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Cross-pollination dynamics of web-based social media: An application of insect-mediated pollen transfer

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Abstract

We propose a model of cross-pollination among online social media (OSM) websites, where the dynamics of user interactions mimic insect-mediated pollen transfer by pollinators (Di Pasquale and Jacobi, 1997). In our model, a pollinator acts as a vehicle enabling users to visit multiple social media sites—akin to visiting different plants in the same field—within a single browsing session. This approach frames geitonogamy and pollen export in self-incompatible plant species as analogous to the distribution of web traffic across the social media landscape. We demonstrate that a theoretical pollinator allowing users to choose among social media sites multiple times per trip can drive an uneven increase in web traffic across platforms, disproportionately benefiting the largest social networks while still providing tangible competitive advantages for smaller OSMs. This heterogeneous landscape fosters monopolistic competition among niche platforms, incentivizing even smaller sites to promote cross-pollination despite the larger relative gains to their bigger competitors. Our findings underscore the broader value of cross-platform user engagement, highlighting how cross-pollination dynamics can intensify network effects and bolster the interconnected social media ecosystem. As cross pollination via new pass-through apps gain traction and web traffic to social media platforms increases proportionately, the platforms will likely have no choice but to embrace the cross-pollination dynamics.

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November 2024

Introduction

The internet—and, more recently, social media—has reshaped society in profound ways. Today, nearly every action we take and good we consume is directly or indirectly affected by the vast, interconnected web of information available online, enabled by seamless smartphone access and rapid social media dissemination. As the ocean of content continues to expand and becomes increasingly accessible, the depth of interconnections between users and content also grows.

In 2024, 66.2 percent of the global population accessed the internet, and 62.3 percent held social media identities, leaving a penetration gap of just 3.9 percentage points—a sharp increase from 30 percent internet and 22 percent social media penetration, with an 8 percent penetration gap, in 2012. Figure 1 illustrates that the penetration gap between internet and social media usage, which remained steady between 2012 and 2014, later widened to peak at 15 points in 2018 before gradually narrowing to current levels.

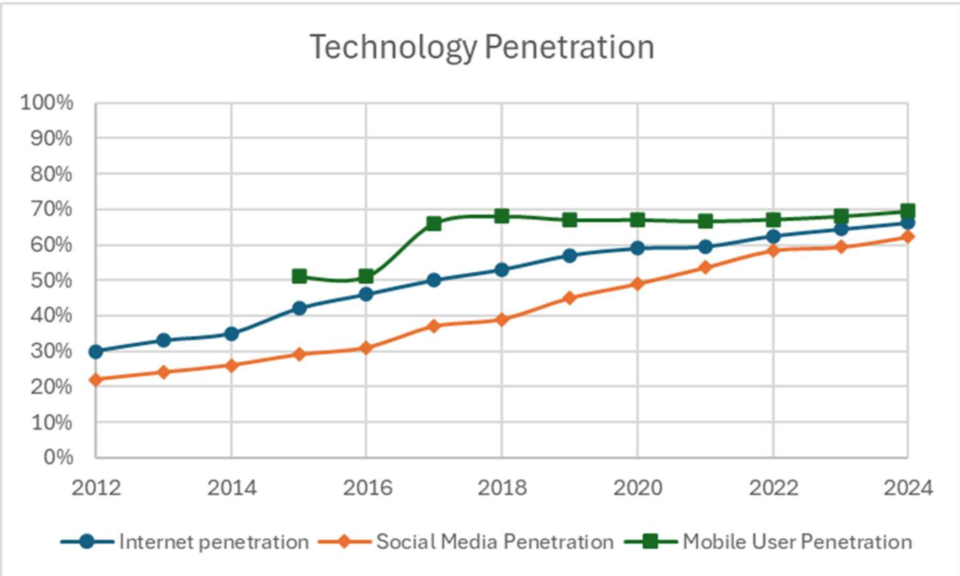

Figure1[1]

Since 2015, average daily internet usage has risen from 4.40 hours (Kemp, 2015) to 6.40 hours in 2024 (Kemp, 2024). Conversely, social media usage has slightly decreased, from 2.40 hours in 2015 to 2.23 hours in 2024, with national variations ranging from 0.7

[1] See Kemp (2024, 2023, 2022, 2021, 2020, 2019, 2018, 2017, 2016, 2015, 2014, 2013, 2012).

hours in Japan to 4.3 hours in Argentina in 2015, and from 0.53 hours in Japan to 3.43 hours in Kenya in 2024. This shift may reflect the growing popularity of other content forms, such as video streaming (3.06 hours), music streaming (1.25 hours), and podcasts (0.49 hours) in 2024.

