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“Változó információs átadási hatékonyság a digitalizáció
fényében, és annak hatása” HU

„Changing information transmission efficiency in light of
digitalization, and its impact.” EN

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I. Introduction

I.1. Introduction

The aim of this paper is to examine the traditional information flow and organizational theories of Hayek and Coase, in the light of significant technical advancements in computing, data collection and analysis, and the emergence of AI in all these fields. Considering, in specific, Hayek's Economics of Knowledge (F. A. V. Hayek, 1937) and The Use of Knowledge in Society (F. A. V. Hayek, 1945), as well as Coase's Nature of the Firm (Coase, 1937). I will review the role of the market mechanism as a medium of information transmission, and its implications on the feasibility of a centrally planned economy. My analysis will incorporate advancements in digitalization and technology, not stopping at today's available technologies, but also taking the theoretical framework to its logical extreme to examine how it behaves in case of maximum information availability, but without any significant additional cost. Likewise, I will review Coase's theories on transactional costs, and its effects on companies' ability to grow while keeping efficiency within the company higher than in the market, also in the light of digitalization, and also taken to their logical extremes. By the end of this investigation into the theoretical limits on planning and company growth, I will hopefully identify the final frontier of efficient central planning and company growth, as well as of the use of digitalization.

I.2. Research methodology

As the above summary implies this paper is purely theoretical in nature, based on an extensive study of the related scientific literature, many hours of individual speculation and reflection, and several productive sessions of discussion with Prof. Drótos György, as well as Prof. Golovics József. However, in the next phase of my investigation, it could also be possible to make real case studies or controlled experiments to validate the conclusions of this study.

I.3. Scope, boundaries

The scope of this paper includes a brief summary of both Hayek's and Coase's relevant theories, the specifics of which will be apparent in the relevant chapters. The intended output of this paper is a solid review of very specific, seminal theories, that each have long reaching influence on many facets of business and theory. As far as Hayek's relevant theories are concerned, I will consider the viability of a centrally planned economy, and its efficiency as a whole, but will not delve deeper into the possible ways to compare it to a free market. I will,

however, propose direction, which if more deeply explored, can lead to viable comparisons of the two systems. When it comes to Coase's theories, I'll be focusing on the issue of the diminishing returns of management, as a limit to company growth, and will be examining how the roadblocks identified by Coase could be circumvented using digitalization. I will not speak of the differing levels of digitalization between companies as of this paper - nor the effects such differences may have on competition – but only about a few select possible state of matters.

II. Reviewed theories

II.1.1. Reviewed theories about market prices as information mediums, and economic policy, as described by Hayek

The author I first consider in this field, is Hayek. His theories about the issue of information distribution will be one of the cornerstones of this paper's theoretical foundation. No issue related to the flow-, acquisition-, or processing of information or data can be approached, without considering how market players can optimally gather said information. (F. A. V. Hayek, 1937) While the theories of Hayek in this field are solid, careful consideration needs to be given to these theories' viability in the information and data driven economy of the 21st century, to see if these theories, and their presumptions still hold their own in a landscape vastly different from the one in Hayek's time. In particular, I'll consider Hayek's theories about the role of market prices as the optimal information medium about the macro environment (F. A. V. Hayek, 1945), and how this role can be affected by new, cheaper methods of data gathering and analysis, while also revisiting its relevance as the cheapest way of acquiring information.

II.1.2. Reviewed theories about the diminishing rate of managements returns, as described by Coase

The second important author whose theories this paper will consider, is Coase. His ideas are relevant to this discussion, since he envisioned the company, as a substitution of the price mechanism in cases when trade would not be feasible using short term contracts, and generally less transactional costs are realized by forming a company (Coase, 1937). These are relevant to this paper, as modern data gathering and analysis, information processing technologies – be it ERPs, business intelligence, or whatever effect AI may have on these fields in the coming years –, as well as smart contract technologies (primarily blockchains, greatly effecting transactional costs) can have the potential to greatly decrease the costs associated with using the price mechanism. This cost not only is an integral part of the reason companies exist, according to Coase, but also sets boundaries for how much a company may vertically integrate or grow in any other way. As such, it is important to investigate the effect of these technologies on theory, as this may reveal opportunities or threats of change and reorganization in many facets of the economy, that otherwise would have gone unnoticed until outside shocks.

II.1.3. Core statement of the paper

Perhaps most of the ideas proposed in this paper could be summarized by defiantly stating: what if certain information related costs – be it directly transactional, the pure cost of using the price mechanism, or costs of organization and information transmission – were indeed that low? So low, that it would defy the expectations of previous scholars, and would allow companies to circumvent certain theoretical limits set by the common sense dictated theory of the previous century? Here, I'd like to take some of the central theories of these two authors to their digitalized extreme, to examine how they behave in that extreme, and what we can learn on the way to that extreme.

II.2.1. Observations about the effect of modern data gathering/analysis on theories of Hayek

