, ‘employee well-being’ and ‘social responsibility’ were included.

Boolean operators (AND, OR) were used to combine these terms to effectively identify relevant studies.

Selection of Database

The SLR was conducted in the scientific databases Scopus, WoS and IEEE Xplore. Google Scholar was deliberately not included for methodological reasons. Although Google Scholar enables a broad spectrum of literature, it only fulfils the main requirements of a systematic review to a limited extent, such as transparency, reproducibility and consistency of search strategies. In particular, the unclear selection and display principles of the source selection, the limited use of Boolean operators and the dynamic presentation of results make

a structurally and methodologically valid study difficult. Scopus, WoS and IEEE Xplore allow this controlled, documentable and qualitatively assured search, which guarantees traceability and comparability of the results. Additionally, the three databases offer an extensive collection of scientific articles in the fields of technology, economics and sustainability and are therefore suitable resources for systematic literature analyses and other academic research in these fields. Since the guidelines of all used databases require abstracts of research articles to be in English, the keywords were formulated exclusively in English (van Weijen, 2012).

The search queries were carried out using the defined search terms and Boolean operators for both databases to ensure a consistency of the search results.

Inclusion and Exclusion criteria

An exclusion criterion was set regarding the publication date to ensure that the results of the SLR reflect current trends and technological developments. Studies published before 2015 were excluded, as the term ‘Digital Twin’ gained increased importance in scientific publications around 2015 (M. W. Grieves, 2023) and the United Nations adopted the Sustainable Development Goals in 2015, making sustainability one of the global priorities (United Nations General Assembly, 2015). Moreover, articles not available in German or English were excluded to secure that the search results could be used in the analysis.

Appraisal

Table 1 documents the applied steps of the PRISMA methodology in the literature review and specifies the number of studies included and excluded at each stage.

Table 1 – Evaluation of the literature according to the PRISMA process

Step	Search Categories	Exclusion	Total			
			SCOPUS	WoS	IEEE	Σ
Step 1: Identification						
Keyword Search	Digital Twin AND Economic Sustainability AND SMEs		64	22	0	86
	Digital Twin AND Environmental Sustainability AND SMEs		89	44	66	199
	Digital Twin AND Social Sustainability AND SMEs		51	20	26	97
Total			204	86	92	382
Step 2: Screening						
Application of Inclusion and Exclusion Criteria	Digital Twin AND Economic Sustainability AND SMEs	- 19	45	22	0	67
	Digital Twin AND Environmental Sustainability AND SMEs	-31	68	42	58	168
	Digital Twin AND Social Sustainability AND SMEs	-18	34	20	25	79
Total		- 68	147	84	83	314
Review of Title and Abstract	Digital Twin AND Economic Sustainability AND SMEs	- 15	37	15	0	52
	Digital Twin AND Environmental Sustainability AND SMEs	- 53	49	24	42	115
	Digital Twin AND Social Sustainability AND SMEs	- 25	25	14	15	54
Total		- 93	111	53	57	221
Removal of Duplicates / Non-accessible documents	All Categories	- 157		64		
Step 3: Eligibility						
Review of Content	All Categories	- 21		43		
Step 4: Inclusion						
Total				43		

Source: Own research (2024)

In the initial identification step, a keyword-based search was conducted across the databases, SCOPUS, WoS and IEEE Xplore, using terms related to DTs and different aspects of sustainability, specifically economic, environmental, and social sustainability in the context of SMEs. This search identified a total of 382 studies, with 204 coming from SCOPUS, 86 from WoS and 92 from IEEE Xplore.

During the screening step, the first step was the application of inclusion and exclusion criteria, refining the selection based on relevance regarding publication dates, language and publication type. This led to the removal of 68 studies, leaving 314 studies in total, of which 147 were from SCOPUS, 84 from WoS and 83 from IEEE Xplore. The second part of the screening process involved a detailed review of titles and abstracts to ensure further relevance regarding the research question. This led to the exclusion of 15 studies in the economic sustainability category, leaving 52 studies, of which 37 came from SCOPUS, 15 from WoS and 0 from IEEE Xplore. For environmental sustainability, 53 studies were excluded, leaving 115 studies, with 49 from SCOPUS, 24 from WoS and 42 from IEEE Xplore. In the social sustainability category, 25 studies were excluded, resulting in a total of 54 studies, with 25 from SCOPUS, 14 from WoS and 15 from IEEE Xplore. The final step of the screening process involved the identification and elimination of 107 duplicate entries from the results of the individual search terms and databases, and the exclusion of 50 inaccessible documents. This step was only carried out at this stage to adequately display the results of the individual search queries for each database and each sustainability dimension.

In the eligibility step, a thorough review of the full content of the remaining studies was conducted to ensure they met the inclusion criteria. The review criteria focussed on the relevance to the research question, whether the document addresses the dimensions of economic, environmental and social sustainability and examines the impact of DTs on the sustainability of SMEs. In addition, it was checked whether the use of DTs was explicitly addressed in the context of SMEs. The lack of applicability of these criteria led to the exclusion of 21 papers. However, it turned out that almost all the studies did not directly examine the sustainability aspect as a primary factor, but rather that sustainability was a side effect of the research analysed in the study.

Nevertheless, in the final inclusion step of the appraisal process, 43 studies were selected for detailed analysis, as they were most closely aligned with the research focus on DTs and their implications for sustainability in SMEs. These studies still can provide a basis for the synthesis and enable an answer to the research question.

Synthesis

A total of 23 of the 43 papers (approx. 53 %) are published in scientific journals. This shows that more than half of the studies have been validated by peer

review and meet scientific standards for methodological rigour. 18 of the papers (approx. 42 %) are conference papers. These publications often cover current trends and technological innovations and offer a practical perspective on the application of DTs in SMEs. The remaining 2 publications (approx. 5 %) are book chapters. These chapters offer a broader, contextual view and are often more theoretical, providing comprehensive overviews of DT applications in SMEs and the challenges they face.

The publication frequency shows an increase in recent years. *Figure 4* shows the development of published papers on the research topic from 2017.

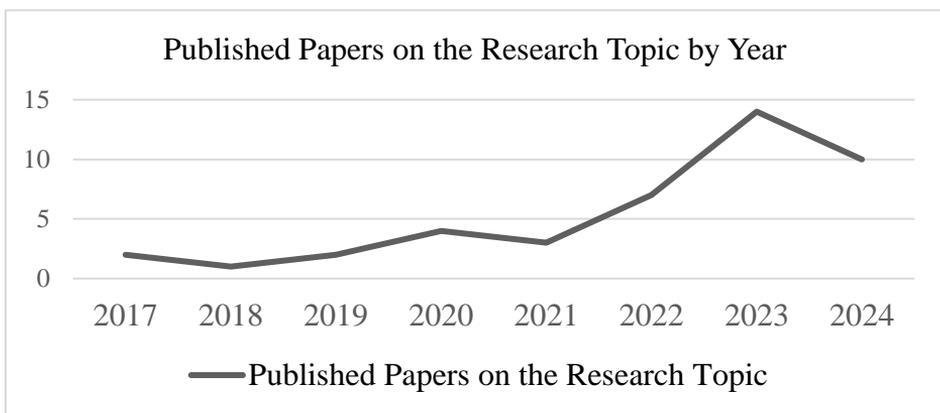


Figure 4 – Published Papers on the Research Topic by Year

Source: Own illustration, based on the research results (2024)

Most of the papers were published between 2022 and 2024, which shows the relevance of the research field. Before 2020, only 5 papers were published, while in 2020, four publications and in 2021, also three publications were submitted. In 2022 7 papers were published in relation to the topic under investigation rising to 14 publications in 2023. 10 publications in 2024 continue to demonstrate an increasing level of scientific activity in this field.

