



Technology and the Creation of Wealth

This paper is part of Doyletech's series on Technology. Our objective is to bring new perspectives on Making Technology Happen™. This brief overview explores the role of technology policy.

While technology is the engine of wealth creation, its impact is deeply affected by systemic, framework issues. In the following pages, we outline why.



Making Technology Happen™

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INTRODUCTION

The market turmoil of autumn 2008 makes it clear that the industrialized nations must re-invent their economies if they are to continue to enjoy the standard of living to which they have become accustomed. The purpose of this paper is to provide a perspective on the key role that technology will play in that process.

Why is technology key? What is it and what drives it?

Technology generates over half of all economic growth. It creates the wealth that drives job creation, a rising standard of living and the overall quality of life.

Technology is seen as the fruit of modern science, its *practical application* to yield *technical inventions*, from Blackberries® and RadarSat® to Challenger jets and tar sands oil recovery plants. However, technology is far more than applied science.

Technology flourished long before science was born. For example, copper was separated from ore and worked into products as early as 5000 B.C. Its bronze alloys transformed the Aegean region around 2500 B.C. – while science was still speculative philosophy.

Science and technology are very different. *Technology is know-how; science is know-why.*

Men flew before science could explain flight. The Wright Brothers succeeded in 1903. Even half a century later, when the sound barrier was finally broken,¹ it was not with aerodynamics: the successful aircraft ‘design’ copied a .50 calibre bullet (known to go faster than sound). And the loss of a second space shuttle (2002) should remind us that aerospace science is still in its infancy.

Software, an even younger industry, has generated enormous wealth without the benefit of scientific theory. In fact, “The vast majority of computer code is still handcrafted...by artisans using techniques they neither measure nor are able to repeat consistently.”²

Nanotechnology is younger still. The science to unravel phenomena at this tiny scale³ has yet to be developed: “too few atoms to obey classical physics; too many to be effectively modeled by quantum mechanics”⁴ Yet nanotechnology has already generated US\$12 billion in sales (2005), from solid-state lighting and catalysis to stain-resistant fabrics.

So if technology is not just applied science, what is it?

Answers from the Past

Ten thousand centuries ago, stone tools could only support a global population of 100,000 – at the meanest level of existence.⁵ Agriculture, a prehistoric technological advance, changed that forever. By 5000 B.C., it supported five million people. By 500 B.C., classical Greek civilization was part of a world 100 million strong, living a better life with technologies like textiles, iron and seafaring ships.

¹ In 1947, by the Bell X-1 experimental aircraft.

² *Software's Chronic Crisis*, Scientific American, Sept. 1994, pp. 86-95.

³ Roughly under 100 nanometres (1nm.= 10⁻⁹ metres). The diameter of the DNA helix is about 2.5 nm.

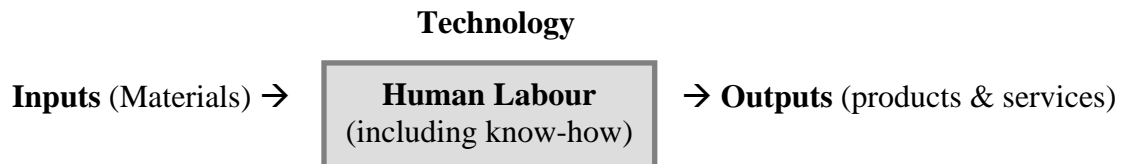
⁴ *Nanotechnology: Emerging Applications in Manufacturing*, D.R. Senik & Associates for Industry Canada, October 2005.

⁵ *Estimating World GDP, One Million B.C. – Present*, J. Bradford DeLong, University of California at Berkeley.

Since the first stone tools, technology has helped humans to both survive and to progressively master their natural environment.⁶

Stripped to its barest essentials, technology is the *application of know-how* to create value by transforming inputs into outputs. When food, rough shelter and warmth from fire were the basics of life, the economic value chain was simple – and technology lay at its centre.

