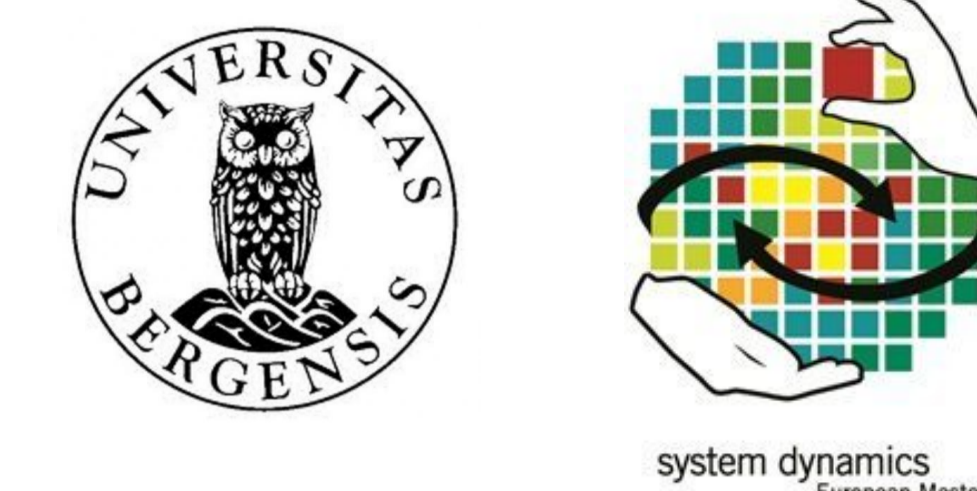


Which product would you buy?

Diffusion Challenges of Circular Economic Products



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<p>LEP Linear Economic Product</p> <ul style="list-style-type: none"> €30/unit CO2: 0.85kg (based on LCA) 	VS	<p>CEP Circular Economic Product</p> <ul style="list-style-type: none"> €45/unit CO2: 0.2kg (based on LCA) Resource Circularity 90%
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*numbers set by author

