Does Information Beget Information?

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Abstract

Professor R. Polk Wagner has recently propounded a theory in the *Columbia Law Review*, purportedly based on a mathematical model, showing that open information grows exponentially with time and that, to the extent that creator control and incentives are correlated, greater control in the creator (author or inventor) results in a larger supply of open information in the long run than less control. While Professor Wagner's assumptions are open to serious question, this article demonstrates that Professor Wagner's model does not, even on the basis of his stated assumptions, lead to the result he claims for it. Rather, his results derive from an unstated assumption that in fact simply assumes his conclusion. The article then goes on to show how we might approach a valid theory of information growth and shows that, whatever that theory might be, it is unlikely to come to us with the precision of mathematics.

Introduction

Authors and inventors create new information. Our whole theory of intellectual property rests on the assumption that, by giving authors and inventors legal protection for information they create, we get more information of the types society deems desirable than we would have under a regime that allowed free copying of all generally available information. Intellectual property laws thus give to information creators a degree of control over the information they produce as an incentive to produce it. But does information itself beget new information? That is, does the availability of information to human beings in itself lead to the creation of new information?

At first, the question seems absurd. Notwithstanding the human tendency or even need to anthropomorphize, information by itself is inanimate and incapable even of reproducing itself, let alone creating new information. On the other hand, there is a sense in which the current supply of information does, indeed, beget new information. Movies and books lead to movie and book reviews. Scientific papers lead to new research and new papers. Yesterday's ball game leads to a new dynamic for today's game. Such examples are literally without limit. While they all involve human intermediaries in the creation of the new information, it is clear that some of the new information would either be different or would not exist at all but for the existence of earlier information. It must therefore be true that the amount and quality of information we as a society generate at any given time depend in some way on the amount and quality of the existing informational base. The amount of information available to us at any given time is thus a complex function of the incentives society gives to information producers and the quantity and quality of information already available to those producers on which they can build.

Professor Polk Wagner has recently argued that the impossibility of fully appropriating the value of information in a rightsholder, such as the owner of a patent or copyright, leads to the surprising conclusion that *expanding* the degree of control of intellectual property rights will, in the long run, increase the sum total of information *not* subject to ownership claims and therefore available as part of the cultural and technological base on which new growth and development can occur.[1] The essence of the argument is that the creation of any new work results in new open information that is indirectly associated with the new protected work but sufficiently removed from it that it cannot be appropriated as part of the original intellectual property right.[2] The claim is that by giving more control over direct uses of the work to the rightsholder, we increase incentives for the creation of such works and thereby get more of them. Even though fewer direct uses can be made of protected works after the increase in control, the increase in the supply of indirect information will, in the long run, more than make up the difference.[3] Thus, granting more control to intellectual property rightsholders and thereby increasing their incentives to create will result in more growth of open information than would occur under the status quo or under a system of reduced rightsholder control.

1. R. Polk Wagner, *Information Wants to Be Free: Intellectual Property and the Mythologies of Control*, 103 COLUM. L. REV. 995 (2003).

2. Professor Wagner calls this Type III information; Type I is the copyright-protected work or patented invention itself, while Type II information is directly derived from Type I information as cumulative innovation, such as invention improvements or copyright derivative works. *Id*. at 1003-05.

3. *Id*. at 1033.

There is much thoughtful and well reasoned analysis in Professor Wagner's paper. It suffers, however, from a fatal flaw. While his presentation, purporting to use the language of mathematics, obfuscates in a serious way exactly how he does his calculations, in fact he simply *assumes* that the formula for compound interest applies to the growth of open information. That is, he asserts that the amount of open information, O_n, at the end of n periods of time is equal to the amount that existed at some time in the past, O_1, multiplied by $(1+z)^n$, where z is a growth factor supposedly related to creation incentives. This mathematical formula accurately predicts the value of a bank account paying compound interest (provided the money is not left in the account too long[4]) and undoubtedly applies to a range of other natural and human-operated processes, such as the growth of bacteria in a medium of unlimited necessary nutrients. Does it, however, apply to the growth of open information, and if so how? Professor Wagner does not attempt to justify his application of the formula for compound interest to information growth,[5] and this article argues that such application is absurd, especially pursuant to an incentives-based theory that looks, as his theory purports to do, to *people* – authors and inventors – for the creation of cultural and technological works.

The Wagner Theory

4. $100 invested in a savings account at 5% per year would be worth some $227 million after 300 years. If the bank somehow forgets about the account, it might not be able to make the payout to the depositor's lucky descendants.