Figure 1: The Economic Value Chain of the Stone Age

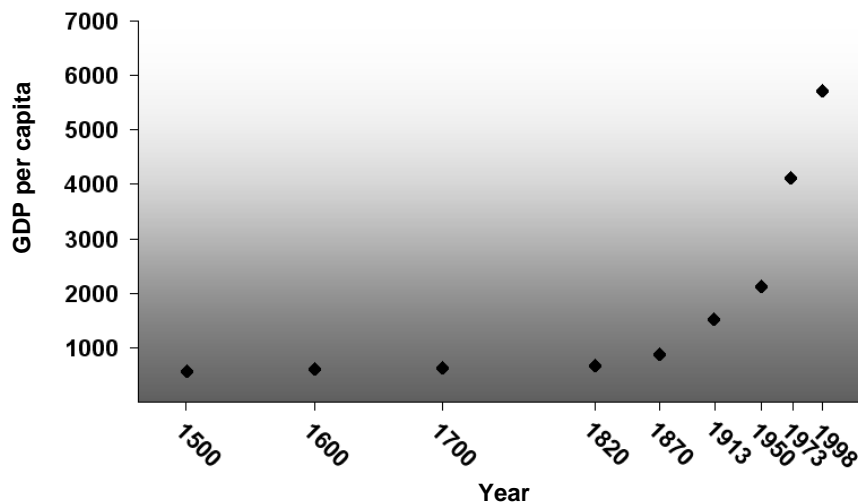


Human technology: skill in the hunt, wooden spears and sharp stone cutting edges transformed resources at hand into valuable outputs: prey into food, hides and bone tools. A single pair of hands – or at most, several pairs – were masters of the universe of technology. The sum of man’s know-how and the power to apply it lay within the span of his own arms.

The Knee of the Curve

Across the ocean of time that stretches back to the Stone Age, earth’s physical resources have changed little. However, our capability to *transform those resources* into value-added outputs has advanced enormously. Technology has enabled population growth and a higher standard of living, both passing a momentous turning point in the Industrial Revolution.

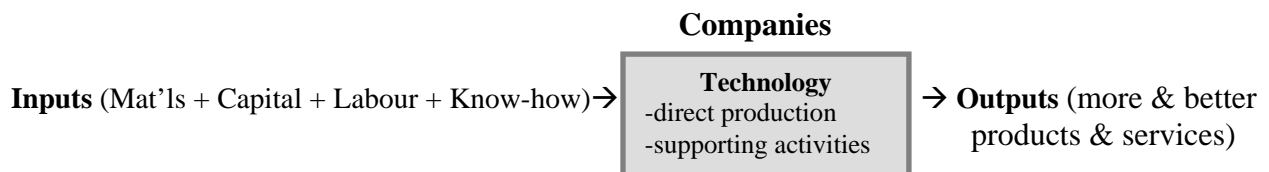
⁶ *A Short History of Technology*, T.K. Derry and Trevor I. Williams, Oxford University Press (1960).

Figure 2: World GDP per capita growth since 1500 A.D.

Source: http://www.j-bradford-delong.net/TCEH/2000/TCEH_2.html

Within a single century,⁷ *both* population *and* income rose over 60 percent. Yet this was just the beginning: in the 20th century, per capita income rose nine fold.⁸

In ten human generations, 1750-2000, wealth creation leapt from slow improvements across millennia to rapid growth. What happened? The answer lies hidden in the modern value chain⁹ where three new elements appear: *companies*, *capital* and *supporting activities*.

Figure 3: The Modern Value Chain

We begin with companies and capital. Both preceded the Industrial Revolution. The development of supporting activities, like R&D¹⁰, took until the late 19th century.

Companies and Capital

Both extend far beyond individuals and the small groups of prehistory. Both come from the middle ages, the result of fundamental changes in *government*.

⁷ 1750-1850.

⁸ *Cornucopia: Increasing Wealth in the Twentieth Century*, J. Bradford DeLong, University of California at Berkeley http://www.j-bradford-delong.net/TCEH/2000/TCEH_2.html (accessed Sept. 8, 2008).

⁹ *Competitive Advantage: Creating and Sustaining Superior Performance*. Michael Porter (1985).

¹⁰ Addressing this key modern addition to the value chain is a task for another day.

Companies were created by feudal charter.¹¹ Feudalism had emerged after the fall of Roman authority in the 5th century A.D., to defend Europe from waves of invaders. Sovereign land grants, in exchange for military service, backed absolute rule over the needed resources. But as the threat subsided, towns, smiths, millers and shopkeepers were absolved from service to the great estates through *charters*. The result was the *Small Business Revolution* of the 10th to 12th centuries. Private property, free markets and regional trade exploded. Thousands of new towns and hundreds of thousands of private farms and businesses blossomed:¹² an economic infrastructure.