24 of the 43 papers analysed followed a qualitative research approach, while 7 papers took a quantitative approach, 8 papers a mixed approach and 4 a descriptive approach.

While many studies do not mention a specific geographical context, 11 focus on the implementation and impact of DTs in SMEs within a certain regional framework.

Asia is an important geographical area, particularly in the context of the manufacturing industry and energy-intensive processes. The study by Dutta

et al. (2021) highlights the challenges and benefits of digitalising production facilities in Indian SMEs. The focus here is on increasing efficiency and introducing innovations to increase competitiveness in a cost-sensitive environment. Govindasamy et al. (2024) introduce a cost-effective and sustainable DT design for entertainment micro SMEs in India. South Korea is represented in studies such as Y. Park et al. (2020), which focuses on the introduction of a cloud-based DT manufacturing system designed for smart manufacturing in SMEs and K. T. Park et al. (2019), which presents a service-oriented platform for the dyeing and finishing industry, aiming to boost energy efficiency through Industrial Internet of Things integration in SMEs. The platform also utilizes analytical tools to manage energy consumption, reflecting sustainability goals, which is of great importance in a highly developed industrialised country like South Korea. The concept of “Lightweight Digital Twin as a Service” is introduced as a scalable digital transformation model for SMEs in China by Guo et al. (2023).

Europe is also playing an important role regarding the geographical context of the reviewed studies. Borghesi et al. (2021) focus on the general advantages and challenges for SMEs when implementing DTs and edge cloud solutions in an industrial context and highlights the support provided by the Horizon 2020 programme of the European Union, but remain at an overarching European level. The work of Jonek et al. (2023) emphasises that in countries with high labour costs, such as Germany, the integration of technologies such as DTs in combination with human-robot collaboration is of particular interest in order to increase productivity and cost efficiency. Grau et al. (2021) address the challenges and advantages of implementing DTs in process plants more generally, without focusing on specific regional or country-specific contexts, while providing application examples and discussions—such as the use of DTs in a biogas plant in Germany. De Felice et al. (2022) examine the implementation of DTs in Italian SMEs and show how this technology makes production more flexible and reduces costs. Løkke and Madsen (2023) analyse the role of DTs in energy and environmental technology to promote sustainability in SMEs, with a particular focus on Danish and European companies.

The Americas are represented with one study by Bi et al. (2023), who demonstrate how DTs are used in the USA to verify and validate sustainable production strategies across various sectors, including automotive applications, and how this technology supports SMEs in achieving their environmental sustainability goals.

Many studies have addressed an impact of DTs in industrial scenarios. Kawtar and Ahmed (2022) highlight applicability in Industry 4.0 contexts. Grau et al. (2021) describe an automated process for generating a digital twin in the process industry and Pacheco-Velazquez (2024) and Wicaksono et al. (2023) discuss the challenges and opportunities of DTs in the transport and logistics sector. However, most of the studies remain in a broad manufacturing context (Borghesi et al., 2021; Caccamo et al., 2022; De Felice et al., 2022; Dutta et al., 2021; Florescu & Barabas, 2022; García et al., 2024; Harrigan et al., 2023; Jonek et al., 2023; Kang & Kim, 2024; Y.-D. Kim et al., 2023; Kuts et al., 2022; Lima et al., 2019; Løkke & Madsen, 2023; Marra et al., 2024; Monek & Fischer, 2023; Mügge et al., 2024; Y. Park et al., 2020; Pires et al., 2020; Shevtshenko et al., 2020; Sommer et al., 2023; Ud Din & Paul, 2022; Uhlemann et al., 2017; Webb et al., 2024; Yang et al., 2023), while some focus on manufacturing in specific sectors, including aerospace (Rodič, 2017), agriculture (Bi et al., 2023; Zambrano et al., 2022), automotive (Bi et al., 2023; Rodič, 2017), automation (Landolfi et al., 2018), electromechanics (Dutta et al., 2021; Sit & Lee, 2023), entertainment (Govindasamy et al., 2024), food and beverage (Bär & Colombo, 2023), furniture (Krommes & Tomaschko, 2023), plastics and sheet metal processing (Zambrano et al., 2022), and textile (Guo et al., 2023; Huayanca Quispe et al., 2024; M. Kim et al., 2024; K. T. Park et al., 2019). Singhaphandu et al. (2024) focus their research on industrial manual assembly.

An important aspect of the synthesis is the distinction between the articles that directly analyse the impact of DTs on SME sustainability and the articles that indirectly identify the impact of DTs on SME sustainability as a secondary factor. Only two papers directly analyse the impact of DTs on the sustainability of SMEs: Bi et al. (2023) analyse the impact of how virtual verification and validation using a DT contributes to the sustainability of an SME, while Wicaksono et al. (2023) describe the development of an intelligent and trustworthy digital platform for the sustainable management of transport infrastructure using digital twins.

All other authors were able to identify the impact on the dimensions of sustainability as a secondary factor.

Figure 5 shows that all 43 studies identify economic impacts of DTs in SMEs, while only 29 address environmental aspects and 21 social aspects:

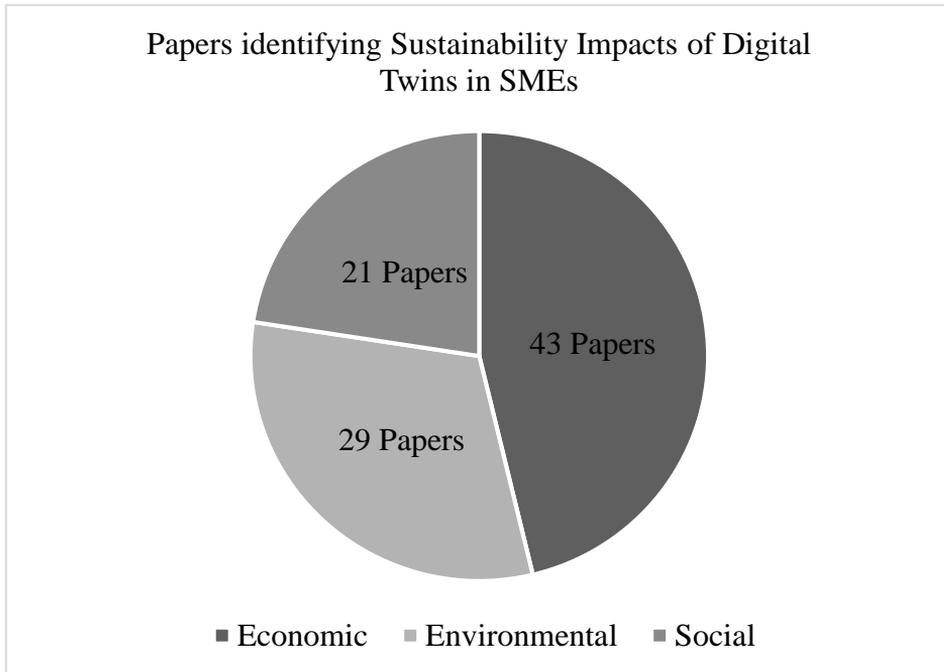


Figure 5 – Papers identifying Sustainability Impacts of Digital Twins in SMEs

Source: Own illustration, based on research results (2024)