Social media is distinct from other forms of media: it functions as a two-sided platform that hosts user-generated content, disseminated algorithmically and enhanced through user interactions. This definition excludes streaming services, which lack a social component; discussion forums, which lack the media component; and email, lacking the platform component (Aridor et al., 2024).

As internet and social media penetration rates converge, anecdotal evidence suggests a similar convergence between social media and other previously distinct online services. For example, playlists from audio streaming services are regularly shared on social media; online discussions flourish on video streaming platforms; hot links populate discussion forums; and email identities often serve as public online profiles. As interconnectivity grows, boundaries blur between social media and other online media services.

Cross-pollination among social media platforms is already happening organically via app such as LinkTree, Link.Me and &Share. We suggest that the expanding diversity of online content, paired with a stable user distribution, will continue driving the convergence between internet and social media penetration via increasingly pronounced cross-pollination.

We propose a model of cross-pollination among online social media (OSM) platforms, drawing an analogy to insect-mediated pollen transfer. Following the theoretical pollination model of Di Pasquale and Jacobi (1997), we conceptualize users as bees that "pollinate" the digital ecosystem by visiting multiple social media sites within a single browsing session, or "trip." In this analogy, bees' geitonogamy and pollen export within self-incompatible plant species mirror the distribution of web traffic across the social media landscape. Here, individual webpages within OSMs represent the "pollen" that attracts users.

Our model illustrates, across both deterministic and stochastic scenarios, that a "pollinator" application—allowing users to select and navigate between multiple social media sites per trip—can drive increased web traffic across all platforms, with the largest social media networks capturing the majority of this growth. However, despite the larger sites' advantage, user heterogeneity also fosters monopolistic competition among smaller social media networks, motivating even the smallest platforms to support cross-pollination despite the comparatively greater benefit to larger competitors.

Drawing insights from nature to better understand complex societal relationships is a well-established approach. For example, in the information technology field, matching algorithms inspired by natural behaviors include those based on krill movement (Gandomi and Alavi, 2012), cuckoo breeding behavior (Nguyen et al., 2015), firefly attraction (dos Santos Coelho et al., 2013), and flower pollination (Yang, 2012). In economics, such applications are common (see Bourgeois-Gironde et al., 2021; Dener et al., 2016; Addessi et al., 2019; de Waal, 2021), especially in neuroeconomics, where researchers integrate psychology and economic methodologies with neuroscience to investigate animal decision-making processes (Hayden et al., 2010; Calvert et al., 2011; de Visser et al., 2011). Similarly, researchers like Barreto (2018, 2024) and Alm and Barreto (2024) have applied fluid dynamics principles from engineering to model dynamic economic systems.

The idea of social media cross-pollination first appeared in the literature with Jain et al. (2013), who found that the most significant benefit of cross-pollination is increased traffic and user engagement on the platform where the pollinator lands. However, to our knowledge, no previous studies have examined the systemic behavioral characteristics of insect-like cross-pollination as a metaphor for user interactions across social media sites.

The Model

There currently social media agglomeration applications that gathers all the social media handles of any person or organization in one place.[2] These pollinator app are the metaphorical bees, or pollinators. The internet user on the pollinator app is drawn to the OSM webpages—analogous to pollen. The systemic sequence of path-dependent landings on pages across the social media landscape by any user represents the trip that a bee takes, moving from flower to flower, plant to plant, and field to field in search of pollen.

Suppose an internet user finds themselves on a social media page of a popular figure or content creator. A click to the pollinator app begins the trip. The field is the choice of OSMs where the popular figure has a presence, and the species of flowers are the OSMs. The pollinator app transports the user from their initial landing to any one of the personality's other OSM pages. The user then engages with the OSM beyond the popular figure's presence there, possibly extending the trip to other fields by visiting different pages within the OSM, or returning to the pollinator app, extending the same trip by visiting another of the personality's OSM pages—a different flower within the same field. The sequence is described in figure 2.