Starting the observations with Hayek, I likewise start at the foundation of economic planning, and the question of centralization. As was proposed by Hayek, the microenvironment of market players is an ever changing one, consisting of small, sometimes daily changes, which could not possibly be reasonably collected and communicated towards a central planner, let alone be processed by one. (F. A. V. Hayek, 1945) (F. A. V. Hayek, 1937). However, this idea contains an important assumption: that such a tidal wave of information indeed cannot be processed and collected, and it's easy to beg the question, what if it is possible to collect and process such an enormous amount of information? While Leinweber and Arnott propose the thought of playing around with infinite computational power (Leinweber & Arnott, 1995), and Chen, Chie, and Tai with the idea of infinite digitalization's effect on societies (Zheng et al., 2018), it's obvious that to pass through the issue of central planning, according to Hayek, one would only need to possess a sufficiently strong computer, with a robust system to transport and collect the information provided by individual players. Many who clashed with Hayek on questions about the free market, still agreed, that "the central planner could never have the requisite information" (Sanford J. & Joseph E., 1976) and others reaffirmed these ideas (Levoie, 1985), even as computational power began to ramp up. This idea stood still for a quite a while, as one would expect, until it became clear, that computers would not stop following Moore's law for a while. After that, some started to question if there really can be no computer strong enough to calculate an optimal central plan. For example, Cockshott and Cottrell, in 1997 argue against the unfeasibility of centralized planning, stating that while it would be anachronistic to expect from Hayek's theories to remain unchanged in light of technologies not even on the horizon in his time, central planning could still be viable with sufficient computational power, and could spare many from the boom-and-bust cycles of the market economy (Cockshott & Cottrell, 1997).

Here, I'll add my thoughts on the matter. Indeed, if the question of central planning were to rest solely on the issue of the computational power of a central planner, a machine playing the part of "the director" (Von Mises, 1949), it's easy to imagine a superintelligent computer, capable of receiving and processing massive amounts of data or information, and capable of also planning accordingly at a moment's notice, revising the plan each time new information comes in. In a system, whose complexity is finite – which can be argued humanity's economy always is – there can also be a computer, which is able to process all that information. The

physical limits to such a computer – be it sheer volume, raw materials required, or thermodynamics itself – fall well outside of this paper’s scope. That being said, there is one limit physical in nature, whose understanding does not require a degree in physics, but does put a – if distant – cap at the virtues of central planning: the highest speed at which information can travel, the speed of light. Central planning necessitates the transfer of information, and does so at a significant volume, always requiring information to travel long distances, which becomes an issue after leaving a planetary scale. To sidestep this problem, and to avoid the very economist sounding question of ‘would it be worth it to open a wormhole to transmit information to the central computer?’, I’ll assume that the central planning that takes place, does so, for now, only on a single planet. However, central planning also has to contend with the input of its information, as well as the execution of the plan itself, both of which include uniquely human elements, putting a bottle neck at the speed at which any central planning including humans at all, would have to deal with. To illustrate this, I’d like to propose how the mechanisms of central planning would look like using medieval technology, and then introduce all the technologies that now exist, and could exist in the near future, to illustrate the limits of this form of planning. Central planning in medieval ages would include the following players and processes: (1) individuals, small communities, or companies (from now on, referred to as: individuals) working directly on fields and in workshops, (2) harbingers of information, who transmit information from the individuals to the central planners, and (3) a central planner, or more likely, central planners, who receive this information, and create a plan for all individuals and communities. The process here starts with the individuals, who, by virtue of their work, collect information about their immediate surroundings, whether that be specific ways local flora and fauna interact with production, the density of oxygen in the air surrounding the blacksmith’s shop, or the location of an especially annoyingly placed puddle on the way to the fields. It’s important to note, that it doesn’t matter, whether individuals came in possession of such information through experience or conscious measurements, what does matter however, is that by virtue of their closeness to the production, they are the ones who can react the fastest to changes in these many microenvironmental factors. Here, we meet our first human barrier: the speed, at which individuals or smaller organizations can themselves collect information about their surroundings, and relay that to a medium that could transmit said information to anyone else. After this, the next step, is to get this information to the central planner. Here too, we encounter a human problem: whatever report an individual may create about their microenvironment, takes up time, and causes time not to be spent on working on production directly. Let us not forget, that if we were to designate someone to create these reports on behalf

of the worker, they would know necessarily less about the microenvironment than the worker, which means they'd have to interview the worker to know well enough, which again, takes time for the reporter, and takes time away from the worker to actually work on production, resulting in a loss of efficiency. This report would then have to travel to the central planner, in our medieval environment, most likely by horse or wagon, which of course, takes significant time, linearly proportional to the distance which it needs to travel. All reports from individuals, as well as assessments about trends outside the environment of individuals (such as weather patterns, emerging biological threats, famines, or other plagues scouring neighboring areas), would have to be accounted for, and processed by the central planners. Assuming the planners were able to conjure the greatest minds in the land, they come up with a single central plan, and assign tasks of production and distribution to each individual player. They then put this in writing, and send the horses and wagons on their way, to each individual. The individuals then read the plan and execute their part accordingly. One can already see many inefficiencies in the loop, however, one also has to remember, that in order for such a loop to be more efficient than a free market, where individual players are able to immediately react based on their microenvironment, this loop would need to be replayed every time an individual finds a change in their microenvironment. So, more horses running around, more plan revisions, and more adopting to the execution of the new plan, by at least the individuals impacted by the revised plan, the number of which could range from a few, to possibly all the parties involved in the plan, every time a revision comes around. Of course, a competent central planner could include in their calculations just a limited number of revisions in a given timeframe, but this would then introduce an increasing number of inefficiencies, inversely proportional to the number of revisions in a given timeframe. It's not a stretch to say, that such a system is vastly inefficient at best, and completely useless at worst. We can see, that given a non-zero probability of change in microenvironmental factors, there are a few outcomes regarding the interaction between the number of central plan revisions, and changes in the microenvironment. First, it may not even be possible to react to all changes in the microenvironment, as its possible, that changes occur simultaneously, each requiring different revisions to the central plan, therefore derailing it, and forcing the system to sacrifice efficiency either making a compromise between solutions to the two simultaneous problems, or directly favor one over the other. Even so, if we assume that it's possible to react to two simultaneous changes without sacrificing efficiency, or we define the optimal central plan as one where decisions between simultaneous changes requiring different revisions coming to a compromise are regarded as the best possible plan, therefore allowing for the plan to theoretically react and plan around all changes, we still encounter the issue of

informing parties about the new plan, as well as said parties executing the new plan. The information transmission issue can be partially, if not entirely negated using digitalization, something we'll be exploring later in this chapter, but for our medieval case, we can see the issue of the frequency of central plan revisions requires a compromise, most likely by reacting to only the most influential of changes in microenvironmental factors – assuming that macroenvironmental changes can all be reacted to – which then introduces a myriad of smaller, but compounding inefficiencies, coming from all the changes in microenvironment unaddressed.