Economic impact of Digital Twins on SMEs

All 43 analysed studies identify an impact of DTs on the economic sustainability of SMEs. Many of the investigated studies show that DTs can lead to significant productivity increases and optimised production processes in SMEs. DTs are increasingly recognised as key enablers of economic sustainability for SMEs, providing cost-effective solutions that improve efficiency, optimise resources, and support the development of new business models (Kaarlela et al., 2020; Lima et al., 2019; Marra et al., 2024; Mügge et al., 2024). Their ability to virtualise processes and equipment allows SMEs to simulate and optimise production operations, leading to reduced downtime, faster troubleshooting, and lower operational costs (Landolfi et al., 2018; Lima et al., 2019; Yang et al., 2023). DTs support real-time monitoring and data-driven decision-making, which enhances risk management, enables predictive maintenance, and improves supply chain coordination (Krommes & Tomaschko, 2023; Pires et al., 2020; Shevtshenko et al., 2020; Webb et al., 2024; Wicaksono et al., 2023). Several studies underline their contribution to

increased productivity, operational flexibility, and resource allocation, particularly when integrated with MES, IoT, and cloud-based systems (Guo et al., 2023; Y. Park et al., 2020; Rodič, 2017; Uhlemann et al., 2017). In addition to direct savings, DTs offer indirect economic benefits by enabling more informed investment decisions, reducing programming and validation expenses, and facilitating faster responses to market changes (Deniša et al., 2023; Kuts et al., 2022; Pires et al., 2020). Their role in cost-effective training and education enhances workforce efficiency and supports competitiveness, particularly in dynamic, low-volume production contexts (Harrigan et al., 2023; Singhaphandu et al., 2024; Sit & Lee, 2023). DT-driven automation also strengthens SMEs' capacity for personalised manufacturing without the need for large capital investments (Monek & Fischer, 2023; Rodič, 2017). Applications in energy monitoring, logistics, and production planning demonstrate measurable returns, especially when aligned with predictive analytics and scenario-based optimisation (Kawtar & Ahmed, 2022; Pacheco-Velazquez et al., 2024; Webb et al., 2024). Despite these advantages, adoption challenges persist, including high implementation costs, limited IT expertise, and integration complexity—factors particularly relevant for resource-constrained SMEs (Caccamo et al., 2022; Sommer et al., 2023; Ud Din & Paul, 2022). Nevertheless, by improving ROI, enhancing agility, and reducing development costs through modular and AR-supported systems (Y.-D. Kim et al., 2023), DTs represent a transformative opportunity for SMEs to improve economic performance while navigating digital and market transitions.

Environmental impact of Digital Twins on SMEs

DTs play a pivotal role in advancing the ecological sustainability of SMEs by enabling both direct and indirect improvements in resource efficiency and environmental management. Through real-time monitoring and analysis of energy and material consumption, DTs help identify inefficiencies, optimize production systems, and reduce waste and emissions (M. Kim et al., 2024; Krommes & Tomaschko, 2023; Lima et al., 2019; Pires et al., 2020; Webb et al., 2024). Their capacity to track environmental indicators such as CO₂ emissions and waste output, provides SMEs with actionable insights for sustainable manufacturing and facilitates alignment with industry expectations for ecological responsibility (Løkke & Madsen, 2023; Mügge et al., 2024). By incorporating life cycle assessment (LCA) data and supporting circular economy principles, DTs allow for continuous monitoring of product and compo-

ment conditions across their lifecycle, promoting more informed and sustainable resource decisions (Løkke & Madsen, 2023; Mügge et al., 2024; Zambrano et al., 2022). Additionally, DT-based simulations empower SMEs to virtually test alternative scenarios, evaluate their environmental impact, and make ecologically sound operational choices before implementation (Huayanca Quispe et al., 2024; Lima et al., 2019; Marra et al., 2024; Pires et al., 2020). Beyond operational optimization, DTs contribute to sustainability through predictive maintenance, which extends equipment lifespan, reduces the need for replacements, and reduces the overall consumption of resources (Landolfi et al., 2018; Pires et al., 2020; Wicaksono et al., 2023). Wicaksono et al. (2023) note that their integration into infrastructure and training systems also supports environmentally conscious practices that lead to more sustainable behaviour in the workplace and a better understanding of energy use among employees. In various high-impact sectors such as textiles, furniture, and manufacturing, DTs have been shown to lower material and energy demands while improving workflow efficiency and minimizing the ecological footprint of production processes (Borghesi et al., 2021; Kawtar & Ahmed, 2022; M. Kim et al., 2024; Yang et al., 2023). According to Rodič (2017) SMEs are able to transition toward more resource-aware and sustainable operations by leveraging sensor networks, Green IT, and intelligent data processing. Altogether, DTs represent an enabling technology that supports SMEs not only in achieving energy and material efficiency but also in meeting growing sustainability standards in a data-driven, cost-effective, and future-oriented way.

Social impact of Digital Twins on SMEs

Only a few of the studies pointed out a social impact of DTs.