5. There are, indeed, some serious studies attempting to show that knowledge has been growing exponentially. For example, Ray Kurzweil argues that the history of technology shows exponential growth in technological change; indeed, the growth is doubly exponential, in that the exponential growth factor itself has been growing with time. Ray Kurzweil, *The Law of Accelerating Returns*, KURZWEILAI.NET, Mar. 7, 2001, available at http://www.kurzweilai.net/articles/art0134.html?printable=1. A similar conclusion can perhaps be inferred from some of Isaac Asimov's work. See *infra* note 23.

Because Professor Wagner does not expressly tell his readers that he applies the formula for compound interest to the growth of open information, it is necessary to summarize his purported mathematical analysis in some detail to uncover the absence of any basis, at least within his analysis, for doing so. While I find his mathematical notation clumsy at best, I adopt it here to allow easier comparison of my analysis to his. To keep the discussion as simple as possible, I also grant him most of his assumptions, indicating their many problems only in footnote.

Professor Wagner looks at a series of time frames of unspecified length during which information is produced by creative authors or inventors. The total information, I, produced in such a time frame consists of i_I, the Type I information relating to the core creations (e.g., patented inventions or copyright-protected works); i_{II}, the Type II information that is directly related to and derived from those core creations; and i_{III}, the Type III open information that results from the appearance of Types I and II information but is beyond the control of any intellectual property rights.[6] The total information produced during the given time frame is $I = i_I + i_{II} + i_{III}$. All Type III information is by definition open, and percentages of Types I and II information are also open, due to intellectual property rights that grant less than full control to the rightsholders. If the respective percentages of these two types of information that are open are c_I and c_{II}, the amount of

6. Type I information is the copyright-protected work of authorship or the patented invention itself. Type II information derives directly from such underlying creations, such as improvements in the patent context and derivative works, like movies made from books, in the copyright context. Type III information derives from the underlying creation but is beyond the control of the intellectual property rightsholder. The new technological avenues that were opened by pioneering inventions like the steam engine and the transistor or new genres of television shows that follow a successful first example are Type III information. *Id*. at 1003-06.

open information produced during this time frame is

$$O = c_I i_I + c_{II} i_{II} + i_{III} \qquad (1)$$

Equation (1) represents, or should represent, the status quo – the amount of new open information that would be created within the given time frame if we make no changes in the incentive schemes of intellectual property law. If we now increase or decrease creation incentives by increasing or decreasing rightsholders' control, Professor Wagner multiplies equation (1) by a factor z reflecting that change:

$$O(z) = z[c_I i_I + c_{II} i_{II} + i_{III}] \qquad (2)$$

The incentives factor z is unity for the status quo; it goes up with increases in rightholder control (increased incentives) and down with decreases in such control. Of course, the coefficients c_I and c_{II} also vary with z. They vary inversely with the change in control, that is, with z, because by definition they represent the amounts of Type I and II information that is not, under intellectual property law, subject to the control of the rightsholder. Fair use of a copyright-protected work seems to be an obvious example. Thus, if the law changes to reduce the number of uses of copyright-protected works that are deemed "fair," the copyright owner will have more control over the uses that can be made of Type I information, so less of i_I will be open information (c_I decreases). On the other hand, to the extent greater copyright owner control increases the incentives to create new works, i_I itself should increase.[7] Similarly, if the notion of "expression" is expanded so that more works based on Type I works are considered infringing derivative works, more of this Type II information will also be subject to copyright owners' control, causing less of

7. Because i_I is itself a function of z, it is double counting to multiply again by z in Equation 2. But that is the least of the problems posed by Professor Wagner's theory.

i_{II} to be open (c_{II} decreases).[8] Presumably, less i_{II} will also be created with the increase in rightsholder control, because more i_{II} will require a rightsholder's permission and some creations will simply not occur due to transaction costs that were not present in the lower-control world.[9] It is perhaps worth noting that there is nothing in Equation (2) that implies a "feedback" of the amount of open information onto itself; that is, Equation (2) includes no term relating the amount of open information O created during the period to the amount existing at the beginning of the period.

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8. Professor Wagner recognizes, but does not address in detail, the possibility that Type II information may also be, or become, Type I information. *Id*. at 1018 n.97. For example, the movie made from a novel has much original material that is protected, if made with permission, as a derivative work. Presumably, the original elements of a protected derivative work constitute Type I information, while the elements that would, but for the copyright owner's authorization, have made it an infringing derivative work are Type II information. Again, the critique of Professor Wagner's theory contained herein does not depend on these details and therefore grants him, for present purposes, whatever assumptions he is making in this regard.