Now, to escape the gloomy pictures of wagons running around the country with libraries worth of documents all year round, let us start automating these processes. Jumping ahead possibly centuries in time, we now assume to have access to the following: fully digital communication between any two players, at a scale so vast, that it's impossible to overload the communication network, a central computer, or system of computers so advanced, that whatever pile of information can be delivered to it, it can process, and can do so at such a speed, that revisions to the entire central plan can be done in practically no time. At this level, we could speak of process level digitalization firstly (the adaptation of digital tools, and the reduction of manual steps), and to a degree, organizational level digitalization (the offering of new services, and of old services in new ways), which would then be certain to bring about business domain level digitalization too. (Parviainen et al., 2022) This sandbox of sci-fi-like technologies nullifies many of the issues experienced by our medieval horse and human central plan scheme. Most importantly, it all but solves both the issues of information transmission, as there is no need to cart around tons of reports, as any reports can be delivered to the central computer at nearly the speed of light, a property against which only civilizations spanning several galaxies could object. Secondly, it also completely negates any inefficiencies that would inevitably arise from the central planning of cognitively capped humans at the site of central planning, as the computer can react and revise the entire plan in no time, and can, theoretically calculate the optimal way to produce and distribute goods. However, in this case, we still have to deal with the issue of the information collection of individual humans at the bottom of the process, as well as the execution of any new or revised central plan. For a worker to discover, and then report a new issue to the central system, still takes time, even in this scenario. Even more, for a worker to physically implement the steps included in the central plan, takes time, time which, in case of central planning, adds up the more revisions come in. Of course, now that we have the luxury of a super intelligent central computer system, revisions would come in quite

frequently, as the computer reacts to possibly billions of new inputs about microenvironment factor. So, in this case too, the issue remains: the computer has to calculate the loss in efficiency incurred due to frequent revisions of the central plan, against the loss in efficiency caused by ignoring certain microenvironmental changes. In either case, efficiency is lost, which puts an imperfect market system back on the playing field against a centrally planned system.

To highlight the main factor not related to either human players, or issues of information transmission in a centrally planned system, lets snap our fingers one last time, and travel into a hypothetical future, where on top of the technologies assumed to exist in the previous phase of this thought experiment, we have the following enviable conditions provided: no human is required to operate the central planning system, not at the central level, not at the lowest level of production. Sensors cover most of the planet, and observe every single change in the environment, with algorithms so advanced, that using this sensor suite will always outperform the observations of individual workers. These sensors collect data not only about the microenvironment of production, but also all macro factors that may affect production. Simply put, there can be no event in the world, with a possible effect on production, that isn't observed, and calculated with by the central computer. Fully automated robots tend to all stages of production, all connected to, and controlled by the central computer. The only part of the system where it interacts with humans, is at the very end, where it delivers the goods needed by humans. In this case, the entire system of production and services of the economy, became a theoretically perfect black box, that can immediately react with perfect accuracy to any change in environment, even dealing with the matching of scarce resources with demand – demand being the calculable direct survival needs of humans in this case – internally. Better yet, all of this equipment, the energy needs and upkeep costs of this whole system, is so inexpensive, that its feasible to build out the system, at a cost lower than if one were to operate under a free market system. For such a god-like system, the points of contention become unique. First, there is the question of the inputs of human needs. Do we let the system dictate the needs of humans, assuming that the system knows best what humans need for happiness, or do we let humans choose? Do we optimize the system for human survival? Two of these options go head-on against the goals proposed by Mises and Hayek that economics policy should address. The greater individual freedom said to be provided by a market economy, both according to Hayek (F. A. von Hayek et al., 1960), and Mises (Von Mises, 1949), gets blown out of the picture, in a quest to optimize processes. A conclusion on which's moral righteousness this paper does not take a stance, but one that should be noted nonetheless, which effectively leads back to the age-

old question of freedom versus security, discussed by great philosophers. (Locke, 1690) (Hobbes, 1651) Assuming to have resolved this, however, still leaves a problem not human, not even informational in nature, but one related the time it takes to finish physical production processes, and the delivering of services. Even if processes all the way from the collection and processing of all relevant micro- and macroenvironmental factors, through the transmission of these information, all the way to the production and service processes itself are all automated, with information collection, interpretation, and plan redistribution all happen in an instant, physical completion of production and services is still required, not to mention the issue of delivering the products to their planned destination, which, inevitably requires time. Time, which, of course, is also required in a free market system, but which puts an inescapable limit to the frequency of central plan revisions. As no assumption here solves the ever-present issue of scarcity, we can start a swift thought experiment to examine the issue of production and service completion time. Let's assume, that the computer completed the first central plan. The instant the plan is completed, every detail of the plan goes out to the fully automated production chain, and production starts. At this moment, a theoretical timer also starts, counting down from the total time required to physically produce a product, or complete a service. We can confidently assume, that the time required to complete production of a product or service, can never be zero, unless technologies were to come into existence, which circumvent our understanding of time and space so hard, that all other considerations are destroyed as well. I understand that this assumption in nature is very similar to Hayek's regarding computing power, but it's also clear that having computing power that was unimaginable in the 1930's it's a goalpost much closer than flipping all of physics in its head. Moving forward with this assumption, we can then bring back the question of central plan revisions, and their frequency. If a production process requires time more than zero to complete, there will always be a chance, that a central plan revision, triggered by an unexpected change in micro-, or macroenvironmental factors, will happen during the production of said product. Here, we have to highlight another assumption, one regarding the predictability of events affecting production and planning. As long as we do not possess a computer or system capable of perfectly predicting the future – a capability whose effects would not impact the question of economic planning the most – we must always reserve the idea of unexpected changes affecting production and planning. It may sound menial to specify that the ideas presented here assume that god-like computers with exact knowledge of the future, and technologies defying known laws of time and space don't, or won't exist, but the thoughts I have on the matter need these specifications, less they devolve into parley about what economic planning would look like in a society which

