Artificial Intelligence, the spare time rebound effect and how the ECG would avoid it

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Artificial Intelligence (AI) promises more convenience and comfort for our every day life in the coming decades. However, this does not come for free. Rebound Effects (Santarius, 2012) will lead to increasing consumption of natural ressources. Using service robots for home help as an example, we give a rough estimate for the size of these effects. The major contributor is the so-called "spare time rebound effect". If the robot takes over household chores, its user gets additional spare time for further activities such as travelling, shopping, exercising etc., leading to a higher energy and ressource consumption in addition to the resources consumed by the robot.
By establishing a common good balance sheet (Vogt & Jäpel, 2019) the ECG may be used to counteract the rebound effects. The external costs caused by robot use could be part of the VAT and a usage tax. Very interesting is the accounting of the spare time Rebound Effect. All activities of the robot owners during their newly gained spare time will be taxed accordingly via the ECG anyway. For social equity we suggest increasing duties to be paid on larger incomes.

Keywords: Service robot, artificial intelligence, rebound Effect, cross factor rebound effekt, spare time rebound effect.

Introduction

Autonomous driving, service robots, smart homes and many other new services will increasingly simplify our life in the coming years. This represents a further step in technological development since the industrial revolution starting end of the 18th century. Until around 1980, machines would primarily be used for mechanical work in order to facilitate human labour. Nowadays, with the help of AI computers and robots also take over intellectually demandings tasks such as determining the optimal route in road traffic.[1]

But these advantages of the technical helpers are faced with certain challenges. Among other things, various rebound effects lead to an increased consumption of resources in contrary to an expected efficiency gain. As an example, we will look at service robots (robots which serve as household helpers) to give a rough estimation of the effects´ dimensions for simple scenarios. The biggest contribution is caused by the so-called spare time rebound effect, i.e. the gain of spare time for the user due to the robot's household work. As long as humans have to do the household chores themselves, it is less likely they will get into mischief. But, once the robot takes over the duties, humans have additional time for activities such as consuming, travelling, doing sports etc. In addition to the robot´s energy consumption this causes double harm to the environment.

Here, the economy for the common good (ECG) could counteract by establishing a common good balance for the purchase and use of a robot. The external costs caused by the use of a robot could be billed with the VAT and a use tax, for example. An interesting issue is this billing concerning the spare time rebound effect. All activities of the users in their newly-gained "robot spare-time" will be billed accordingly by the ECG anyway. Nevertheless, one should investigate the option of billing one more addtional tax. Another issue is social equity. Wealthy people will be more likely able to afford a robot, especially if it is even more expensive due to a

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ECG tax. Is it possible to integrate social equity in the common good balance and if so, how can that be done?

Already in 1865, the British economist W. S. Jevons observed that technological innovations, which improved the efficiency of machines fuelled by coal, ultimately lead to a higher consumption of energy. Although the machines burned less coal for the same amount of work the burning of coal overall did not decrease but increase. This effect was called the Jevons Paradox and is nowadays better known as rebound effect (Alcott, Giampietro, Mayumi, & Polimeni, 2012). If the expected gain due to an improvement of efficiency of a certain technology is reduced by other effects such as e.g. higher consumption, this is *called rebound effect*.

A descriptive example for the rebound effect is the private use of cars. The energy efficiency of cars is constantly improving, which theoretically should lead to less petrol consumption and lower costs, if the car´s size and mileage stays the same. But due to the lower costs, people tend to use their car more often or drive even faster or buy an even bigger car or they do all of it at the same time, which ends in higher energy consumption. According to (Santarius, 2012) this would be a direct financial rebound effect. Mostly, the rebound effect refers to an improvement of energy efficiency and it´s consequences. There are many instances for this since the beginning of the industrialisation in the eighteenth century.

Formally the rebound effect is quantified as the ratio of the additionally spent energy caused by the rebound effect to the gain caused by the efficiency enhancement. Hence, if a more energy efficient car only burns 4 liters of fuel instead of 5 liters per 100 kilometres, there will be an efficiency enhancement of 20%. If the driver uses his or her new car 10% more than before, there will be a rebound effect of 10%/20% = 0.5 = 50%. Apparently, the rebound effect can be bigger than 100%. This is called *backfire*.