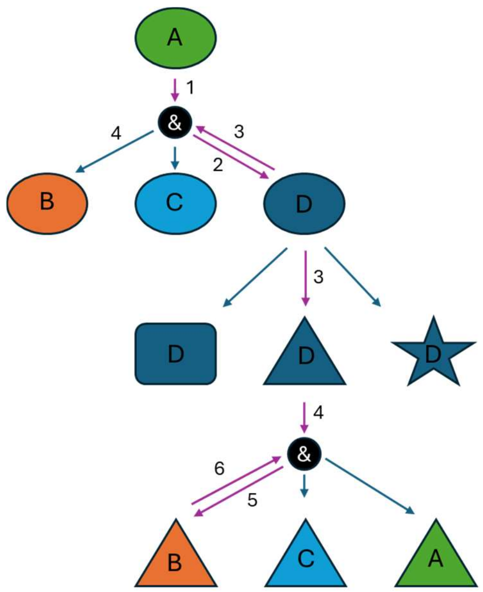

Figure 2

[2] Examples include Link.Tree, Link.Me and &Share. They range in motivations and target markets, but provide the same fundamental service of consolidating user handles into a single account or "stream" as in the case of &Share.

The algorithm in equation [1] defines all possible sequences of social media cross-pollination stemming from a user landing on the social media page of a personality and clicking the pollinator to investigate the personality's other OSM pages. We assume there are *N* OSMs, less than *M* number of personalities per OSM. T_n is the average time spent on OSM *n* and p_n is the probability of landing there.

$$\begin{aligned}\bar{T} &= \sum_{n}^{N-1} p_n T_n \sum_{m}^{M-1} p_{mn}(f_{mn}) + \alpha_1 \left\{ \sum_{n}^{N-1} p_{mn}(f_{mn}) T_n \sum_{m}^{M-1} p_{mn}(f_{mn}) \alpha_2 \left[\sum_{n}^{N-1} p_{mn}(f_{mn}) T_n \sum_{m}^{M-1} p_{mn}(f_{mn}) \alpha_3 (\ldots) \right] \right\} \\ &= \sum_{n}^{N-1} \sum_{m}^{M-1} p_{mn}(f_{mn}) p_n T_n + \sum_{x}^{\infty} \sum_{n}^{N-1} \sum_{m}^{M-1} \alpha_x \left(p_{mn}(f_{mn}) \right)^2 T_n\end{aligned} \quad [1]$$

Suppose a user lands on the social media page of a personality, Mr. Oval on OSM A. Via the pollinator, the user can choose to visit any of Mr. Oval's other landing pages on OSM B, C or D with probability p_n. Suppose the user visits Mr. Oval's page on OSM D. The user spends some time T_n engaging with OSM D. The user can either return to the pollinator or investigate the other personalities on OSM D with some probability p_{mn}. Suppose he visits the personality, Ms. Triangle on OSM D. The sequence now starts over again from the landing at the new Ms. Triangle's page on OSM D. With each successive repetition, we assume a diminishing probability of extending the trip another stage, such that $1 > \alpha_1 > \alpha_2 > \alpha_3 > \ldots$ and $\lim_{x \to \infty} \alpha_x = 0$.

The probability of choosing a different OSM page from the initial landing on one of Mr. Oval's social media pages is p_n. From there, the probability of visiting another personality, Ms. Triangle within OSM D is $p_{mn}(f_{mn})$, where f_{mn} is the vector of characteristics unique to the personality *m* on OSM *n*. Alternatively, the user can return to the pollinator with implicit probability, $p_0(f_0) = \left(1 - \sum_{n}^{N-1} \sum_{m}^{M-1} p_{mn}(f_{mn}) \right)$. The greater the scale and scope of personalities within the OSM, the lower the probability of returning immediately to the pollinator. With each interesting personality within the new OSM, the sequence begins again.