A number of studies emphasize the contribution of DTs to occupational safety through real-time monitoring, predictive maintenance, and ergonomic task allocation, which help reduce physical strain and mitigate operational hazards (Jonek et al., 2023; Kuts et al., 2022; Mügge et al., 2024; Yang et al., 2023). These safety benefits extend to human-robot collaboration, where DTs facilitate hazard detection and promote adaptive task distribution, while also supporting regulatory compliance in resource-constrained settings (Jonek et al., 2023; Mügge et al., 2024; Yang et al., 2023). In terms of workforce development, DTs offer SMEs cost-effective and scalable training environments that promote employee upskilling and knowledge transfer through virtual sim-

ulations and learning ecosystems (Dutta et al., 2021; García et al., 2024; Harrigan et al., 2023; Kaarlela et al., 2020; Singhaphandu et al., 2024; Uhlemann et al., 2017). This is reinforced by intuitive interfaces such as augmented and virtual reality, which enhance accessibility for non-technical staff and reduce the learning curve for engaging with complex systems (Bär & Colombo, 2023; Guo et al., 2023; K. T. Park et al., 2019; Zambrano et al., 2022). By empowering employees to perform skilled tasks and engage in continuous learning, DTs not only close knowledge gaps but also increase job attractiveness and employee satisfaction (Bär & Colombo, 2023; Harrigan et al., 2023). DTs further strengthen social structures within and beyond the organization by improving transparency, supporting collaborative decision-making, and enabling knowledge sharing via shared data platforms (Pacheco-Velazquez et al., 2024; Pires et al., 2020; Shevtshenko et al., 2020; Wicaksono et al., 2023). Involving users in the development and application of DTs – particularly through accessible and comprehensible systems – also builds trust in digital technologies and fosters broader acceptance within the workforce (Bär & Colombo, 2023; Pires et al., 2020). Ultimately, the overall integration of digital technology into SMEs' operations contributes to socially sustainable practices by improving employee wellbeing, inclusion and long-term adaptability in a rapidly evolving technological landscape, even if certain digital skill challenges remain (Y.-D. Kim et al., 2023).

***Analysis: Interpretation of the results
in the context of existing literature***

The SLR highlights a rapidly emerging, yet underdeveloped research area. It examines the ecological, economic, and social impacts of DTs on SMEs using 43 papers published between 2017 and 2024. While the scope of the studies predominantly centres on the economic dimension of sustainability, limited exploration of environmental and social aspects stress significant research gaps in this field. A summary of the identified impacts can be found in *Figure 6*.

Identified Sustainability Effects of Digital Twins in SMEs		
Economic Effects	Environmental Effects	Social Effects
<p><u>Positive Effects</u></p> <ul style="list-style-type: none"> Increased productivity and process optimisation Increased efficiency and resource utilisation Development of new business models Virtualisation of processes and systems Real-time monitoring and data-based decisions Better resource allocation and operational flexibility More informed investment decisions, lower programming and validation costs Rapid response to market changes Strengthening the ability to personalise production Improved return on invest Increased agility and competitiveness Reduction of development costs through modular, AR-supported systems 	<p><u>Positive Effects</u></p> <ul style="list-style-type: none"> Supporting environmental awareness and sustainable behaviour Virtual testing of alternative scenarios through simulations Real-time monitoring and reduction of energy and material consumption Tracking of other ecological indicators (e.g. CO₂, waste) Predictive maintenance (predictive maintenance) Promotion of the circular economy Fulfilment of sustainability standards through data-supported decision-making <p><u>Negative Effects</u></p> <ul style="list-style-type: none"> None identified 	<p><u>Positive Effects</u></p> <ul style="list-style-type: none"> Increasing occupational safety Safer human-robot collaboration Employee training and qualification development Access for non-technical personnel Strengthening expertise and learning culture Promoting transparency and collaboration Building trust in digital technologies Contributing to long-term adaptability and inclusion <p><u>Negative Effects</u></p> <ul style="list-style-type: none"> Challenges in digital skills
<p><u>Negative Effects</u></p> <ul style="list-style-type: none"> High implementation costs Limited IT expertise in SMEs Complexity of integration into existing systems 		

Figure 6 – Identified Sustainability Effects of Digital Twins in SMEs

Source: Own illustration, based on research results (2024)

Economic, Environmental, and Social Impacts of Digital Twins on SMEs

All 43 evaluated studies included in the analysis explicitly identify the economic benefits of DTs for SMEs.

DTs are recognised for their potential to increase operational efficiency, reduce costs and boost productivity. They enable predictive maintenance, minimise downtime and streamline resource allocation - outcomes critical for resource-constrained SMEs. Examples such as Huayanca Quispe et al. (2024) and Webb et al. (2024) showcase how real-time data-driven insights facilitate energy and resource optimization, leading to financial savings and enhanced return on investment. Additionally, DTs drive agility, enabling

SMEs to adapt swiftly to market demands, a trait increasingly vital in the modern industrial landscape.

Despite the promise, adoption barriers like high implementation costs and technical complexity remain persistent themes. Studies, including Sommer et al. (2023), highlight these challenges, emphasizing the need for targeted financial and technological support for SMEs.

The review found fewer studies (29 out of 43) addressing the environmental impact of DTs, though they universally point to positive outcomes. DTs enhance resource efficiency and waste reduction, align manufacturing with circular economy principles, and enable real-time energy consumption tracking. For instance, Mügge et al. (2024) and Webb et al. (2024) illustrate how DTs promote sustainability by reducing carbon footprints through optimized energy use. Similarly, Borghesi et al. (2021) and Zambrano et al. (2022) discuss how integrating DTs with LCA supports sustainable production by minimizing material waste.

A notable observation is the absence of any identified negative environmental impacts of DTs. This consistently positive assessment could reflect the still young state of the research field and a potential bias towards positive results.

The social dimension remains the least explored, with only 21 studies addressing the topic. DTs contribute to workplace safety, employee well-being, and skill development. For example, García et al. (2024) emphasize the use of DTs in structured employee training, while Mügge et al. (2024) discuss their role in predictive maintenance, which ensures safer work environments. Furthermore, DTs foster inclusivity by enabling non-technical staff to engage in digital transformation, as highlighted by Zambrano et al. (2022) and Y. Park et al. (2020).

Like the environmental domain, the review identifies no specific negative social impacts. This absence suggests either a lack of research focus on unintended consequences or genuinely negligible adverse effects, warranting further investigation.

Practical Recommendations for SMEs

A finding by Hansen et al. (2019) that is also discussed in the paper by Kaarlela et al. (2020) suggests, that many SMEs are already faced with the challenge of understanding the term Industry 4.0 in their own context and

identifying concrete potential use cases for it. Based on the previously discussed findings, this section provides practical recommendations for SMEs to effectively utilise DTs in the pursuit of sustainability goals.

Pires et al. (2020) argue that the use of real applications and demonstrators is a suitable way to familiarise SMEs with new and innovative technologies and approaches such as the Digital Twin and to demonstrate the applicability, benefits and best practices of Digital Twin solutions.

SMEs can actively use digital twins to improve their sustainability performance by monitoring and optimising resource consumption, especially energy, in real time (Lima et al., 2019; Pires et al., 2020). Furthermore, digital twins enable predictive maintenance, which reduces downtimes, extends the service life of systems and thus allows resources to be used more efficiently (Landolfi et al., 2018; Pires et al., 2020; Wicaksono et al., 2023). By virtualising and simulating processes, SMEs can analyse different scenarios and identify more sustainable operating parameters (Lima et al., 2019; Pires et al., 2020). In addition, DTs offer valuable opportunities for circular economy strategies by improving transparency across the entire product lifecycle and enabling data-driven decisions, especially at the end of the lifecycle (Løkke & Madsen, 2023; Mügge et al., 2024).