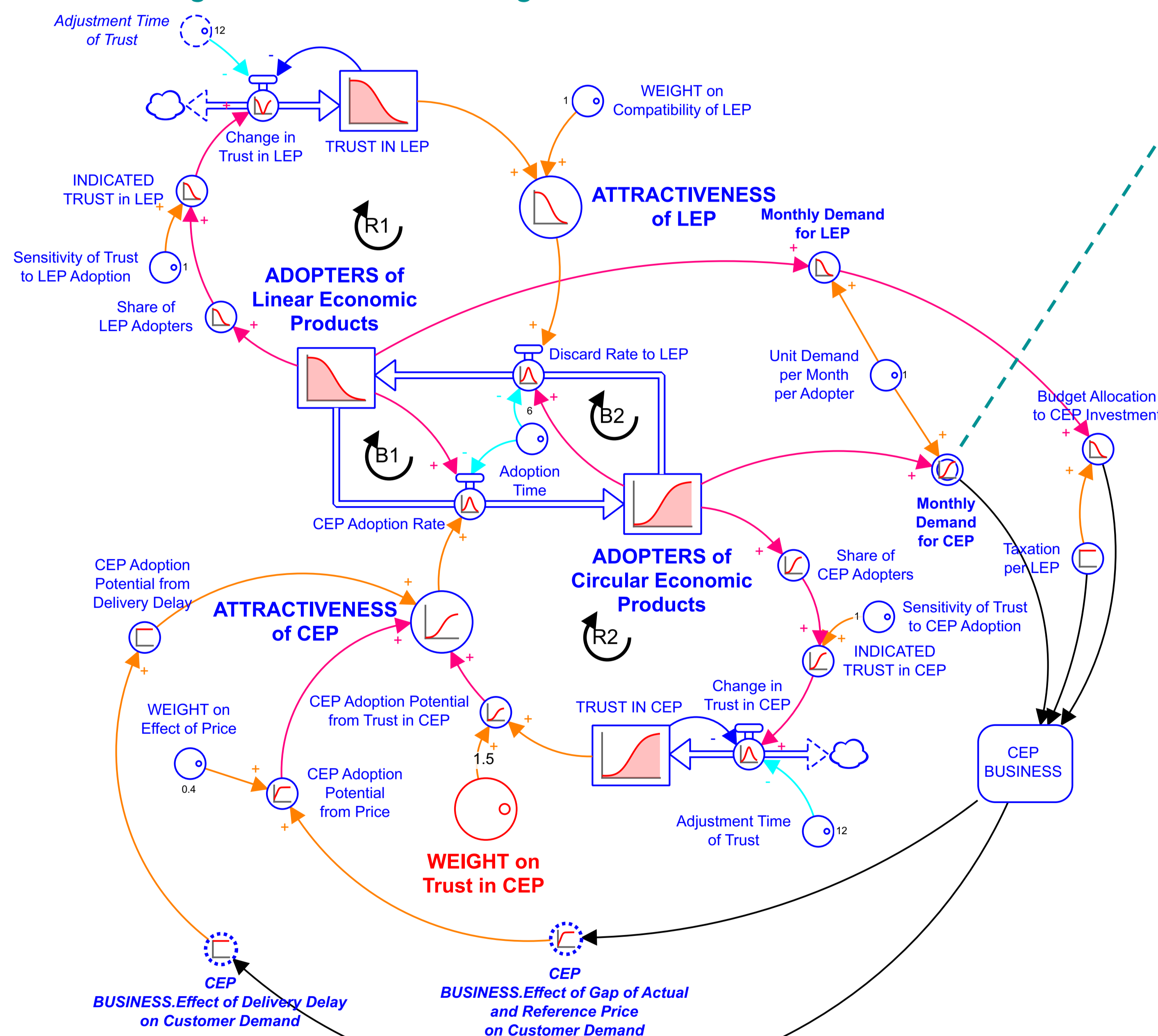
Introduction

- Today's technology already allows some of the commercial products to be fully recycled through a **closed loop supply chain**, dramatically improving the natural resource effectiveness.
- **Despite many technological and commercial effort, and even though consumers' environmental consciousness has been growing, such "circular economic" products are often prone to low market penetration and fail to reach a critical mass before their businesses become self-sustaining.**
- **A simple model case of polyester garment market is conceptualized by the author and analyzed.**

Model Setting

- For simplicity, **the model market is fixed in total size of 10,000 adopters and assumed to be consisting of 2 types of products:** the conventional Linear Economic Product (LEP, polyester garment made from virgin resource such as crude oil and incinerated at the end of use) and the Circular Economic Product (CEP, polyester garment made from recycled polyester via closed loop supply chain).
- **The initial state represents an LEP dominant market with 95% market share, enabling LEP a unit price of €30**, which is used as a **constant competitor's price** in the simulation.
- **CEP business initially has only limited market share, trust and capacity, with an initial unit price of €43.**