9. I address later some of the difficulties this Type I, II, III taxonomy of information has for a correct analysis of the open-information growth problem. It is considerably more complex than Professor Wagner's model, even correctly implemented, can account for.

Professor Wagner now considers three scenarios: Scenario 1 is the status quo, where he takes c_I to be 10% and c_{II} to be 40%. Scenario 2 reduces rightsholder control, thereby opening up more of Type I and II information to free use, and takes c_I to be 40% and c_{II} to be 60% (which corresponds to a decrease by 1/3 in rightsholder appropriability from Scenario 1); and Scenario 3 gives perfect control over Type I and II information to the rightsholders, so that both c_I and c_{II} are zero. Apparently he also takes his change-in-incentives factor z to be 1 for Scenario 1 (the status quo), 2/3 for Scenario 2 (reduction of incentives by 1/3) and 4/3 for Scenario 3 (increase of incentives by 1/3).[10] He then seeks to compare the increase in the amount of open information created during the given time frame, assuming that $i_I = i_{II} = i_{III} = 1$.[11]

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10. Professor Wagner is not entirely clear about what he means by an increase in incentives (via increased creator control over the product). Because he sees an increase or decrease by 1/3 in the total information output, I, when control is increased or decreased, it appears that his definition of incentives is based on the results of whatever change in control he hypothesizes. That is to say, if we make a change in control that has the result that i_I output increases by 1/3, we by definition have increased incentives by 1/3. There is no obvious reason why the coefficients in his Equation (2), c_I and c_{II}, should change by the same percentage. Thus, if we increase c_I from 10% to 40% (corresponding to a 1/3 reduction in rightsholder control from 90% to 60%) and increase c_{II} from 40% to 60% (corresponding to a 1/3 reduction in rightsholder control from 60% to 40%), there is no obvious reason, and Professor Wagner supplies none, to believe that total *output* will increase by 1/3. This is a detail that would demand closer discussion if Professor Wagner's basic theory bore any reasonable relationship to the real world. Indeed, he emphasizes that a crucial implication of his theory is the need for a closer examination of the relationship between control and incentives. R. Polk Wagner, *supra* note 1, at 1023. This critique is aimed at his assumption of exponential growth based on the incentive factor z, and for this critique it matters little exactly what z is or how it is derived.

11. This is another assumption that would require much more careful analysis if the underlying theory otherwise had any validity. For present purposes, however, we may accept it, because it reflects only the initial conditions for the analysis. If information really did grow like compound interest and we agree, with Professor Wagner, to look only to the long term, the initial conditions will make little difference (because we can *define* "long" to be a period of sufficient length that the initial conditions are largely irrelevant. This is always possible with exponential growth. See *infra* note 17 and accompanying text.

Applying Equation (2), the increase in the amount of open information that results during time period 1 for each of the three scenarios is $O_{11} = 1[0.1 + 0.4 + 1] = 1.5$ for Scenario 1, $O_{12} = 2/3[0.4 + 0.6 + 1] = 2/3 \times 2 = 4/3 = 1.333$ for Scenario 2, and $O_{13} = 4/3[0.0 + 0.0 +1] = 1.333$ for Scenario 3.[12] How much open information is then produced in the second time period? By hypothesis, incentives for producers of works (by giving them the same, less, or more control over their creations) have not changed from the first time period. Under Scenario 3 (increased incentives) the change has resulted in higher productivity by existing creators or in inducing more people to become creators. The opposite has occurred under the reduced incentives of Scenario 2, and nothing has changed with respect to incentives for Scenario 1. Unless the total amount of open information itself somehow begets new information, perhaps by allowing the group of creators that now exists in response to the change in incentives to work more efficiently, we should get identical increases in open information in time frame 2 and, indeed, in all successive time frames. Equation (2) does not incorporate any term representing efficiency "feedback" to creators based on the total amount of open information that is available to them to work with that increases their productivity. Assuming for the moment, therefore, that there is no such feedback, it is easy to see that open information under Equation (2) grows faster under the status quo and

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12. For reasons that I do not understand, Professor Wagner seems not to apply his incentive factor z to this first iterative period, so the numbers he gets for the increase in the amount in his first period are 1.5, 2, and 1 for the three Scenarios, respectively. *Id*. at 1020-21. By hypothesis he has changed the incentives for Scenarios 2 and 3. He has stated that the change in incentives will be reflected in changes in the coefficients c_I and c_{II}, the amounts of i_I and i_{II}, respectively, that cannot be appropriated by the rightsholder. But he asserts that the total number of works produced will also change, which is why he introduces the factor z. Given that Scenarios 2 and 3 both reflect a change in incentives, it would seem that the total amount of open information produced during the first period should take into account the assumed change in the number of works produced during the period, which means multiplying by z. Fortunately, whatever choice is made on this issue does not affect any subsequent conclusions under either Professor Wagner's method of analysis or the one presented here (because his assumption of exponential growth swamps all these details).

equally slower in both the reduced and the increased incentives Scenarios (increasing by 1.5 in each time period for Scenario 1 compared to 1.333 in the others).[13]

13. I will return to this question of whether information begets information after laying out the analysis the Professor Wagner makes of the problem. See *infra* paragraph accompanying note ? and following paragraph.