It is advisable for SMEs to choose low-risk, scalable solutions as a starting point, such as lightweight digital twins offered as a service (LDTaaS) or pluggable IoT-based frameworks (Govindasamy et al., 2024; Guo et al., 2023; Kang & Kim, 2024). These options enable modular implementation without the need for significant upfront investment. In addition, SMEs should focus on specific, high-impact processes that directly affect their sustainability goals and apply cascading digital twins within these areas (Caccamo et al., 2022). Improving employees' digital skills is equally important; simulation-based training platforms can support this transition by fostering practical understanding and engagement for digital transformation (Uhlemann et al., 2017).

Furthermore, examples like Borghesi et al. (2021), Caccamo et al. (2022) and Deniša et al. (2023) show the need for collaboration with external experts, research organisations or other SMEs to facilitate knowledge sharing, cost reductions and implementation acceleration (Kawtar & Ahmed, 2022).

In addition, DTs offer valuable opportunities for circular economy strategies by improving transparency across the entire product lifecycle and enabling data-driven decisions, especially at the end of the lifecycle (Løkke & Madsen, 2023; Mügge et al., 2024).

Identified Patterns and Research Gaps

A significant pattern identified is the heavy emphasis on the economic benefits of DTs. All 43 studies discuss economic impacts, whereas only 29 and 21 studies address environmental and social impacts. However, this can be explained by the fact that almost all selected papers did not analyse the sustainability aspect as a main objective.

The limited number of 43 studies, many of which were conducted using qualitative methods, shows that the topic is still relatively new. The focus on DTs in sustainability for SMEs has emerged predominantly in recent years, with most papers published after 2020. This trend underscores the field's developmental stage and the need for longitudinal, empirical research to substantiate current findings. Notably, only two studies (Bi et al., 2023; Wicaksono et al., 2023) directly examine the sustainability impact of DTs in SMEs, while the remaining literature explores sustainability as a secondary or incidental factor. This highlights a critical gap: the lack of focused, empirical investigations into DTs' role in advancing sustainability across all three dimensions in SMEs.

Contradictory findings are minimal within the reviewed literature, likely due to the field's emerging status and the dominance of qualitative studies. Most sources align in presenting DTs as enablers of economic, environmental, and social improvements. However, few challenges such as high implementation costs and technical complexity, mentioned by studies like Krommes and Tomaschko (2023), contrast with the generally optimistic narratives of DT benefits. These challenges may deter SMEs with limited resources, underscoring the need for scalable, cost-effective solutions tailored to SMEs' capacities.

The studies do not report direct or significant negative impacts on the environmental or social sustainability dimension. This absence may either be due to an oversight in previous research or a genuine lack of harmful effects in the early stages of implementation. Given the increasing reliance on DTs, future research needs to directly and critically examine potential unintended consequences, such as resource-intensive initial implementations or workforce disruption. The fragmented treatment of the TBL across studies indicates a lack of holistic perspectives. Few studies attempt to consider all dimensions, limiting comprehensive insights into how DTs can simultaneously address all aspects of sustainability.

Further, the geographical focus is uneven, with significant representation from Asia and Europe but limited insights from other regions like Africa or

the Americas. Similarly, the industrial focus is skewed toward manufacturing, with limited exploration of DT applications e.g. in service-oriented SMEs.

Discussion and Conclusion

This SLR aimed to answer the central research question:

‘What is the current state of literature regarding the economic, environmental, and social impact of Digital Twins on SMEs?’.

By synthesizing insights from 43 studies published between 2017 and 2024, the review provides an essential overview of the field and fulfils its objective of offering a structured understanding of the role of DTs in promoting sustainability in SMEs.

The findings suggest that the research on the sustainability dimensions of DTs on SMEs is emerging but remains fragmented and underdeveloped. The economic dimension dominates the discourse, with all 43 studies identifying significant positive effects. DTs are recognized as transformative tools that enable SMEs to reduce operational costs, optimize production processes, and increase productivity. They facilitate predictive maintenance, real-time decision-making, and resource efficiency, helping SMEs overcome some of their inherent limitations, such as resource constraints and operational inefficiencies.

In contrast, the environmental and social impacts of DTs are less frequently addressed. Only 20 of the reviewed studies explore environmental aspects, focusing on positive outcomes such as energy efficiency, waste reduction, and alignment with circular economy principles. DTs are shown to support life-cycle assessments and promote sustainable production, although there is a noticeable absence of studies investigating potential negative environmental consequences.

The social impact is the least examined, with only 18 studies touching on this aspect. Research highlights contributions to workplace safety, employee training, and inclusivity, emphasizing the potential of DTs to foster skill development and ergonomic task distribution. However, the lack of studies explicitly addressing social sustainability as a primary focus represents a significant gap.

In conclusion, this review achieved its objective of providing a structured overview of the literature on the sustainability impacts of DTs for SMEs. By

employing the PRISMA and SALSA frameworks, the review systematically identified, screened, and analysed relevant studies. It demonstrated that DTs hold substantial promise for SMEs in achieving sustainability goals but also exposed critical gaps in the literature, particularly in longitudinal studies and integrative approaches that address the TBL. However, it is important to highlight that the results of the literature review are only seen and interpreted in the context of the outlined significant research gaps.

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Noise: A Flaw in Human Judgment
(A Book Review)

HOUNA Safaâ¹

¹PhD student, University of Sopron, Alexandre Lamfalussy Faculty of Economics, István Széchenyi Economics and Management Doctoral School | PhD-student, FOM – University of Applied Sciences for Economics and Management in Frankfurt am Main, Germany

[Daniel Kahneman, Olivier Sibony, and Cass R. Sunstein: *Noise: A Flaw in Human Judgment*, HarperCollins, 2021, ISBN 978-0063029726, 464 pages]

KEYWORDS

- decision variability
- perceived utility
- noise reduction
- behavioral economics
- structured decision-making

ABSTRACT

The book *Noise: A Flaw in Human Judgment* by Kahneman, Sibony and Sunstein (2021) examines decision variability, referred to as noise, as a significant yet often overlooked source of error in human judgment. Drawing on empirical case studies from law, medicine and finance, the authors demonstrate how noise leads to unpredictable inconsistencies, re-sulting in substantial economic and societal costs. To address this issue, they introduce the concept of Decision Hygiene, which refers to structured decision-making procedures, standardized evaluation criteria and the use of algorithmic support to reduce random variability. While the book convincingly highlights the prevalence and impact of noise, several open questions remain. These include the practical implementation of Decision Hygiene, its relationship with nudging strategies and the longterm effectiveness of the proposed measures. Furthermore, a more indepth discussion of the potential benefits of variability and the limi-tations of algorithmic decision models would have added valuable nuance. Nevertheless, *Noise* makes a significant contribution to research on decision making and offers practical insights for improving decision architecture in business, public policy and administration.