Fig. 1 Stock Flow Diagram of the main model structure

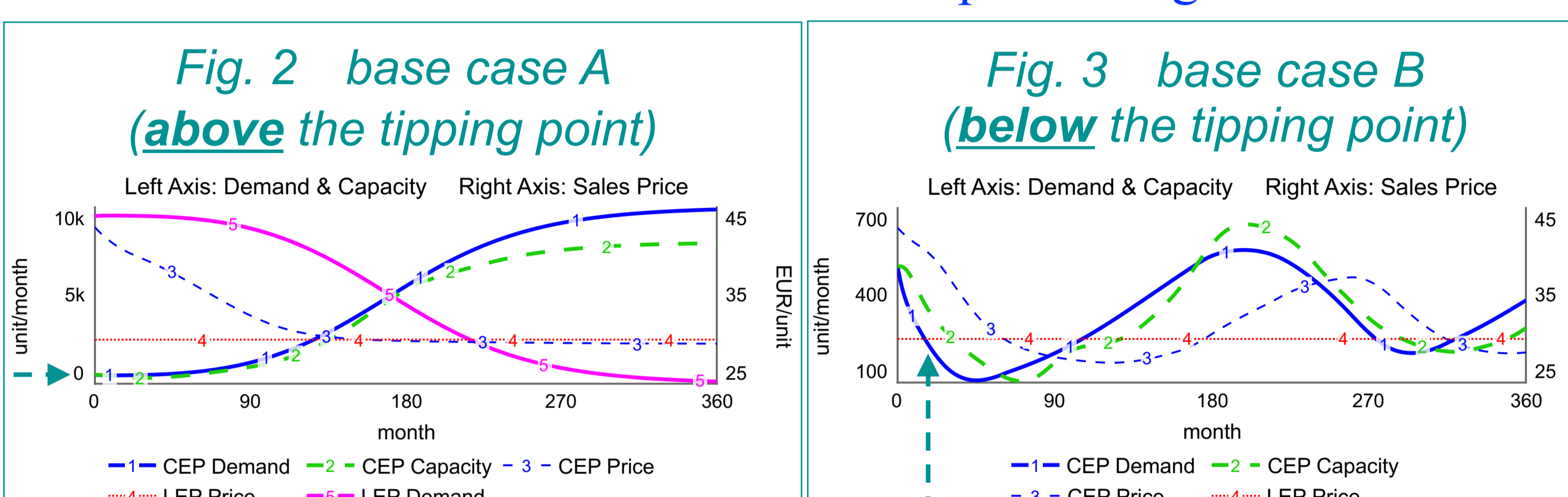


Hypothesis

1. The market growth is constrained by reinforcing loops originating from economies of scale, learning curve and accumulation of social recognition such as trust in the product (Loop R1, R2 and R3 in CLD). Thus, **the nature of the diffusion process is path dependent, eliminating any accumulated effort below the tipping point.**
2. Compared to LEP, **CEP bears a disadvantage of significantly higher fixed cost since it has to invest both in production and recycling capacity.** This forces higher initial cost and price, higher risk and increased difficulty to adjust to changes of the demand.
3. **The standard accounting and economic system will be biased against investments to improve environmental performance** because the costs of investment will be accounted for while its long term benefit will not be reflected to market prices.

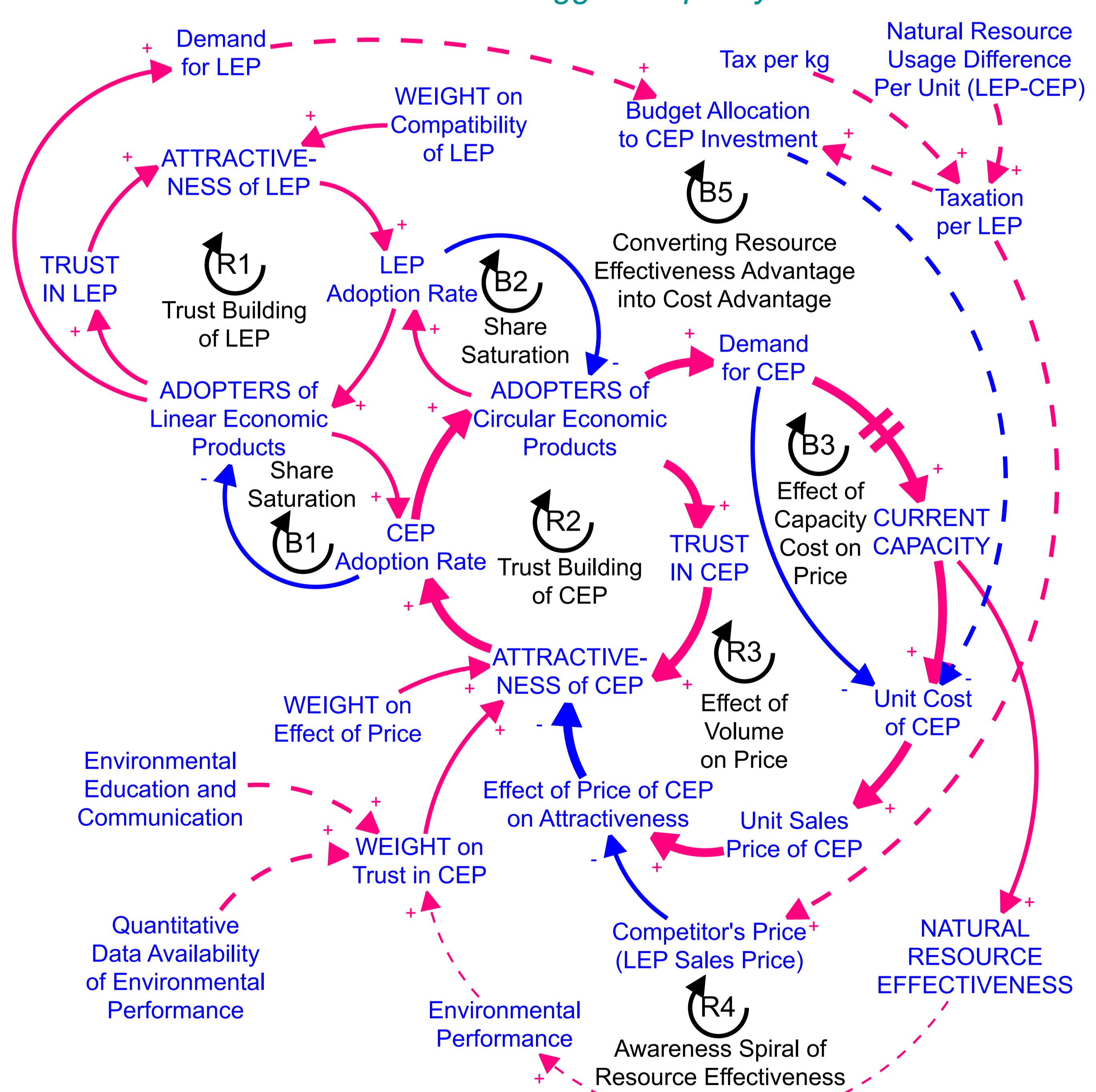
Analysis

- **The behavior of monthly CEP demand can be categorized into 2 basic patterns**, determined by the parameter value of "weight on trust in CEP" which affect consumer's purchasing choices.