has already solved all issues regarding scarcity, a practice, which may be interesting, but has no bearing on how a society may get to that point, or how it fairs on the way there. With this set, we have the following inputs to the issue of what I'd like to call here, "resource locking": a non-zero time of production, and the frequency of central plan revisions. The frequency of plan revisions is itself influenced by the random appearance of changes in factors affecting production, and revisions matter only, if the affected productions are already underway. This way, when production begins, resources used in said production, are effectively locked in, until production is complete, and cannot be used in the production of any other products. This issue becomes more serious, the more heterogeneous products required by the plan are, as even if production at its time can be stopped, and resources allocated to the production of a different product, the less similar the product required by the new plan compared to the one needed by the old plan is, the harder and more time consuming it will be, to change that product mid process. Here we can then conclude, that as long as there are unpredictable events affecting production, which require revision to the central plan, and as long as production requires a non-zero amount of time, there will always be inefficiencies in a centrally planned economy, even with perfect information gathering and processing capabilities, and even while having no humans in the entire production and planning process. The factor of production that is material in nature, stands in the way of even the theoretical might of infinite information gathering and processing ability. The extent of this system wide inefficiency is the function of the frequency of changes in relevant micro- and macroenvironmental factors, the rate at which central plans are revised, and the severity of ignoring any given change in environment.

In such a system, its clearly visible, that all capital theory would previously have called human, has been replaced entirely by non-human capital, with the capabilities of, and exceeding those of humans. Even if such an entirely automated system isn't on the horizon, it's not hard to see, that the replacement of human capital with non-human capital is an existing trend, one which appears to have been exploding in the realm of non-physical work as well in the past decades. As one of the extreme logical outcomes of this trend is the one described above, it's clear that much thought needs to be given to how any such transformation could go by (Nordhaus, 2007), as we may risk preemptively losing much of the good that can come out of such a radical new system, if the orchestration of this change is not well organized.

Interestingly enough, one solution to the problem material in nature would be to push digitalization to its final conclusion, and to incorporate the most important piece of the economy into the digital realm, humans themselves. One could call this a simulation, VR, or an upgraded

reality, making humans part of a digital system, through integration using physical channels, or through fully digitalizing the human mind and experience – disregarding all philosophical, ethical, and technological hurdles this may pose – is one interesting way to cheat the issue of production time and unexpected events. By taking away the material constraints of production, scarcity itself is non-existent – in the digital world at least – which solves all issues of production time, unexpected events, and all physical restraints. This way a digital world can be created, identical in most aspects to the real one, while solving the above issues by using only a few modifications. An idea to be explored more likely by computer scientists and philosophers, but one that gives a surprisingly attainable solution to the material issues discussed above.

II.2.2. Observations about the effects of digitalization on the theories of Coase

Continuing the observations with Coase, more specifically his ideas about the reasons behind the formation of companies against the price mechanism, and most importantly, transactional costs, looking specifically at ideas found in “The Nature of the Firm” (Coase, 1937). The main question I’d like to consider here regarding Coase’s ideas about companies, is how they are, and can be affected, in theory, by a drastic decrease in transactional costs, led by digitalization. As the questions proposed by Coase, regarding the position of companies within an economic system come from the observation, that companies do not coordinate their internal activities by using the price mechanism, but by a centralized system of control, (Coase, 1937) eerily similar to that of a centrally planned economy, I too, will be referring back to many of my observations in this topic from the previous chapter on centrally planned economies. I’ll be using Niehans’s interpretation of transactional costs, that being costs arising “from the transfer of ownership or, more generally, of property rights” (Niehans, 1989). As Coase proposed, the reason behind the existence of companies is the very fact, that the usage of the price mechanism has costs associated to it. As the reasonable inquiry would follow, he poses the question: if planning within a company can be less cost intensive, than outside of it, using the price mechanism, why isn’t all production conducted by one large company? To this, he points to the idea of “diminishing returns to management”, and names the three key areas which influence such diminishing returns, as the spatial distribution of transactions organized, the diversity in the nature of the transactions organized, and the probability of an increase in relevant prices. From this, he concludes, that as a company organizes more transactions, the internal organization of the company becomes less efficient, getting closer to that of the market. He further notes, that any effects that dampen the impact of the above three key forces, will let the company grow larger, while still keeping internal efficiency higher than the market’s. (Coase, 1937) In this chapter, I’d like to closely view the possible effect these three key areas can experience through digitalization.