Professor Wagner, however, does not calculate the growth in open information in this way, notwithstanding that this is the logical implication of the equations he presents. Rather, and without informing the reader that he is doing so, he drops Equation (2) entirely and uses a completely different formula, not presented in his paper, that results in the following table for the growth of open information over the first five iterative time frames:[14]

	p1	p2	p3	p4	p5
Status Quo (scenario 1)	1.5	3.0	6.0	12.0	24.0
Less Control (scenario 2)	2	3.3	5.6	9.3	15.4
More Control (scenario 3)	1	2.3	5.4	12.7	29.6

Professor Wagner's results for the end of period p1, under the assumption that the amounts of the three different types of information are equal (to unity, for simplicity), follow directly from Equation (1) and the values of the c_I and c_{II} coefficients that have been assumed for each of the three scenarios.[15] However, the remaining entries in the table are calculated from the following formula:

$$O_n = O_{n-1} + zO_{n-1} = O_{n-1}(1+z) \quad (3)$$

14. R. Polk Wagner, *supra* note 1, at 1018.

15. His numbers for the end of period 1 should be 1.5, 1.333, and 1.333, for the three Scenarios, respectively. For some reason, Professor Wagner does not apply his incentives factor z, shown in Equation (2), to this first iteration period. See *supra* note 12.

where O_n is the total amount of open information at the end of period n.[16] Thus, instead of calculating the amount of open information produced during a given period and adding that to the total of the prior periods, he assumes that an amount equal the total amount existing at end of the prior period, O_{n-1}, multiplied by the incentives factor z, is produced *in the next single period*. This amount is then added to the total existing at the end of the prior period to get the new total. This is information begetting information with a vengeance that would drown all of us in information if it were a correct model of the real world. It is worth noting that, under this model, even without any change in incentives, the amount of open information *doubles* in every time frame – and Professor Wagner has not even specified how long the time frame is!

Another way to look at Equation (3) is to relate the total amount of open information at the end of period n to the amount existing at the end of the first period:

$$O_n = O_{n-1} + zO_{n-1} = O_{n-1}(1+z) = O_{n-2}(1+z)^2 = \ .\ .\ .\ . = O_1(1+z)^{n-1} \quad (4)$$

Inserting the values of z for Professor Wagner's three Scenarios, we see that

(a) $O_n = 2^{n-1}O_1$ (Scenario 1, status quo)

(b) $O_n = (5/3)^{n-1}O_1$ (Scenario 2, reduced control) (5)

(c) $O_n = (7/3)^{n-1}O_1$ (Scenario 3, increased control)

16. In a private communication Professor Wagner has confirmed to me that this is the formula he used to create his table as well as the graphs shown in his article.

Thus, the amount of open information at the end of period 5 under Scenario 1 is $2^4(1.5) = 24$; under Scenario 2 it is $(5/3)^4(2) = 7.72(2) = 15.44$; and under Scenario 3 it is $(7/3)^4(1) = 29.64$. These numbers exactly match those shown in Professor Wagner's table. Although the value of O_1 differs for each scenario, that initial value becomes irrelevant with a sufficient number of time periods, because it is swamped by the exponential growth that this model attributes to the increased incentives. As a matter of pure mathematics, there will invariably be a period, call it N, beyond which it is always true that Scenario 3 outperforms Scenario 1, which in turn outperforms Scenario 2, whenever $n > N$, regardless of the values of O_1,[17] and the differences keep getting larger. It is, however, far from obvious how the amount of open public information can be said to be an exponentially growing factor multiplied by the amount of open information generated during the first period after a change in incentives.[18]

Equation (4), which is the equation actually used by Professor Wagner to calculate the growth of open information, is precisely the formula for compound interest:

$$FV = PV(1+r)^n \quad (6)$$

17. That is, there exists a number N such that $(7/3)^{n-1}O_1 > 2^{n-1}O_1 > (5/3)^{n-1}O_1$ whenever $n > N$, regardless of any variance in O_1 from one Scenario to another.