JEL-codes: C91, D03, D70, D81, D91, M54

KULCSSZAVAK

- döntési variabilitás
- észlelt hasznosság
- zajcsökkentés

ABSZTRAKT

A Flaw in Human Judgment (Könyvismertető) | A „*Noise: A Flaw in Human Judgment*” című könyvben Kahneman, Sibony és Sunstein (2021) a döntési variabilitást – amit a szerzők „zajnak” neveznek – az emberi ítéletalkotás egy jelentős, ám gyakran figyelmen kívül hagyott hibaforrásaként

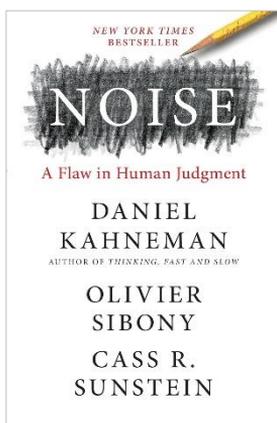
¹ E-mail: safaahouna@gmail.com

MTMT: 10096233 | ORCID: 0009-0001-2778-3346

- viselkedési közgazdaságtan
- strukturált döntéshozatal

vizsgálják. Jogi, orvosi és pénzügyi esettanulmányokra támaszkodva a szerzők bemutatják, hogyan vezet a zaj kiszámíthatatlan következtetlenségekhez, amelyek jelentős gazdasági és társadalmi költségeket eredményeznek. A probléma kezelésére bevezetik a „döntéshigiéné” fogalmát, amely strukturált döntési eljárásokat, standardizált értékelési kritériumokat és algoritmikus támogatást foglal magában a véletlenszerű variabilitás csökkentése érdekében. Noha a könyv meggyőzően világít rá a zaj elterjedtségére és hatásaira, több nyitott kérdés is megmarad. Ezek közé tartozik a döntéshigiéné gyakorlati alkalmazhatósága, annak kapcsolata a „nudging” stratégiákkal, valamint a javasolt intézkedések hosszú távú hatékonysága. Emellett egy mélyebb elemzés a variabilitás lehetséges előnyeiről és az algoritmikus döntési modellek korlátairól értékes árnyalatokat adhatott volna hozzá. Ennek ellenére a Noise jelentős mértékben hozzájárul az ítéletalkotással kapcsolatos kutatásokhoz, és gyakorlati megfontolásokat kínál az üzleti, közigazgatási és közpolitikai döntéshozatal architektúrájának javításához.

JEL-kód: C91, D03, D70, D81, D91, M54



Given the increasing awareness of inconsistencies in professional decision making, the book *Noise: A Flaw in Human Judgment* by Kahneman, Sibony and Sunstein (2021) makes an important contribution to understanding judgment quality. In many fields, such as law, medicine and finance, decisions are expected to be accurate, fair and consistent. However, as the authors demonstrate through real world examples and empirical studies, judgments often vary significantly even under identical conditions. These discrepancies are not explained by bias alone, but by random variability, which the authors refer to as “noise”.

The book provides a clear and well researched exploration of this phenomenon, explaining its causes, consequences and possible solutions. It is particularly relevant for researchers and professionals in domains where consistency in decision making is critical. The concept of decision hygiene, which includes structured procedures and the use of algorithms, addresses real world challenges in business, public administration and policy making. By combining psychological theory with practical insights, the authors present an interdisciplinary approach that highlights the relevance of noise reduction for both academic and applied contexts.

This review discusses the main arguments and contributions of the book, with a focus on its scientific relevance and its potential to improve decision quality across different fields of practice.

Building on this foundation, the authors present the central concept of noise through a range of vivid empirical examples. The book's strength lies in the clarity with which it illustrates this core argument. Particularly striking is the range of real-world cases that highlight noise as an omnipresent and often underestimated phenomenon. For instance, the authors show that judges often arrive at vastly different verdicts in comparable cases, thereby undermining the principles of fairness and consistency in the judicial system. In medical diagnostics, noise results in physicians making divergent diagnoses despite identical symptoms, which can have serious implications for patients and the healthcare system. The same issue is evident in the financial sector, where credit decisions vary depending on the case officer, leading to customers with identical profiles to receive different conditions. These examples illustrate that noise is deeply embedded in decision-making structures, and that measures to reduce it are essential.

To address this problem, the authors propose the concept of Decision Hygiene, a set of measures aimed at reducing noise through structured decision-making processes, standardized evaluation procedures, and algorithmic support. Emphasis is placed on the use of machine-based decision models that aim to reduce random judgment variability by applying consistent rules. The authors argue that more systematic approaches to decision making lead to more reliable judgments. This is especially pertinent in fields where objective and consistent decisions are of critical importance, such as the judiciary or medical diagnostics. At the same time, the question remains as to whether comprehensive standardization is desirable in all areas. While high judgment precision is essential in regulated environments, excessive noise reduction in creative or strategic decision making may have adverse effects by limiting adaptability to new challenges.

After outlining the core concept and its practical relevance, the book also invites a critical discussion of its underlying assumptions and broader implications. The book represents a significant extension of existing research approaches and contributes to key debates in decision science. Whereas Kahneman in *Thinking, Fast and Slow* (2011) identified systematic biases as the main source of flawed judgments, *Noise* demonstrates that random judgment variability plays an equally important role. In comparison to *Nudge* by Thaler & Sunstein (2008), which focuses on the targeted steering of decisions through changes in choice architecture, *Noise* highlights how uncontrolled variability can undermine the effectiveness of such interventions. This raises

the question of whether specific nudging techniques can be deliberately employed to reduce noise, for example, by structuring decision processes in ways that minimize inconsistencies. However, this connection was not explored in detail in this book.

Gerd Gigerenzer (2002, 2014) offers a contrasting view to Kahneman by emphasizing intuitive, rule-based heuristics over formalized models. In *Adaptive Thinking* and *Risk Savvy*, he argues that simple strategies often outperform standardized procedures in uncertain or information-poor settings. While Kahneman promotes algorithmic structure to reduce noise, Gigerenzer highlights flexibility and robustness in dynamic environments. His position challenges the approach in *Noise*, which calls for increased standardization to reduce judgment variability.

The authors of *Noise* convincingly demonstrate that uncontrolled variability in judgments is problematic, the question remains whether complete elimination of noise is always beneficial. Gigerenzer's research suggests that variability may promote adaptability in dynamic contexts such as creative or strategic decisions. A deeper engagement with this perspective would have enriched the discussion, especially in terms of identifying when noise reduction genuinely leads to better decisions, and when it might introduce unintended disadvantages. In addition to these theoretical comparisons, a stronger empirical validation of the proposed measures is desirable.

The book presents numerous case studies, broad-based quantitative studies on the long-term effectiveness of Decision Hygiene are lacking. Earlier works, such as those by Kleinmuntz (1990) and Arkes (1991), indicate that standardized decision processes do not always produce optimal outcomes in every context. Particularly in dynamic environments, where conditions change rapidly, excessive formalization can result in insufficient consideration of important contextual information. A critical reflection on whether the proposed measures are universally advantageous or might give rise to new forms of distortion would have further strengthened the argument.