To start off, I’d like to immediately point to the fact, that Coase does not put a theoretical hard cap on the size of a company, and as long as the three key areas can be improved, and therefore the diminishing returns to management kept in bay, a company can grow endlessly. First, let’s consider the first key area, the spatial distribution of transactions organized. Quite possibly, this is the easiest area to tackle, as its practically a question of information distribution, we can look at through the lens of the ideas discussed in the previous chapter. If we say, that after a certain distance, the information relevant to a transaction or coordination can be more

efficiently communicated through the market and the price mechanism, than through the internal workings of a company, we practically invite in the question of optimal information transmission. As such, we can examine the same factors, and state, that most issues arising from the spatial distribution can be solved by digital communication systems. There is no limit to the information transmission capacity of current digital systems, aside from the obvious bandwidth and digital infrastructure ones, but these are of course more a hurdle of the operational type. I would wager, that digital infrastructure of advanced economies nowadays is already more than enough to handle companywide transaction related communications, but even if this wasn't the case, it's not a far fetch to imagine the proper infrastructure, whether that's from an investment from a state, or by a company itself. Assuming the investment to build out this infrastructure is made by the company as a fix cost, the costs within a company related to mitigating the diminishing return of management, from the direction of spatial distribution, is nothing but the cost of operating the communication system of the company. What is quite interesting here, is that assuming that the proper infrastructure is present at every location - regardless of if it was built by the company or not – the usage of this system does not scale with the spatial distribution of the company, but rather with the intensity at which data is being distributed throughout the system, in the form of energy and increased wear and tear costs. This means, that the company can not only suppress the costs of mitigating this effect by using new technologies, and optimizing the transmitted information, but can scale – within the planetary bounds established in the previous chapter – indefinitely. Such a trend is indeed admitted by Coase too, stating that: “Changes like the telephone and the telegraph which tend to reduce the cost of organising spatially will tend to increase the size of the firm” (Coase, 1937). At this rate, the price mechanism will be competing with a vast system of communication within the company, giving us a relatively easy way out of this problem. With this approach, we find no limit to how much one can decrease the inefficiencies tied to growing a company, especially since with a vast communication system, the costs incurred by widening the system stop scaling with the company's operations and conducted transactions.

Next, let's look at the issue of dissimilarity between the type of transactions handled by the company. The problem here, is also mostly information transmission based, that is, how does a company organize transactions that are vastly different in nature? The solution here appears to be the company's know-how, in relation to the facilitation of certain types of transactions. As such, anything affecting either the company's know-how, or the simplicity of handling a particular transaction, will positively affect the diminishing rate of management returns, and

therefore enhance the company's ability to grow in size. A company's know-how is near impossible to quantify, however, for our purposes here, I'd like to propose a measurement that is rather simple. That being, the amount of time a given company had been doing a given type of transaction. This experience can either appear at the individual level, or at an organizational level, with the company's processes being managed in a way, that is prepared to more efficiently conduct a given type of transaction. This type of capability has less potential to be impacted by digitalization, but it should be noted, that more efficient information transmission can benefit this area as well, simply by giving individuals improved ability to communicate and record their experiences in a digital form, with the know-how being able to reach more individuals within a company, faster. This could also retain both the individual and the organizational level know-how more effectively within a company, as widely available recorded experience makes it less likely that a shake-up within the company – be it the departure of an experienced employee, or the loss of a business unit – drastically sets back the company's know-how related to a specific transaction. However, we need not be this conservative about our assumptions regarding digitalization, as I haven't shied away from more sweeping assumptions regarding the potential of technology in the previous chapter, and I won't start now. It's clear that there is nothing uniquely human about the facilitation of transactions, therefore it's not a stretch to assume that a digitalized system can handle most, if not all transactions from the company's side. The cost of operating and indeed creating this system would still be proportional to the complexity of transactions on the market – an issue upon which I'll touch in a bit – but the automation of transactions from the company's side is a relevant approach too. It's not easy to put a finger on how a fully automated or digitalized transaction operator would look like, the answer probably lies in the combination of many different software solutions and systems, at least under current technological circumstances. Indeed, a fully realized, fully digital transaction operator system would be indistinguishable from any other company wide digital system, as many processes go into facilitating a transaction from the side of the company, most of which are relevant to other operations of the company as well. For our purposes, the final evolution of a company's transaction operator system would have the following requirements: no human interaction is required for most, if not all transactions regarding production inputs or outputs, and the system should be able to flawlessly communicate with all other systems that are part of the market, be it a standardized communication system, or several individual systems tied to their respective companies. A fully digital transaction operator system would also be able to receive and process all information relevant to transactions from within, and outside of the company, even if the system itself is not integrated further into a companywide software. We've already seen

proposals for systems that provide similar solutions, whether it be for supply chains (Korpela et al., 2017) (Davidson et al., 2016), or for financial markets (Domowitz & Steil, 1999).

The other way digitalization may ease the negative effects of dissimilar transactions organized by the company, is by simplifying the transactions on the market itself. As in, the less complicated transactions become on the market, the less know-how is required by a company to conduct them efficiently. Thus, if digitalization can simplify transactions on the market, – the same way many institutions do (Loasby, 2001) – a company will need less know-how to organize transactions, therefore allowing it to grow larger. Further yet, if we assume a way, that completely standardizes the manner in which any transaction is conducted, we will reach the theoretical minimum of know-how required to conduct any and all transactions. This means, that any company in possession of this standard know-how, - or a software system equivalent to it – would be able to scale its operations infinitely – as far as the complexity of transactions goes. Here, we yet again meet the comfortable position, in which the company reaches a required level of knowledge (or digital infrastructure in the case of spatial distribution of transactions in the previous part), after which margins are no longer against the company, meaning, in this case, that the added capacity to use the existing know-how, or equivalent software, will always scale with the costs in a linear manner. As seen on *Figure 1*, the cost added by a new transaction organized by the company will stop growing after reaching the required standard know-how for taking part in the market, just as it does when the requisite communication infrastructure is reached, on which I have already expanded previously in this chapter. This allows the company to theoretically grow indefinitely, within the confines of the built-up communication infrastructure and the required know-how for the market.