18. The factors 2, 5/3, and 7/3 for Scenarios 1, 2, and 3, respectively, result from Professor Wagner's assumption that open information grows by his incentive factor z multiplied by the total amount of open information existing at the end of the previous period. When the two are added to get a new total, the factor becomes (z+1).

where FV is the future value, PV is the present value, r is the interest rate, and n is the number of compounding periods.[19] The future amount (value), $O_{n,}$ of open information at the end of period n is equal to the amount (value) present at the beginning, $O_{1,}$ times the nth power of 1 plus the growth rate. Because Professor Wagner does not even state in his article that his calculations are based on the compound interest formula, he makes no effort there to justify such use, let alone the 100% growth rate he assumes for the status quo. Mathematical modeling can be useful when the model approximates in some way how the real world operates. Without justification that the compound interest model does actually approximate in some plausible way the operation of the real world of information growth, Professor Wagner has shown no more than that he knows how to calculate compound interest and that, given enough time, a higher interest rate always wins over a lower rate regardless of the amount of initial principal.

Toward a Real-World Theory of Incentives

The exponential increases assumed by Professor Wagner and shown in his table and the accompanying graphs do not fit any theory of incentives for the production of creative works that comports with the reality of intellectual property law. They simply cannot be correct. Effectively, Professor Wagner has arranged his model so that the increased incentives operate on *works* rather than on *creators*, notwithstanding that his assumed changes in incentives come from giving *creators* more control over their intellectual property. He apparently assumes that increasing incentives in one period will not only increase the number of works created as a result of the new

19. *E.g.*, Charles J. Goetz, LAW AND ECONOMICS 159 (1984).

spur to authorship and invention that the incentives provide but that the now increased supply of information will itself be the generator of yet new information in the succeeding period. This information self-generation is essentially independent of what authors and inventors are doing, because, as the formulas show, the result after n periods depends solely on the initial amount of open information and the supposed incentive factor z.

Works do not create works, however. Authors and inventors create works. We vary the incentive structure to induce authors and inventors to change their behavior. If the changes succeed and authors and inventors do begin to create more works (and/or more people decide to become authors or inventors), further increases in creative production can only come from increasing the number[20] or the production efficiency of authors and inventors. The former might be accomplished by yet another increase in incentives, but absent such an increase or an increase in creator efficiency we should expect the supply of new works to increase and then level off at a now higher production rate for creative works – an arithmetic rather than a geometric increase.

20. For simplicity, in referring to increases in the "number of authors" I mean to include both increases in the total number of people producing works of authorship *and* any increase in the amount of time spent on producing works of authorship by people who were already working as authors.

This brings us to the question of whether the steadily growing amount of open information (under any of Professor Wagner's Scenarios) leads to the required increase in creator efficiency. We can imagine cases in which the existence of a pioneering advance in technology or art paves the way for a later author or inventor to develop the idea further and where, without the initial advance, the second creator would have been stymied. Professor Wagner discusses a number of areas in which a new work has stimulated a large response by people who came later (e.g., hybrid corn leading to other hybridization technologies, steam engines leading to other rotary motion machines, semiconductors leading to many advances in binary logic, a given television show developing an entire genre of shows[21]). Examples like this, however, do not show how much the *total* amount of open information has contributed to these pioneering advances or by how much these pioneering advances themselves actually increased the total beyond what would have occurred without them. After all, many of the people taking part in the follow-on creations may well have been creating something else absent the pioneering advance on which they actually did base their work. Moreover, the pioneering advances, measured solely as a quantum of information, constitute a very small portion of the total. That a pioneering advance can lead to exponential growth in *that* field, at least for a time, in no way shows that *all* open information leads to such exponential growth. In fact, we would expect that most information will lead to little further growth at all. How many patents actually lead to commercially exploited products, for example, and how many of those that are exploited are pioneer in the sense of the transistor?[22] How many

21. R. Polk Wagner, *supra* note 1, at 1007.

22. For some extremes in the patent area, see Ted Van Cleave, *Totally Absurd Inventions - America's Goofiest Patents* (2001); Kenji Kawakami, *101 Unuseless Japanese Inventions* (1995)(describing inventions that are almost useless in a campy way that gives them an honored status).

films, novels, and paintings are produced that are seen, read, or admired at all, let alone serve as inspiration for exponential growth?