The marginal impact of the pollinator on time spent interacting with any given OSM is determined by the derivative of $\bar{T}$ with respect to T_i. Note that equation 2 is strictly positive.

$$\frac{\partial \overline{T}}{\partial T_i} = \sum_{m}^{M-1} p_i p_{mi}(f_{mi}) + \sum_{x}^{\infty}\sum_{m}^{M-1} \alpha_x \left(p_{mi}(f_{mi}) \right)^2 > 0 \qquad [2]$$

If we assume the trip ends after a visit to any of the personality's other OSM pages from the initial landing, we can discount the second term in equation 2 completely. Analytically, this is tantamount to $\alpha_1 = 0$ and the pollinator has no indirect impact on traffic or engagement in OSM. Nevertheless, even under such an extreme restriction, there is still a significant increase in traffic to all OSMs simply due to greater exposure.

The increase in direct traffic from the pollinator is a function of the ability of personalities on the OSM to capture and hold the attention of the user, $p_{mi}(f_{mi})$. In other words, the greater the depth and scope of a social media userbase, the greater the direct benefit from direct cross-pollination. The benefit to the largest OSM is further increased indirectly as the user interacts with other personalities, who attract online attention heterogeneously. The OSM with the greatest depth of personalities that commands the longest attention from its users per visit will reap greatest indirect benefits from the pollinator.

The pollinator's impact on the social media landscape creates a strictly positive-sum gain. While traffic rises across all platforms, the depth of personalities and their prominence on more heavily trafficked social media channels skew the distribution of these gains in favour of larger OSMs at the expense of smaller ones.

Suppose the initial landing page is on a relatively small OSM serving a niche audience. Once engaged with the pollinator, the user will likely navigate to one of the personality's other OSM pages. Statistically, the user will tend to land on the personality's page within the largest social media platform with the highest traffic.

Large OSM sites have a clear advantage in capturing users from the pollinator. Nevertheless, smaller sites have a strong incentive to participate in cross-pollination, even though it may benefit larger OSMs more, as their user base is often defined by a specific niche. For smaller OSMs, joining cross-pollination helps grow their niches by tapping into the vast number of users who pass through the pollinator. Ultimately, every small OSM is compelled to participate in cross-pollination because their direct competitors—other small OSMs—are doing so as well.

The baseline model describes the probabilistic effect of a user being confronted with a limited choice among OSMs. The choice is curated based on which OSMs the personality has a presence on. Analytically, all social media platforms with a presence on the pollinator benefit from increased traffic.

Imagine the personalities within the pollinator, in addition to links to their other OSM pages, also maintain a curated pool of content available to the user. The user is thus exposed to an expanded choice that includes the personality's OSM pages as well as a pool of curated hyperlinks to places across the social media landscape that the personality finds interesting. This is analogous to the user being allowed to sample the personality's own pollen sack. Figure 3 illustrates this additional choice to visit the personality's curated content pool across OSM pages.

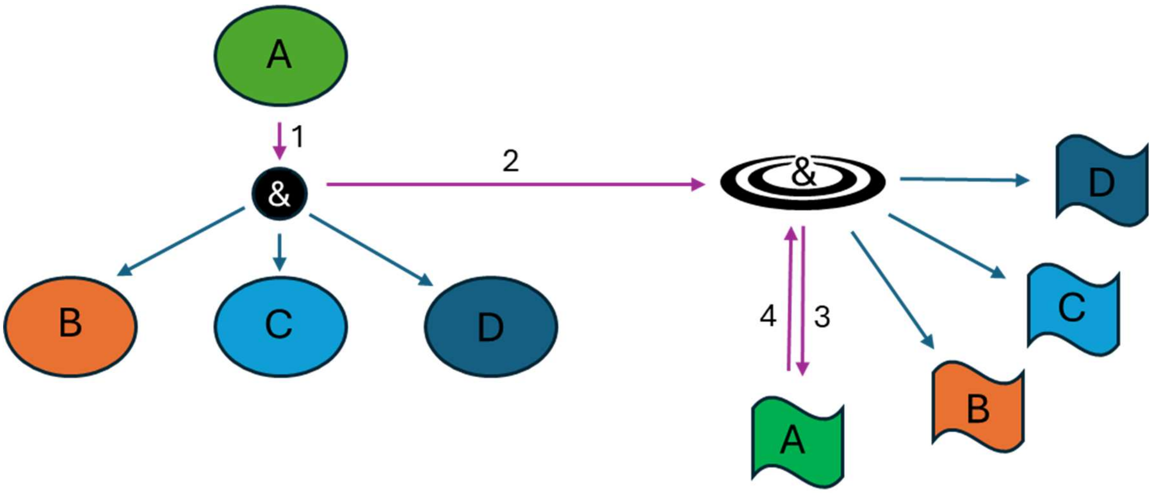

Figure 3

From the perspective of the OSMs, the extra pool option has no net impact on the views received. Remember, the probability of reaching any OSM is a function of that OSM's traffic. Therefore, the content pool of curated links by any given personality will mirror the traffic of the sites to which they lead. In aggregate, there is no change in the additional views to the OSM resulting from the inclusion of the extra option in personality content pools, as the probabilities within any given pool reflect the underlying probabilities among OSMs.