It is often not energy, which is saved by using machines, automation or Artificial Intelligence but human labour time. Here, higher demand for energy yields a productivity gain for the factor labour, which is called *material cross factor rebound effect* (Santarius, 2012). Take the example of a cordless screwdriver: Instead of a conventional screwdriver a portable electric drill is used which replaces labour time by consumption of resources for production, energy for operation and resources for disposal. Apparently, this rebound effect is increasing the more expensive human labour is in contrast to energy.

Service robots as a typical example of a new AI application

Service robots can be used for household chores such as vacuum cleaning, ironing, tidying up, filling and emptying the dish washer and many others. In about five to ten years, these intelligent robots with learning abilities will be sold for less than 10.000 Euro in our local electronics store and many people will probably purchase one of these little helpers because it simplyfies daily life and increases labour productivity which leads to more spare time. Especially in rich countries with a high salaries these robots will be an interesting purchase for many consumers.

The increase in labour productivity is typical for many technological innovations. Therefore service robotics is a useful example for a new technology and it is irrelevant, whether the use of these robots will actually spread. In the following, two with this example connected rebound effects will be discussed.

The material cross factor rebound effect

The material cross factor rebound effect leads among other things to an increased consumption of resources and to environmental pollution due to production and recycling of robots. In absence of accessible life cycle assessment there is no quantitative estimate possible. Hence, we will disregard this fraction of the rebound effect in the following. Furthermore, the robot constantly consumes 100 watt of electricity 24 hours per day. Assuming that the use of robots will increase strongly in the years coming, we would have one billion service robots (with a world population of eight billion people). With an average power of 100 watt per robot this would amount in a worldwide demand of 100 gigawatt. A medium-sized nuclear power plant produces about one gigawatt [2], leading to about 100 additional nuclear power plants. Alternatively, we could install 33,300 big wind power plants with three megawatt gain and 200 metres height each. Or a photovoltaic power plant with a surface of approximately 5000 km^2, which is about twice the size of the German state Saarland.

The gain in comfort humanity will experience in the near future caused by many universal machines has to be purchased at the expense of much higher consumption of energy and resources. A robot would use 876 kWh of electricity per year. This amounts to 22% of the average electricity consumed by a German four person household.[3] In order to quantify the rebound effect, we have to investigate the efficiency enhancement by the use of

[2] https://de.wikipedia.org/wiki/Kernkraftwerk

[3] Please note that production and recycling of the robot are not considered.

the robot. Since it is an increase in labour productivity and not directly an energy efficiency measure, one can not simply calculate the ratio between increased labour productivity and energy efficiency measure. As a remedy, we try to convert the increase in labour efficiency into the saved energy of the respective person. In order to do so, we assume that the service robot is used in a 4-person-household and takes over one hour of labour every day from each household member.

According to (Dittmann, 1998) a human can perform the continous power of approximately 60 watt. [4] Hence, per day four hours of labour are saved which corresponds with approximately 240 watt hours. The efficiency of human muscles is at approximately 30% (Böning, Maassen, & Steinach, 2017). This means that approximately 800 watt hours of energy must be consumed in the form of food. The robot, in contrast, uses 2400 watt hours of electricity per day. Thus we calculate

$$\begin{aligned}&\text{cross factor rebound effekt}\\ &= \frac{\text{energy consumption by robot/day}}{\text{saved energy from human/day}}\\ &= \frac{2400\text{Wh}}{800\text{Wh}} = 3 = 300\%.\end{aligned}$$

Under the assumptions we have made the robot consumes 3 times as much energy as a human for the same amount of labour. This is quite plausible, since the robot will work much slower and less efficient than the human, at least in the decades coming.

The spare time rebound effect

What will the owners of the robot do in their newly gained spare time? They could, for example, spend this time for meditation (at home) and would consequently not use any enery or resources in addition to their basal metabolic rate. They also could spend this time for activities such as exercising, travelling or simply consuming. These activities are all bound to additional consumption of enery and resources. Let us investigate the following two scenarios for the 4-person-household with its service robot and assume like before that the robot takes over one hour of labour per day from each household member.