One can also posit examples in which the total amount of existing information has a *negative* effect on subsequent creator incentives, such as where a given field or genre becomes so crowded that later creators feel they have little to add and would not do well against so much competition. In short, while the amount of open information available to current creators on which to build new works probably does have some effect on creation incentives, we need a much more complete theory of the connection between open information and creator productivity. Professor Wagner, at any rate, has provided no basis for his implicit assumption that the total amount of open information grows exponentially by a power of one plus his incentive-change factor, in other words, like compound interest at a 100% interest rate.[23]

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23. Ray Kurzweil has developed a "law of accelerating returns," which argues that both biological and technological processes involve positive feedback mechanisms that lead to exponential growth. Ray Kurzweil, *supra* note 5. He concedes a law of diminishing returns for any given technology, but observes that, at least up to the present, a new technology has always come along to keep things growing. Thus, vacuum tubes give rise to a burst of technology that continues to grow at increasing rates until displaced by the transistor and then with the integrated circuit, the computer, and finally computers designing computers. Isaac Asimov has also reviewed the growth of knowledge generally (not just technological knowledge). Isaac Asimov, CHRONOLOGY OF SCIENCE AND DISCOVERY (1989). Asimov makes no claim concerning the growth rate, but it is apparent that 2 million years passed between human bipedalism and the use of stone tools, another 1.5 million years to the harnessing of fire, 300,000 years to the advent of religion, and 180,000 years more to the development of human art, the bow and arrow, and oil lamps. Then, starting about 8,000 B.C.E. things start to speed up, with new major developments every 1,000 years or so, then every few hundred, then roughly every decade until the Renaissance, then every few years, and so on until modern times when there are often ten to twenty major developments in a single year. Obviously, Asimov sees scientific knowledge as having grown exponentially, essentially from the beginning. Neither Kurzweil nor Asimov, however, makes any attempt to relate the growth they observe to the incentives of intellectual property law. Indeed, Kurzweil's theory applies even to evolutionary biological processes, and not even the proponents of intelligent design have tried to make the case that intellectual property laws might somehow affect the intelligent designer's incentives. Moreover, both Kurzweil and Asimov see the exponential growth of major developments in human knowledge as having continued for millennia, during most of which society did not even have any intellectual property protection for creative individuals. For Kurzweil, it is apparent that it is always a key pioneering discovery that keeps the process going. While it is possible

that these key discoveries would have come faster had intellectual property protections been stronger, we need some theoretical or empirical framework before we go about increasing rightsholder control under intellectual property law, because we can lose as well as gain when we strengthen such rights. Moreover, Kurzweil's theory applies only to the fruits of technology. He supplies no basis for saying that copyright subject matter, such as literature, art, and music, grows in the same way. Even the most casual observation would suggest that they do not. While the novel was at one time a new form of literature, and cubism a new form of art, that inspired numerous later creators, I have seen no evidence that growth inspired by the novel or any given painting school, is exponential.

We also know from nearly every sphere of activity that there is a law of diminishing returns. Professor Wagner's theory starts where it should, by concentrating on creators. Giving creators more control, he posits, would likely spur them into more creative activity (and bring others not currently working as authors or inventors to try their hands). That is a plausible assumption and one around which we can understand trying to build a general theory of information creation. Such a theory will depend on the relationship between creator control and incentives on increased output, and Professor Wagner understands this fully.[24] The question is how more control to creators over their creations can continue to spur production at an exponentially increasing rate. Indeed, nearly all of human experience suggests precisely the opposite, namely, diminishing returns: Once the supply of open information gets very large, further increases can contribute very little to the production of new information. In particular, any theory of creativity that depends on the total volume of open information available to creators to build on must recognize that efficiency cannot exceed 100%. Once that level is reached, the existing group of authors and inventors simply cannot produce any more than they do already, regardless of how much more new information we give them to work with, so all growth would have to come from increasing the number of working authors and inventors. Yet, without additional rounds of increased incentives, what reason is there to expect that more people will try their hand at the creative arts?

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24. *Id*. at 1023 ("The analysis suggests that the production of open information is determined by the details of the control-incentives relationship. . . . [T]he impact of intellectual property policy proposals are best evaluated according to their effects on *incentives*, rather than on their perceived effects on the public domain or open information"(emphasis in original)).

Professor Wagner might argue that the increased supply of new information will induce others to join, because it is now easier for them to be authors and inventors than it was before. But this, too, must sooner or later reach some limit. Some people in society could not be creators of economically useful information (the main type with which our intellectual property laws are concerned) regardless of how big an information base society gives them. There are also significant limits on the demand side, as there is only so much time that readers can devote to books or drivers can devote to operating autos with lots of nifty new patented bells and whistles.