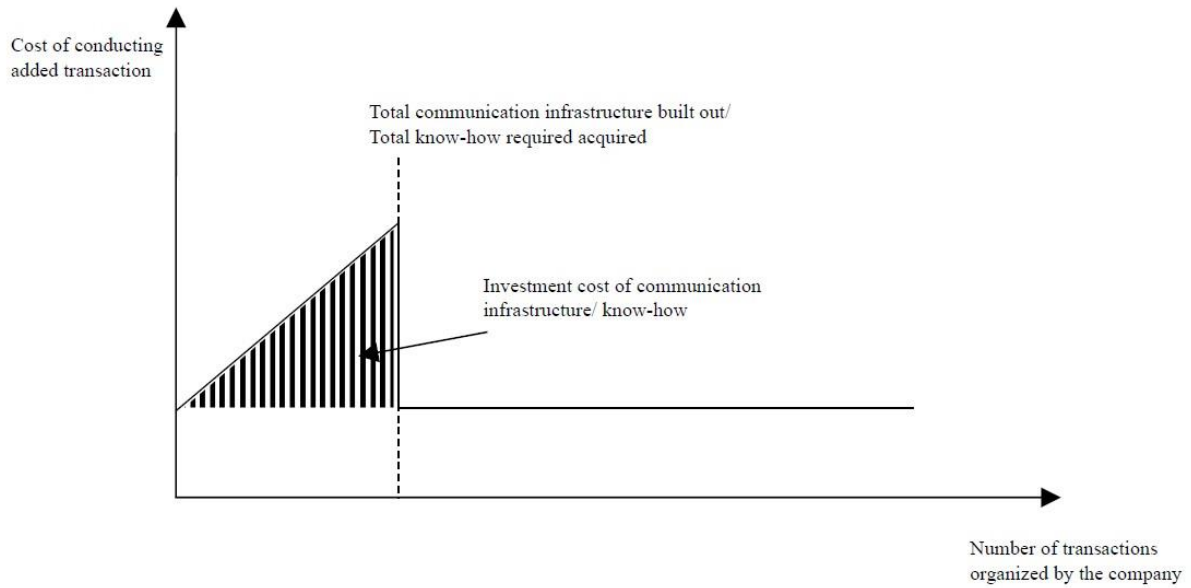


Figure 1.: The cost of conducting added transactions in relation to the number of transactions organized by the company, for the cases of increasing spatial distribution and dissimilarity.

Such standardized transaction communication systems could be called by many names but can mostly be divided into two main categories: centralized and decentralized. Centralized transaction communication systems require a central database of all transactions, as well as a system which coordinates all transactions, and records them all. A simple example for how such a system would look, could be any public record of tenders approved by the governments, or any contracts of public interests between companies, that have a central database containing them, aside from the parties that were directly involved in the transaction. This model, while possible to expand to a universal scale – used in a compulsory way – has a single point of failure and manipulation: the central data base of transactions. Furthermore, any one organization having exclusive, or outsized influence on the workings of a standardized transaction communication system, would have market distorting effects. This can be a tool for government to implement policy but will decrease the efficiency of the system by nature. On the other hand, a decentralized approach, based on the style of a blockchain, a technology which holds many opportunities as of yet only partially discovered by business (Zheng et al., 2018). Since a blockchain system is essentially the final form of decentralization by itself, we can safely run with its theoretical implications without any additional assumptions here. Unlike the centralized approach, this type of system has no single point of failure, and therefore will inevitably have more trust attached to it by any parties. However, it still enjoys all the other advantages a centralized system provides as well. First of which, is trust itself. As records of all transactions are kept at all nodes, constantly checked against each other, all parties can be assured, that no

tampering can be done with the records of all, effectively creating an economics institution (North, 2000), but one that is not affected by the actions – and the mistrust that brings with itself – of any one party. Better yet, a blockchain can be the perfect platform for a standardized system of communicating all transactions. If all companies admit to themselves, that such a decentralized system is the one that will be able to bring the lowest transactional costs for all of them, and after a critical mass of companies join the system, even short-term interests of companies will require them joining. While we could theorize about how such a system could be implemented, whether there'd be a first mover advantage, whether players would accept a central organization having effect on the system, that's well outside of the scope of this paper. What does matter here, is that a blockchain system, the type that already exists today, is the perfect platform for a fully standardized transaction platform, if the “language” of the transactions is indeed standardized within the system. In this case, it appears we achieved the lowest cost theoretically possible for the facilitation of transactions between players, that being the cost of operating the blockchain. A relatively pricy endeavor, no doubt, but one that is only linear in nature to the number of transactions facilitated, and yet again avoids the pitfalls of rapidly decreasing margins put forward by Coase, as discussed at the beginning of this chapter. With this, we have another roadblock out of the way of endless company growth, at least as far as Coase's concerns go, yet again, we see a way to defeat the diminishing returns of management.