Meditation. If the four persons decide to meditate instead of doing household chores, no spare time rebound effect will occur, since no additional energy is consumed. [5] Thus, we calculate

$$\begin{aligned}&\text{spare time rebound effect}\\ &= \frac{\text{energy consumed by human in spare time/day}}{\text{saved energy from human labour/day}}\\ &= \frac{0}{800\text{Wh}} = 0.\end{aligned}$$

Surely, this scenario seems to be unrealistic in contrast to the following.

Business as Usual. To keep it simple, we assume that a person behaves as usual. According to the CO_2-Calculator of the German Federal Environmental Agency https://uba.co2-rechner.de, the overall CO_2-emissions per person and year of 11.61 tons can be divided into 4.87 tons for public infrastructure, food, heating and electricity, even if a person is not active and 6.74 tons for mobility and other consumption. 1/2 kg CO_2 per kWh of electricity were emitted for the German electricity mix of 2018. [6] Hence, 6.74 tons of CO_2 correspond to an electricity consumption of 13.500 kWh per year, respectively 1.54 kW per person. Thus, we can estimate the spare time rebound effect of a 4-person-household as follows:

$$\begin{aligned}&\text{spare time rebound effect}\\ &= \frac{\text{energy consumed by human in spare time/day}}{\text{saved energy from human labour/day}}\\ &= \frac{1540\text{W} \cdot 4h}{800\text{Wh}} \approx 8 = 800\%.\end{aligned}$$

Overall balance

As a result, the purchase of a service robot for a 4-person-household leads to a rebound effect, which is the sum of both effects and has a value of 11. Energy consumption of the robot and the new spare time activities exceed the original energy consumption for the household chores as a multiple. Surely, the factor 11 comes with degree of uncertainty. But this should not be of big concern because what matters here is only the order of magnitude. Another interesting aspect is that the spare time rebound effect is about 2.5 times as big as the material cross factor rebound effect.

A solution via the economy for the common good

As described before, the high rebound effect leads to a high additional energy consumption which should be avoided to protect the environment. Here, the ECG matrix provides a very interesting tool. Of special interest is the element D3 (Impact on the environment of

[4] The performance of 60 watt is the mechanical performance of every human in addition to the basal metabolic rate of approximately 80 watt für all body functions such as brain activity or metabolism.

[5] Nevertheless, implicitly the energy consumption for public infrastructure, food, heating and electricity still accumulates, but this amount will be as high as in the following scenario.

[6] https://www.umweltbundesamt.de/themen/co2-emissionen-pro-kilowattstunde-strom-sinken

the and disposal of products and services). Also, matrix element E1 (Purpose of products and services and their impact on society) should be considered. For this, further studies must be conducted.

A simple ECG certification of the companies producing robots and/or the service robots as products would probably not result in the necessary steering effect. In fact, the figures derived from the ECG matrix should be converted into a corresponding percentage of the VAT. A CO_2 tax would be part of this taxation and must be high enough to achieve a steering effect. Exact values cannot be determined theoretically because the customers' reaction to this taxation is difficult to foresee. Experience should be gathered empirically and on this basis the parameters of the tax matrix should be adapted.

Social balance is crucial, since wealthy customers will be able to afford a higher tax much more easily. Indirectly the Common Good Balance will take effect because it provides with C2 (Self determined workarrangements) an improved distributive justice for the population. Additionally, the taxation rates for luxury goods such as service robots mentioned above should be adjusted progressively to the customers wealth so wealthier customers have to be billed with a bigger share for repairing environmental damage.

Conclusion

AI as one of the most important driving forces of technological progress brings many new products and services to us now and in the near future. The service robot as an example eases our lives but at the same time leads via the rebound effect to more consumption of resources, environmental damage and possibly negative effects on lifestyle and society. The gain of spare time generated by AI represents the major part of the rebound effect. Damages are not so much caused by using AI but by doing harm to environment and society with our newly gained spare time.

An implementation of the Common Good points from the ECG matrix 5.0 into corresponding shares of the VAT for certain products would develop a steering effect and eventually prevent the rebound effect. Furthermore, the Common Good Economy would lead to more social justice in internalising the external costs for environmental damage.

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