Therefore, even granting the possibility that the existence of a larger supply of open information *might* add something to overall efficiency to increase productivity, no theory can be correct that does not predict some diminishing returns effect. Moreover, there is utterly no reason to think that an increase in creator control would have any effect on the efficiency with which creators can make use of the available open information. How creative persons discover, extract, and use open information in producing new works is a fascinating question but one about which we know very little. Giving a creator more control of her work product, by hypothesis, will induce her to work harder (or to switch into the creativity business), but how does that help her make use of the existing base of open information? Moreover, even under Professor Wagner's theory, the status quo results in the production of 1.5 units of open information in his first iteration period, while the increased control scenario gives only 1.33.[25] Consequently, to the extent the *amount* of open information does make creators more efficient, we should still do better under the status quo

25. In fact, Professor Wagner concludes that the more-control Scenario 3 results in only 1 unit in the first period. See *supra* note 12. That, too, we place by the way.

than we do under Professor Wagner's increased-control scenario.

What is the correct way to determine the growth of open information? Staying as close as possible to Professor Wagner's notation, let us return to Equation (1):

$$O = c_I i_I + c_{II} i_{II} + i_{III} \qquad (1)$$

First, this equation seems to miss an important contributor to the public domain (and therefore to open information), namely, those works whose copyrights expire in the given period. Because we are interested in the effect of changes in incentives for the creation of works, however, we can perhaps treat this factor as a constant for periods of equal length, because the number of works falling into the public domain, in the short-term at least, is determined by the number of works that were created at various times in the past, before the new incentives went into effect. Of course, if incentives do increase the number of works created and we wait long enough, those works will enter the public domain and the "constant" in the equation representing their contribution will begin to increase. In the short term, however, the differences in contributions to open information from the number of works entering the public domain due to copyright expiration will not be significant from one period to the next. Patent, of course, expire much faster and presumably should be accounted for somehow. Doing so, however, would require our specifying the time period in question more precisely, so that we know how to bring in the 20-year patent term.

The bigger problem with the model underlying Professor Wagner's Equation (1)[26] is that *all*

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26. The model underlying Equations (1) and (2) is *not* the compound interest model that Professor Wagner uses to do his calculations. See *supra* text accompanying note 14.

of the five variables in Equation (1) are themselves dependent on the incentives factor z. They are also dependent on each other, resulting in very complex and nonlinear mathematical analysis. Under Professor Wagner's analysis, for example increasing incentives by giving stronger controls to the copyright (or patent) owner reduces the constants c_I and c_{II} in Equation (1). However, by hypothesis, increased incentives will also increase the supply of Type I information i_I and that, under Professor Wagner's theory, automatically increases the indirect Type III information i_{III} that is generated by the Type I information. If the decrease in c_I is counterbalanced by an increase in i_I, that together with the increase in i_{III} would imply an increase in the amount of open information. (In Professor Wagner's perfect control Scenario 3, c_I is zero, so all of the increase has to come from i_{III}.) However, increased control should also reduce c_{II} and that may not be offset by an increase in i_{II}. That is, increased control by the rightsholder leaves less of her work free for building new works by others, which in turn can reduce i_{II}, the new derivative works based directly on i_I. This reduction in i_{II} can directly reduce i_I as well, because, as Professor Wagner realizes,[27] many new works that are derivative from Type I information will themselves be eligible for intellectual property protection.[28]

The result under a correct application of Professor Wagner's model, therefore, is a bit messy, to say the least. It is insufficient simply to multiply Equation (1) by a factor z representing a change in incentives and start calculating, even if one calculates correctly (that is, additively) from then on. All five variables in Equation (1), namely, i_I, i_{II}, i_{III}, c_I, and c_{II}, are themselves

27. *Id*. at 1018 n.97.

28. See *supra* note 8 and accompanying text.

functions of z that do not move in the same direction when z (i.e., incentives or control) is changed. This is a problem that is likely to bedevil any mathematical model of human behavior. If we knew even the general shape of these functional dependencies, we could perhaps draw some general conclusions, but we do not. One thing seems clear, however: Whatever the character of these variables, one cannot calculate growth or diminution of the amount of open information by simply iteratively multiplying a constant factor, however that factor is derived, over and over again.