Discussion

Cross-pollination in OSMs is already occurring organically. As expected, the largest social media networks command the greatest traffic. While the average percentage of OSM account holders who use other social media platforms remains relatively stable, note that the percentage of random users on an OSM who also hold accounts on other OSMs is declining as the service's popularity grows. Figure 4 suggests structural differences between visitors to the four most popular OSMs and visitors to other platforms. Visitors to the less established OSMs are necessarily less likely to have accounts on the large OSMs. In other words, cross-pollination across the OSMs is occurring and appears positively correlated with OSM traffic.

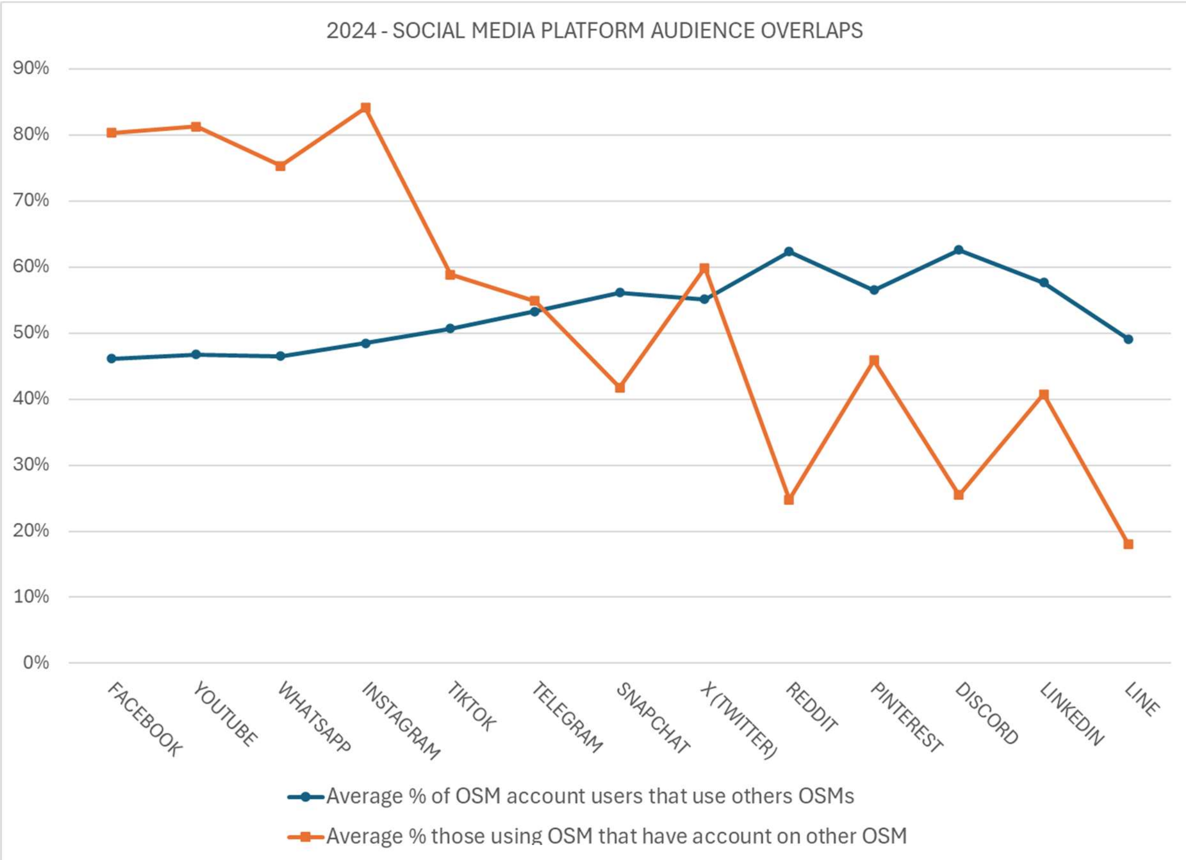

Figure 4

In addition to traffic volume, there is the time each user spends on social media. Extrapolating from global Android usage data between 01 July 2023 and 30 September 2023, we can estimate the daily time spent on each social media platform by a representative user. Comparing