Another point of discussion is whether noise is inherently negative or might yield positive effects in certain contexts. Although bias is correctly regarded as a distortion, it remains unclear whether the complete elimination of noise is desirable in every case. Especially in creative fields or decision-making contexts that demand flexibility, a certain degree of variability may support the development of novel solutions and foster innovative perspectives. The book focuses primarily on scenarios in which noise is problematic, but it leaves open whether there are cases in which variability might be beneficial.

A further topic of debate is whether algorithmic decision models offer a sustainable solution to reducing noise or introduce new distortions. Although the authors advocate such systems to improve judgment quality, recent research shows these models are not immune to noise. Biased training data, flawed assumptions or lack of transparency may cause algorithms not only to reduce random variability but also to reproduce or amplify systematic errors. This problem is particularly evident in the financial sector, where algorithmic decision-making increasingly influences credit approvals, risk assessments and investment recommendations. Studies on algorithmic bias confirm that machine learning models often learn discriminatory or suboptimal patterns if not carefully regulated. While algorithmic consistency can reduce random variability, it may also amplify distortions because models cannot distinguish between benign and problematic variability. Although the authors acknowledge this challenge, a deeper discussion of how to improve algorithmic models and the conditions under which noise reduction leads to better decisions would have strengthened the argument.

Despite these open questions, *Noise: A Flaw in Human Judgment* is a landmark work that sheds light on a previously overlooked dimension of decision-making research. The authors make a valuable contribution to academic discourse by identifying noise as an independent problem and proposing practical strategies for its reduction. Especially noteworthy is the robust empirical analysis, which impressively demonstrates how pervasive noise is across various domains and what consequences this has for both organizations and individuals. The book's clear and well-structured argumentation makes it highly relevant not only for academics, but also for practitioners in business, politics, and public administration.

From a research perspective, the book opens further reflections on how decision architectures in the digital space can be designed to balance consistency with relevance. In financial services, where algorithms increasingly support complex decisions, the concept of reducing noise may benefit from integration with approaches that emphasize perceived utility. A structured focus on decision transparency and relevance, for example by personalized or dynamic nudges, could enhance the quality of judgments beyond simple standardization. Such an interdisciplinary expansion is consistent with the book's objective to improve the quality of decisions while also encouraging further exploration of practical applications.

This book is particularly recommended for professionals who are involved in high-stakes decision making, such as judges, physicians, financial

analysts and public administrators. It is equally relevant for researchers and students in the fields of psychology, behavioral economics and organizational studies who are interested in understanding and improving decision quality. The clear structure, empirical foundation and practical focus make it a valuable resource for both academic and applied contexts. While the book presents a compelling case for reducing noise in professional judgments, it also opens the door for further research. Future studies could explore the long-term effectiveness of decision hygiene measures, the contextual limits of algorithmic decision support, and the potential trade-offs between consistency and flexibility in dynamic environments.

Declarations

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Industry 4.0 Technologies for Environmental Sustainability **– A Book Review**

Magdalena WITTMANN¹

¹PhD student, University of Sopron, Alexandre Lámfalussy Faculty of Economics, István Széchenyi Economics and Management Doctoral School, Sopron, Hungary
FOM Hochschule für Oekonomie und Management, Essen, Germany

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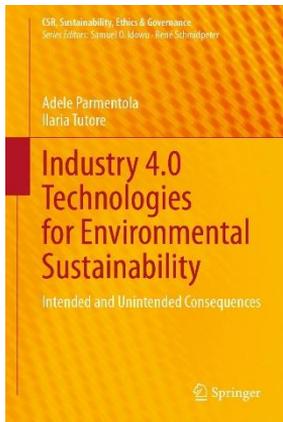
ABSTRACT

The book *Industry 4.0 Technologies for Environmental Sustainability* by Adele Parmentola and Ilaria Tutore (Springer, 2023) analyses the ambivalent effects of digital technologies of the fourth industrial revolution on environmental sustainability. Based on a systematic literature review (SLR) and bibliometric analysis, the authors show that Industry 4.0 (I4.0) technologies such as IoT, big data, blockchain and additive manufacturing can contribute significantly to increased efficiency, resource conservation and transparency. At the same time, potential negative effects, such as high energy consumption or unintended environmental impacts, are addressed. The results are structured along macro, meso, supply chain and micro levels. A key contribution is the case study analysis on the role of blockchain in the context of environmental Sustainability Development Goals (SDGs). The work provides a differentiated, practical contribution to the scientific debate, highlights gaps in research and offers companies impetus for the sustainable use of digital technologies.

JEL-codes: O32, Q01, Q55, M11, L86, Q56

¹ E-mail: wittmann.magdalena@gmail.com | ORCID: 0009-0008-1109-3843

Introduction



Digitalisation in the industrial context, summarised under the term Industry 4.0 (I4.0), is increasingly seen not only as a driver of innovation and efficiency, but also as a potential lever for environmental sustainability. The book *Industry 4.0 Technologies for Environmental Sustainability* by Adele Parmentola and Ilaria Tutore, published in 2023 in the Springer series *CSR, Sustainability, Ethics & Governance* systematically focuses on this aspect. It aims to provide companies and researchers with a differentiated understanding of the intended and unintended effects of I4.0 technologies on the environment and sustainability.

Content

The book has 85 pages and is structured into four core chapters, each building on the last to form a coherent framework for analysing the interplay between I4.0 and environmental sustainability.

The first chapter, *Environmental Sustainability and Firms' Competitive Advantage*, outlines theoretical foundations and key concepts such as the Sustainable Development Goals (SDGs), triple bottom line (TBL), and circular economy (CE). Frameworks like ReSOLVE (Ellen MacArthur Foundation et al., 2015) and 9Rs (Potting et al., 2017) serve as structuring approaches. Orsato's (2006) strategy types are particularly relevant: Eco-efficiency, Beyond Compliance Leadership, Eco-branding, Environmental Cost Leadership. Internal and external drivers of sustainable behaviour, including regulation, stakeholder pressure, and cost factors, are explored. The chapter highlights the role of innovation, especially green and open innovation, as levers for ecological proactivity and competitiveness.

Chapter 2, *Fourth Industrial Revolution and Firms' Digitalisation*, explores Industry 4.0's impact on competitiveness and sustainability. It describes the shift to cyber-physical systems and digital integration across value chains. Key technologies include Big Data, autonomous robots, simulation, IoT, cybersecurity, cloud computing, additive manufacturing, and augmented reality. These enable real-time optimisation and new business models. Ad-

vantages include shorter time-to-market, enhanced services, and SME opportunities. Sustainability aspects span economic (efficiency gains), social (better working conditions, upskilling), and ecological (reduced resource use). However, high energy and material demands of digital infrastructure pose challenges, revealing a double-edged impact.

The third chapter, *I4.0 Technologies Adoption and Environmental Sustainability*, presents a systematic literature review (SLR) and bibliometric analysis. Research on this topic has grown rapidly since 2016. Main themes are categorised into macro (economic), meso (ecosystem), supply chain, and micro (technology application) levels. Most studies emphasise benefits, while unintended consequences of digitalisation – the ‘environmental dark side’ – remain underexplored.