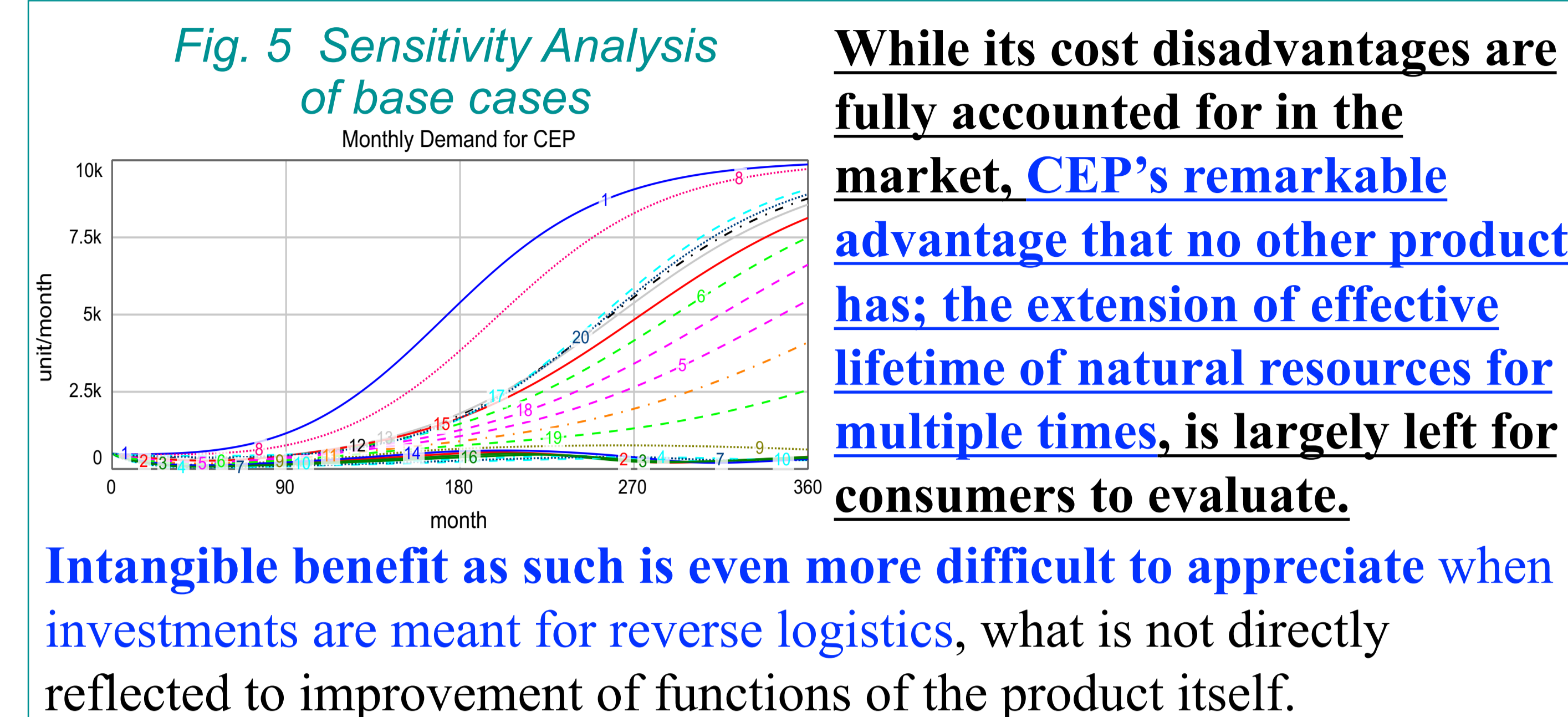


- **Base case A represents a swift transition scenario** from an LEP dominant to a CEP dominant market. It is enabled by consumers putting a high enough priority on trust in environmental advantage of CEP, which always outweighs CEP's price disadvantage for a long time. This does NOT represent today's struggle of CEP business, indicating that the majority of consumers are usually more sensitive to price.
- **Base case B describes a more realistic behavior of CEP demand stagnating at a low level**, which aligns with the problem statement. Consumers are assumed to put weight on trust in CEP just enough to choose CEP if they are only slightly more expensive than LEP. A slight growth of CEP demand initiates the capacity expansion to satisfy demand, which will come in operation and takes effect on price with a significant delay (loop B3 in CLD), generating a limit cycle.