A simple example might help make bring the difficulties into the open. Consider the recent extension of the copyright term in the United States, from life + 50 years to life + 70 years, effective retroactively to cover works published after 1923.[29] While it is doubtful that this term extension had *any* effect on creation incentives in the real world, there is a theoretical possibility that incentives did increase slightly.[30] Under Professor Wagner's analysis, that is enough to make it a positive contributor, in the long run, to the amount of open information available to our society. But consider what the term extension actually brings about: By hypothesis we will assume that it results in some (small) increase in new works due to the now higher incentive to create new works. That should increase i_I slightly, and under Professor Wagner's theory it should also increase i_{III}

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29. Sonny Bono Copyright Term Extension Act, P.L. 105-298, tit. I, 105th Cong., 2nd Sess. (1998). For works published after 1922 and before 1964, the term was extended only if copyright in the work had been validly renewed in the 28th year after publication.

30. *See* Luck's Music Library v. Gonzales, No. 04-5240 (D.D.C. 5-24-05)(stating that knowledge that Congress may pass laws in the future strengthening copyright rights affects the returns from investing time and effort in producing works).

because some i_{III} always develops from i_I. However, for 20 years (from 1998) there will be effectively *no* increases in the public domain due to expiration of copyright on previously protected works. That means that works that otherwise would have been available to current authors as a basis for creating new works (more i_I) remain subject to authorial control, and the transaction costs associated with licensing those still-protected works will reduce the number of new works of this type that are created, in comparison to what would have been created without the term extension. This has to count as a reduction in i_I (to the extent of new material) and i_{III} (to the extent the information contained in the still-protected work fails to get further disseminated and discussed). When one thinks of the number of high schools or local drama groups that would like to perform *Showboat*, a single 1923 work that was "saved" from the public domain by the Sonny Bono Act, it is difficult to imagine that the purely theoretical increase in incentives from the Act can overcome with new i_I the i_I and i_{III} losses that continued protection engenders.[31]

31. In a private communication, Professor Wagner agrees that I apply his theory correctly here, IF the term extension does increase both control and incentives. He thinks it possible that the term extension does increase control but unlikely that it increases incentives. If the incentive effect is indeed very small, he believes, the retroactive term extension effected by the Sonny Bono Act was a major policy error, because it will take too long for the small incentive effect to overtake the huge immediate loss from the extended term for existing works. Email from R. Polk Wagner to Dennis Karjala, August 11, 2005. His mathematics purport to show, however, that eventually even this most disastrous of recent copyright legislation will work out for the best, if we just wait long enough (assuming the extension does increase creation incentives by some nonzero amount). That should have been an indication that something was awry in the theory.

This discussion helps focus on another problem with Professor Wagner's analysis. He attempts to look at increases in open information, which is information that is not subject to a copyright owner's control. He does this, admittedly, not because increasing open information is *his* goal but because that is the goal he attributes to public domain advocates.[32] The overall social goal, however, is not simply to get works into the public domain for the sake of the public domain. The public domain has real economic value to the public in that works no longer subject to copyright are generally more broadly available and for a lower price. If this were all there were to it, "the larger the better" might be the watchword. But the public domain also is the source of many new works – in copyright terms, derivative works – that themselves are protected by intellectual property law. The creation of these new works does not immediately increase the size of the public domain, but that does not mean they are without interest for those who seek to build and maintain a vibrant public domain. A film based on a public domain story, such as many films from the Disney company, contributes nothing directly to the public domain, but no public domain advocate of whom I am aware questions the potential value of such works to the growth and development of our culture. The goal, then, is the creation of *works* that are desired by society, not just the total amount of freely available information. The question is how to optimize the underlying factors that affect achievement of this goal, given that many of them pull in different directions. If there were no need for creation incentives – that is, if authors and inventors would do

32. R. Polk Wagner, *supra* note 1, at 997 & n.8. He goes on to say that the best way to determine the impact of a proposed change in intellectual property rules is to consider the change's effect on incentives. *Id*. at 1023. I do not disagree with any of this. The problem is not with his assumption of a positive relationship between control and incentives, which he agrees requires examination. *Id*. The problem is that even if you *do* get the incentives right for the production of i_I, his mathematical analysis does not throw any light onto the growth of the public domain or indeed even onto the growth of i_I, because it does not account for the loss of derivative works *not* created due to the increase in primary incentives for i_I.

their work regardless of the exclusive rights of copyright and patent – we would indeed be better off without either regime of intellectual property protection. But we know that, without some degree of protection, we will get fewer works, as authors and inventors turn to more (economically) rewarding tasks. Once some works have been made available, others will try to use and improve upon them. That activity, too, leads to new and desirable works. Too much protection increases creation incentives but not enough to counterbalance the loss of even newer works that, but for the increased protection, would have been based upon earlier works. This has long been the basic intellectual property problem. Unfortunately, it is not amenable to analysis with the precision of mathematics.