The last impediment in the way of indefinite company growth, as seen by Coase, is the probability of changes in relevant prices. A much trickier problem to overcome, as we are essentially trying to solve the issue of price volatility and its effects on the complexity of transactions. The complication here is, that while we could approach the questions of spatial distribution-, and dissimilarity of transactions from both the sides of the market and the company, and we are technically able to implement systems to both sides, we can only react to complications arising from market volatility from the company's side. While the issues of contract negotiation complexity can be solved, by having computers do the negotiating for us – as partially seen in previous parts of this chapter, with automated transaction operations and standardized and automated transaction platforms – with a given set of parameters, the outside forces that influence the inputs of these negotiations, we cannot affect. No matter how accurately a machine considers all parameters, how quickly it negotiates with its robotic partner, if the optimal, or much less, the required, contract conditions of company A do not match with those of company B, the contract will not come to fruition. Furthermore, as we discussed in the

previous chapter, in lieu of machines that can predict the future with certainty and accuracy – and therefore can predict the development of market prices as well, taking out the need for hedging against such risks in a contract, and thus decreasing the nominal value required by any one side in a contract - contracts will always include increased demands proportional to the risks associated with the terms of the contract, in light of the uncertainty posed by fluctuating market prices. And since such fluctuations can come from entirely outside factors, some of which even my assumed god-like system from the previous chapter couldn't predict, we can safely say, that smaller, company sized systems could not predict these either. This however, leaves us with the inevitable conclusion, that no theoretical technology, no matter how digitalized or smart, can alleviate the uncertainty caused by market volatility, and therefore contracts will most likely always include imperfections and nominal requisitions above what's strictly needed for operations, – an issue exacerbated by more efficient negotiating machines, that can more accurately determine and demand requirements for a company, mutually decreasing wiggle room for both sides – causing this third point to be the one, that upholds the issue of diminishing returns to management, and putting a cap on company growth, that cannot be removed by digitalization, at least not by implementation of systems from the side of the company.

There are, of course, specific steps identified by Coase, that negate the negative impact of price fluctuations in specific, one of those being, the idea of vertical integration. Here, I'm specifically using Coase's definition of vertical integration, that being a type of integration, not combination, that not only brings control of the transactions managed by two firms into one, but also brings transactions conducted between those two firms inside the new, integrated one. (Coase, 1937) We have to consider this type, as combinations that do not bring transactions conducted between two companies under the same roof do not have transactional cost decreasing effects, only the increasing ones. This poses a fascinating possible solution to the above issue of price fluctuations, as the two forces align: vertical integration is one way for a company to grow, growth which should bring with it an increased number of transactions (outside the company), which increases, in particular, the company's exposure to price fluctuations, therefore increasing transaction costs. However, as Coase himself said, one way to decrease transaction costs, is to vertically integrate a supplier. (Coase, 1937) This, then leaves us with two questions: how does the decrease in transaction costs incurred by vertical integration measure to the increase in transaction costs caused by the company growth, and how do other types of growth – acquisitions driven by other factors, combinations, and simple

market growth – impact the transaction costs of a company. With this, we have two counteracting forces: transactions that came from the market into the company, decreasing transaction costs, and the company growth induced increase in transactional costs. For cases of vertical integration, we have three options: (1) a given case of vertical integration brings with it more of an increase in transactional costs than the integration itself, (2) a given case of vertical integration brings with it an equal amount of increase and decrease in transactional costs, and (3) a given case of vertical integration brings with it less of an increase than in decrease in transactional costs. Option (1) reaffirms the diminishing returns of management, option (2) brings the company to the same linear scaling as it effects of digitalization would do previously in this chapter, effectively eliminating the diminishing returns of management, while option (3) pushes back further, and reverses the diminishing returns. However, it would be pointless to try and force a trend on all cases of vertical integration, so evaluating how integration will affect a company's transactional costs should be done on a case-by-case bases. Thought needs to be given to both the prospect of simple market-based growth, as well as integration efforts where other considerations supersede the issues of transactional costs. Both of these, of course, do increase the exposure to price fluctuations through growth – as well as the other transactional cost increases tied to growth, but these we've established previously in the chapter, can be negated fully by the techniques discussed here – increasing transactional costs, but without necessarily enjoying the positive effects of a well-timed vertical integration based on a will to decrease transactional costs. With this, there is room left for management to navigate, but technically, if the effects increasing overall companywide transactional costs – be it inefficient vertical integrations or organic growth – can be balanced by integrations that decrease it, there is a chance against the diminishing returns of management, which means, that there is a theoretical possibility to grow indefinitely. This possibility is quite different from the previous two in this chapter, as in its not a state to work towards, where success will be determined by whether a given state of matters is achieved, but a divergence of possibilities, the outcome of which will be determined by factors well outside of any given company's control, let alone the effects of digitalization. While it could be easy to task a computer with calculating the ideal ratio of integration types in order to nullify the diminishing return, based on data collected from possible targets of integration, - most likely, a human could also calculate this with reasonable accuracy – we have to realize, that the limit in this case is not the information collection or processing capacity of anyone or anything, but the composition of companies out in the market, that fit the criteria for integration. If the sum of this group of potentially acquirable companies' – whether it's a small group, or all other companies in the world – transactional cost effect is

negative, then after all acquisitions, the company will have lost from its efficiency, and will have increased its transactional costs, even if it fully and successfully embraced both previous directions of digitalization discussed in this chapter. Note here, that the net effect of companies to be purchased, should be calculated with the inclusion of any possible synergy effects – between the companies to be acquired, not between the main company and each company, as these synergy effects are already part of the calculation under Coase’s assumptions – delivered by a certain combination of the possible acquisition subjects. This calculation can be rerun countless times, with millions of different groupings of potentially acquirable companies, using perfectly fast and accurate computers, in a market so digitalized that all relevant information is readily available to this computer, the underlying conditions will always dictate the final result. As seen on *Figure 2*, the increased exposure to changes in prices is the only factor determined by Coase, that is not entirely influenceable by the firm through digitalization.

Sources of diminishing returns of management with company growth			
Spatial distribution of transactions organized	Dissimilarity of transactions organized	Increased exposure to price changes due to growth	
Can be nullified by digitalization	Can be nullified by digitalization	There is a possibility to be nullified by digitalization, depending on the composition of below options	
		Integration	
		Net <i>positive</i> integration	Net <i>negative</i> integration
		Net <i>zero</i> integration	Always net <i>negative</i>

Figure 2.: Sources of diminishing returns to management, according to Coase, and this paper’s theoretical conclusions about the effect of digitalization on each.