The *capital* they needed to grow came from financial innovations developed by northern Italy's city states. The resulting *Commercial Revolution*, around the end of the 12th century, was built on new *institutions* like merchant banks and the limited stock company. By the end of the 15th century, the models pioneered by Florence and Venice had spread to the Atlantic nations. The Dutch borrowed these innovations and added their own: a central bank and a warehousing system with financial instruments to facilitate trade. By the early 17th century, the Dutch East India Company was creating enormous wealth from overseas trade.

The British, in turn, built on Dutch achievements. By the end of the 17th century, British government took a crucial turn away from monarchy: establishing the supremacy of parliamentary rule. Parliament took over sovereign debt, originated the treasury bill system to pay for it and created a monopoly on bank notes – controlling the money supply and interest rates. The first modern stock exchange opened in London in 1698: part of a comprehensive infrastructure for trade and commerce.

As the coming Industrial Revolution would demonstrate, companies and capital had evolved far beyond mere adjuncts to technology:

The Industrial Revolution

For all of the massive developments along the value chain up to 1700, at its core, it had remained *unchanged*. The technology of goods production was the same as in the Small Business Revolution: family-scale craft output, the cottage system.

Its replacement by the *factory system* was the very essence of the Industrial Revolution. Pieces of the new system had been there for centuries; mills driven by water wheels; capital to make the necessary investment; and, in the 15th century, factory production techniques had been foreshadowed by the printing press.

In the 18th century, a wave of mechanical invention built the craftsman's skills right into machines. Massed into factories and driven by water-power, not human or animal labour, machines multiplied output far beyond what human hands could achieve. Cotton textiles, the leading-edge industry of the times made manufactured goods available to all, increasing output by a factor of fifty.

The new system had realigned the strategic centre of the economy from labour to capital.

¹¹ The charter was a written grant from the feudal lord absolving the holder, a person or town, from service to the noble. It defined the purposes the holder could pursue.

¹² *Winning the Future: Succeeding in an Economic Revolution*, Robert Arnold Russell, Carroll & Graff (1986).

The term *factory* designates the combined operation of many orders of work-people, adult and young, in tending with assiduous skill a system of productive machines continuously impelled by a central power. [The term] involves the idea of a vast automaton, composed of various mechanical and intellectual organs, acting in uninterrupted concert for the production of a common object.

Andrew Ure
The Philosophy of Manufactures (1835)

The factory became the centerpiece of the value chain. *Labour* became just another input among many. The know-how it once brought in the bargain became a separate factor of production. In fact, know-how extended its scope, from doing to *systems integration*.

From Value Chains to the Value System¹³

Inputs became sophisticated products in their own right: value chains built on *outputs* from other value chains: a *value system*. Cotton textiles, a leading industry, expanded by a factor of seven in just 30 years, reaching almost 18 percent of GDP.¹⁴ It was a triumph of value systems: improvements in iron enabled advances in machinery. New canals halved the price of coal, making iron cheaper, expanding applications. Increased textile production was driven by waterpower and fueled by intercontinental trade: cotton from the West Indies and British products to the world.

In the new world of value systems, wealth creation was far more than the sum of its parts.

The individual value chains of countless companies were now just solitary threads in wealth creation. *Industries* wove these threads into the fabric of the national economy. *Cities*¹⁵ were literally the factory floors and government shaped the framework within which these elements were fused into GDP.

The last element to emerge in the modern value chain would be distinct *supporting activities*: adjuncts to *direct production* – like procurement and R&D. But this would take a Second Industrial Revolution and more.

CONCLUSION

The preceding journey brings us to the early decades of the 19th century. But we have travelled more than far enough to appreciate the true character of technology and the powerful role that value systems and the framework that shapes them play in value creation:

Technology can alter the value chain, but institutions govern the value system.

¹³ From Michael Porter's term for the larger interconnected system of value chains

¹⁴ As *Time Goes By: From the Industrial Revolutions to the Information Revolution*, Freeman & Louca, Oxford University Press (2001).

¹⁵ Cities are another value system element that has long been neglected in traditional analyses.

In feudal times, all the *value chains* of the coming Industrial Revolution were there: textiles, waterpower and iron metallurgy. Yet it took several more centuries to happen. Why?

Textiles were already a major industry. Waterpower was used to mill grain: William the Conqueror¹⁶ had recorded more than 6,000 water mills in England. And iron was fashioned into sophisticated products, even steel. But the medieval smith was above all an armourer, outfitting the feudal knights in defence of the realm.