The final chapter, *Unveiling the Positive and Negative Effects of Blockchain Technologies on Environmental Sustainability in Practice*, investigates blockchain’s role through case studies across seven domains, including supply chains, energy, finance, and climate change. Blockchain supports sustainability via transparency, traceability, and decentralised data. It aligns with SDGs such as clean water (SDG 6), renewable energy (SDG 7), and sustainable consumption (SDG 12). However, energy-intensive mining and implementation hurdles are acknowledged as critical drawbacks.

Scientific Classification

The authors, recognized experts in sustainability and digital transformation, employ an SLR and bibliometric analysis to identify research trends and derive robust findings. Noteworthy is the integrative approach combining technological, organizational, and regulatory aspects.

Compared to other titles in Springer’s “CSR, Sustainability, Ethics & Governance” series, which tend to emphasize ethical, normative, or strategic CSR perspectives, *Industry 4.0 Technologies for Environmental Sustainability* stands out for its strong focus on digital technologies such as IoT, AI, and blockchain in the context of environmental sustainability. It offers a practical, management-oriented perspective and highlights both the opportunities and potential risks of digitalization, especially for SMEs in the manufacturing sector.

However, the book differs not only from normative CSR literature, but also from other established scientific works such as Stock and Seliger (2016),

who view Industry 4.0 from a more production-technical perspective, or Oláh et al. (2020), who analyse its influence on environmental compatibility, this book stands out for its business-oriented foundation. Likely due to its recent publication, the book has only been cited four times so far. However, this does not diminish its potential relevance.

It connects technological feasibility with corporate strategy and shows how digital innovations can be integrated into strategic sustainability efforts, offering a differentiated analysis and important starting points for further research. Although the TBL concept is acknowledged, the title already suggests the clear focus on ecological aspects. Social and economic dimensions are addressed selectively, primarily in Chapter 2.4. The book mainly highlights the positive environmental effects of digitalization, but potential negative impacts such as rebound effects or indirect burdens are briefly discussed. A deeper examination of systemic limitations (see Allwood & Cullen, 2012; Ness, 2023) would have further enhanced the contribution. Moreover, it remains unclear to what extent digital efficiency improvements yield absolute environmental benefits without structural changes in production and consumption.

Critical Evaluation

Despite its strengths, the book exhibits certain content-related limitations. The presentation often remains focused on technological potential and pays insufficient attention to the political and cultural prerequisites necessary for sustainable transformations. The social dimension of sustainability is mentioned only marginally, although the acceptance of new technologies and changes in consumption and production patterns are crucial success factors.

Furthermore, while the authors do acknowledge risks such as digital lock-in effects, energy-intensive IT infrastructures, and regulatory uncertainties, these issues are not discussed in sufficient depth. A stronger connection to current debates on greenwashing and the systemic tensions between growth, digitalization, and sustainability (see Nygaard & Silkoset, 2023) would have added additional depth and critical perspective to the book.

Applicability in Business Practice

The book offers valuable insights for companies aiming to leverage Industry 4.0 technologies to achieve their sustainability goals. Practical concepts such as the CE, the ‘Digital Thread’ and the ‘Digital Compass’ are presented as instruments to make processes more transparent, flexible, and resource efficient. The authors illustrate how companies can use big data and IoT to detect inefficiencies, optimize resource allocation, and integrate sustainability metrics into operational decision-making. These concepts are already being applied in practice, particularly in the automotive industry, which faces growing regulatory requirements alongside ambitious sustainability targets. BMW’s iFACTORY strategy, for example, connects all phases of vehicle development and production through digital twins, IoT, and AI-driven real-time data analysis (BMW Group, 2022, 2023). Audi’s Smart Production initiative pursues similar goals with end-to-end data integration to make production more agile, efficient, and resource-saving (Audi AG, 2022).

However, the question remains to what extent these approaches are scalable and adaptable for SMEs. While the book addresses this aspect, it does not sufficiently demonstrate empirical evidence or detailed case studies for the SME context. The idea of linking data throughout the entire product life cycle is equally relevant for smaller companies, which could benefit from standardized cloud solutions, IoT applications, and platform technologies to enhance resource use, supply chain traceability, and compliance without requiring complex IT infrastructures. This scalability also applies to other frameworks introduced in the book, such as CE models, the Digital Compass, and blockchain-based transparency tools. Nevertheless, future research should investigate the practical applicability of these models in different industries and company sizes, with particular attention to sector-specific challenges, implementation barriers, and risks like greenwashing.

In this context, future interdisciplinary research should more consistently consider economic and social dimensions in addition to ecological ones to reflect the holistic ambition of the SDGs.

While barriers for SMEs and industry-specific challenges remain underexplored, there is also a lack of empirical, quantitative analyses concerning rebound effects and indirect environmental impacts. Moving beyond theoretical discourse, such studies are essential to assess whether digital efficiency gains translate into absolute environmental improvements or are offset by increased consumption and demand-driven growth.

With the Corporate Sustainability Reporting Directive (CSRD) taking effect in 2024, the discussed transparency approaches gain further relevance, as it is essential for companies to develop credible, long-term sustainability strategies. Research should better align digital transformation strategies with the changing regulatory framework and examine how companies can meet these complex requirements without losing credibility or greenwashing.

Conclusion

The book *Industry 4.0 Technologies for Environmental Sustainability* by Adele Parmentola and Ilaria Tutore is a well-founded, systematically structured contribution to the interface between digitalisation and environmental sustainability. By combining theoretical foundations, an SLR and practical case studies, it offers valuable insights for both research and business practice.

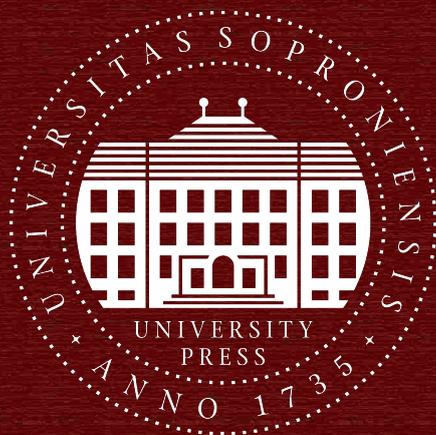
The authors provide a comprehensive analysis of the intended and unintended effects of Industry 4.0 technologies and link them thoughtfully to the SDGs.

The book identifies critical research gaps, which include the ‘dark side’ of digitalisation, such as rebound effects, data ethics concerns, and systemic limits to technological efficiency. Particularly for companies, the book remains an important starting point and provides practical approaches that could guide implementation.

However, both academia and industry are called upon to further empirically and practically resolve the highlighted contradictions between efficiency gains, regulatory compliance, and actual economical, ecological and social effectiveness, as well as the scalability and transferability of concepts like the digital thread, blockchain-based transparency tools, and CE frameworks across industries and company sizes. Only by addressing these questions, the transformative potential of Industry 4.0 technologies for sustainability can be comprehensively assessed.

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