III. Conclusions

III.1. Conclusions about reviewed theory

After the examination of Hayek's theory relating to the question of central planning, and the role of the price mechanism to optimally distribute information, as well as to guide economic policy, I can conclude, that while many systematic issues in the way of a centrally planned economy can be solved, if a certain degree of digitalization and technological advancement is assumed, the issue of what I called in the respective chapter, resource locking, persists, and makes a fully efficient centrally planned economy untannable. This, by itself, does not mean, that a centrally planned economy is not feasible under certain conditions – some of which may be closer to reality today than some might feel, based on my outlandish assumptions in the second chapter – nor does it speak to the relative efficiency, or the required resources and other possible, non-economical costs needed to create such a centrally planned system. Both of these problems require further research of both the theoretical and the empirical kind. The topic of relating the efficiency of a centrally planned system to a free-market system was also only slightly touched upon in this paper, and a proper comparison will require additional research.

As far as the examined theories of Coase go, I was able to conclude that the three main sources of the diminishing returns of management – as they were proposed by Coase – all can, although to a varying degree, be negated through digitalization. Both diminishing returns caused by the increase in spatial distribution of transactions, as well as by the increasing dissimilarity of transactions organized by a company, can be course corrected to become linear in relation to the company growth, therefore, theoretically allowing infinite growth. When it comes to the increased exposure to price fluctuations, I can conclude, that my theory allows a company to utilize digitalization to infinitely expand, only, if the companies that can be integrated into the company would altogether positively affect the efficiency-, and therefore transactional costs of the company. The resultant conclusion, therefore, is that the diminishing rate of management returns can be negated by digitalization only, if the composition of the companies available for acquisition allow it, a piece of information not always known, or available to market players, but one that can draw a red line for the expansion of a company.

III.2. On overlapping conclusions from the examined theories

As my conclusions theoretically open the door for the formation of a single company to manage all of production on earth, we can then ask the question: would this not be the same as a centrally planned economy? As this paper did not examine the exact final structure of a

centrally planned economy – or the single, theoretical company, for that matter – it cannot be stated with certainty, that a single large company would not suffer from the same issues, as a centrally planned economy. However, this steers us back to the question of efficiency under a free market system, versus under a centrally planned system. If one extrapolates the supposed efficiency advantage of a free market with several companies, if we are able to then scale that up into a single company, the advantage should remain. This, of course, also requires more than just insinuation, and my previous statement should only be considered as a call for further research and theorizing.

IV. Appendix

IV.1. Figures

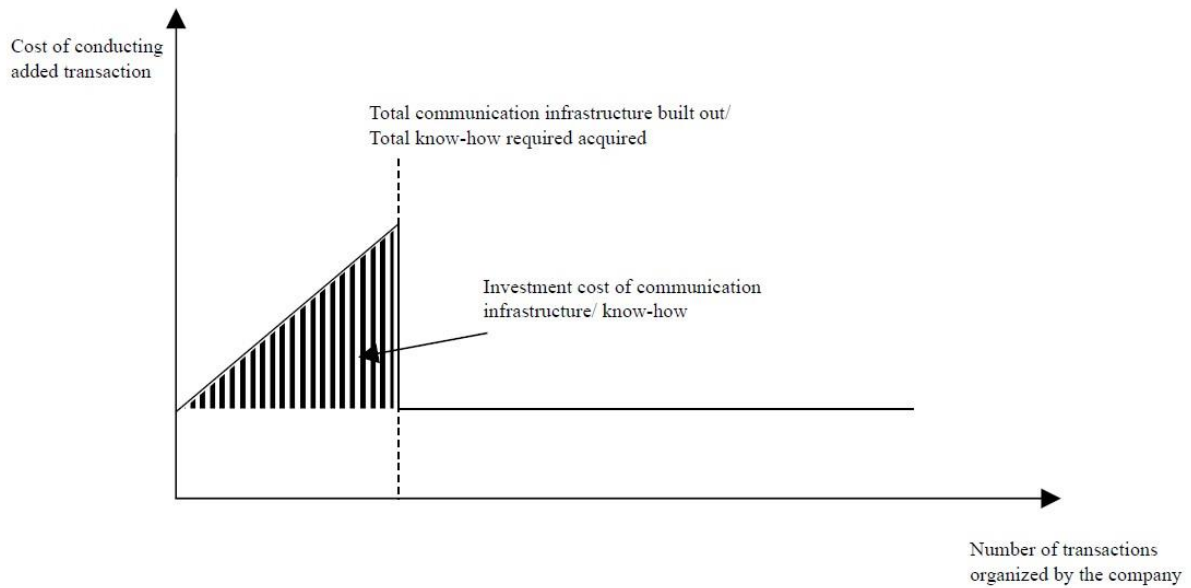


Figure 1.: The cost of conducting added transactions in relation to the number of transactions organized by the company, for the cases of increasing spatial distribution and dissimilarity.

Sources of diminishing returns of management with company growth			
Spatial distribution of transactions organized	Dissimilarity of transactions organized	Increased exposure to price changes due to growth	
Can be nullified by digitalization	Can be nullified by digitalization	There is a possibility to be nullified by digitalization, depending on the composition of below options	
		Integration	Combination
		Net <i>positive</i> integration	Net <i>negative</i> integration
		Net <i>zero</i> integration	Always net <i>negative</i>

Figure 2.: Sources of diminishing returns to management, according to Coase, and this paper's theoretical conclusions about the effect of digitalization on each.

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