In the feudal value system, the sole basis of wealth was land, tightly held in an unequal arrangement of duties and privileges. Common people were mere chattels of the great estates. The manor economy was self-sufficient. Commerce was mostly in kind and trade was largely non-existent. Society's two great institutions, the nobility and the church, were rigid hierarchies – imposing a straightjacket from which the threads of innovation could not escape.

However, by the time of the Industrial Revolution, much of the missing framework that would support a new value system was in place. The technological innovation of factories was just the trigger that unleashed a *systemic* torrent of wealth creation.

The Scientific Revolution of the 16th century had shattered dogma's explanations of the physical world. Science was driven by open enquiry founded on mathematics, causality and systematic experimentation. Literacy and publishing flourished, creating a fertile climate for new ideas. The English Patent Act¹⁷ was soon in place to protect the fruits of those ideas.

The application of capital and merchant banking to international trade, backed by the might of the state, was aligned to powerful effect. Venice had shown the way in the 13th century, creating a Mediterranean empire. This value system was built around monopoly trade, on terms dictated to captive colonies, defended by permanent military outposts and a standing army and navy. Copied by the British and other Atlantic nations, it became the *Mercantilist System*.¹⁸

What technology is and what drives its creation of wealth *in concert with value systems* can be summed up in four words:

Inputs → Process → Outputs
Framework

Technology, the process of creating value by transforming inputs into outputs, does not stand alone.

Technology is powerfully supported, indeed, enabled by the framework of society. Its technical inventions are just the visible tip of the value chain. Wealth is the integration of many chains into the fabric of *value systems*. Technology, the *process* of value creation, is the Philosopher's Stone, the magical substance that could transform base metals into gold.

“Any sufficiently advanced technology is indistinguishable from magic.”

Arthur C. Clarke
"Profiles of The Future" (1961)

¹⁶ *The Doomsday Book*, commissioned in 1085, contained records for 13,418 settlements in the English counties south of the rivers Ribble and Tees (the border with Scotland at the time).

¹⁷ The Act of 1624 allowed the Crown to grant exclusive rights under letters patent for not more than 21 years.

¹⁸ Mercantilism emerged in the 16th to 18th centuries. Government encouraged exports of manufactured goods and discouraged imports of all but basic materials to improve economic well-being, measured as bullion held by the state.

But the wizardry of technology has distracted us, as the magician does, from learning the secrets of his art. Dazzling outputs, from spaceships to artificial hearts have blinded us to the truth: *Technology draws far more of its transformative power from the framework of society than traditional analyses maintain.*

In a world of countless value chains, societal wealth is more and more the result of successful integration at the *systems level*. Society's institutions, government in particular, are the pillars of systemic value creation. And as modern management science has confirmed, the larger and more complex the system, the more resources are needed to manage it.¹⁹

The widespread faith in the god of markets and the corollary view of government as part of the problem is best summed up by Thoreau's words: "That government is best which governs least."²⁰ Yet markets have led us into a world where trillions in wealth have evaporated while wealth creation's foot soldiers, technologies, march largely alone. This is the single greatest challenge that the industrialized nations must face in working with the Philosopher's Stone. We need to commit *more resources*, not less, to the role of government in creating societal wealth.

About the Author

Dennis R. Senik has worked over thirty years in the commercialization of advanced technologies. Over the past six years he has partnered with Doyletech Corporation on a series of projects that have broken new ground in understanding the market dynamics of technology.

As Secretary-General, he directed Québec's largest-ever strategic review of the Montreal region's science and technology capabilities. As part of BCE Chairman Ray Cyr's initiative, he led the subsequent implementation to better connect Québec universities' R&D assets with the region's high-technology companies.

As a partner in Montreal's largest international consulting firm, he led major projects in technology strategy for clients such as Hydro-Québec, Bombardier, the National Research Council and the Prime Minister's National Advisory Board on Science and Technology. As a professor at McGill University, he developed graduate courses in the management of technology and R&D.

He is a professional engineer (Chemical, Queen's University) and an MBA (Policy) graduate of McGill University.

¹⁹ Strategy and Structure: Chapters in the History of the American Industrial Enterprise, Arthur D. Chandler Jr., MIT Press (1962).

²⁰ Henry David Thoreau (1849).