Fig. 4 Causal Loop Diagram* of the model case
*dashed arrows indicate suggested policy intervention



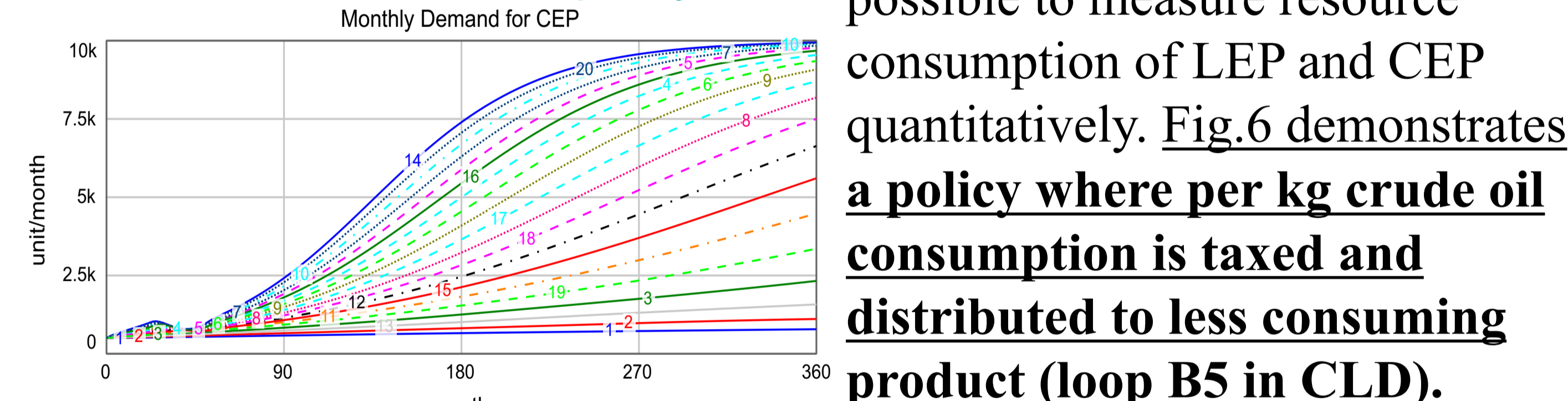
- **A sensitivity analysis** by changing the weight on trust in CEP (Fig. 5) shows an uneven distribution of CEP demand, suggesting a **strong dominance of reinforcing loops over the system**, strictly separating scenarios below or above the tipping point.
- This "Either Or" situation severely limits the chance of diffusion, since small but firm efforts and results of CEP businesses cannot accumulate in the system. (As hypothesized in 1.)
- If CEP had the same cost requirements as LEP (higher material cost, much lower capacity cost), the diffusion above the tipping point would be quicker and the oscillation below the tipping point would be less amplified. **CEP bears a disadvantage of cost structure. (hyp.2)**



Policy

- **One policy suggestion is to enhance the weak link in CLD to fully activate the awareness spiral loop (R4 in CLD) by education and improved information transparency.**
- Aligning with hypothesis (3), H. Lehmann et al. [5] points out that **market prices are wrong due to discounted externalities**, and economic instruments should be deployed to facilitate a shift away from overheads on labor and towards taxing raw materials.

Fig. 6 Sensitivity Analysis of tax allocation policy



Conclusion

- **The simulation model explains the path dependence of diffusion process and CEP's disadvantage of cost structure as main hurdles of diffusion of CEP.** The path dependence mainly originates from **biased market prices that discount externalities such as environmental advantages.** Thus it provides an insight about how effective a dynamic policy which endogenizes the environmental advantage into economic advantage can be.
- As an example, **the model demonstrates that a policy based on so called "material added tax" could function as a powerful balancing loop** that allows to address a fundamental market growth problem of path dependence.

Limitation

In this model, the physical stock and flow structure of the closed loop supply chain, the dynamics of LEP price and adopters disaggregation were intentionally omitted for simplicity. Further research is required to capture the interactions of them with suggested policies to test whether the policy recommendation can be still valid under the complexity of material flow in closed loop supply chain.

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