Figures 5 and 6 illustrates the difference between traffic volume and time spent on each platform. For example, TikTok has lower volume but higher engagement, while engagement on smaller platforms such as Snapchat and Pinterest appears to be less than their traffic volume would suggest. Taken together, smaller OSMs struggle to reach the mass audiences of larger OSMs as the user bases of those larger platforms become more homogeneous, gradually reducing their ability to attract users from either tail of the distribution.

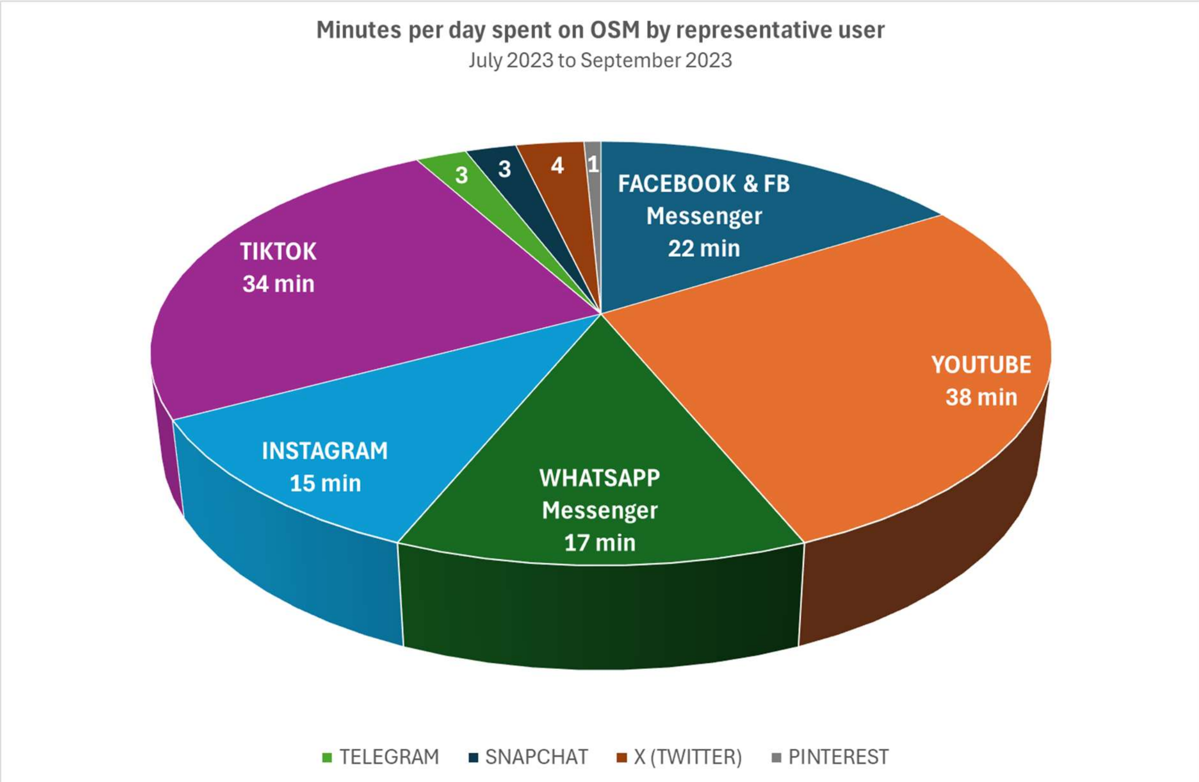

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Figure 5

Figure 6 illustrates the frequency with which users log on to OSMs during the same period covered by Figure 5. While users log on to WhatsApp almost 6 days a week, they spend only 17 minutes there. TikTok and YouTube show a similar pattern; their users log on at least 4 days a week and spend the most time on these platforms. Interestingly, Instagram has the same log-on frequency, over 4 days, but users spend less time on the platform.

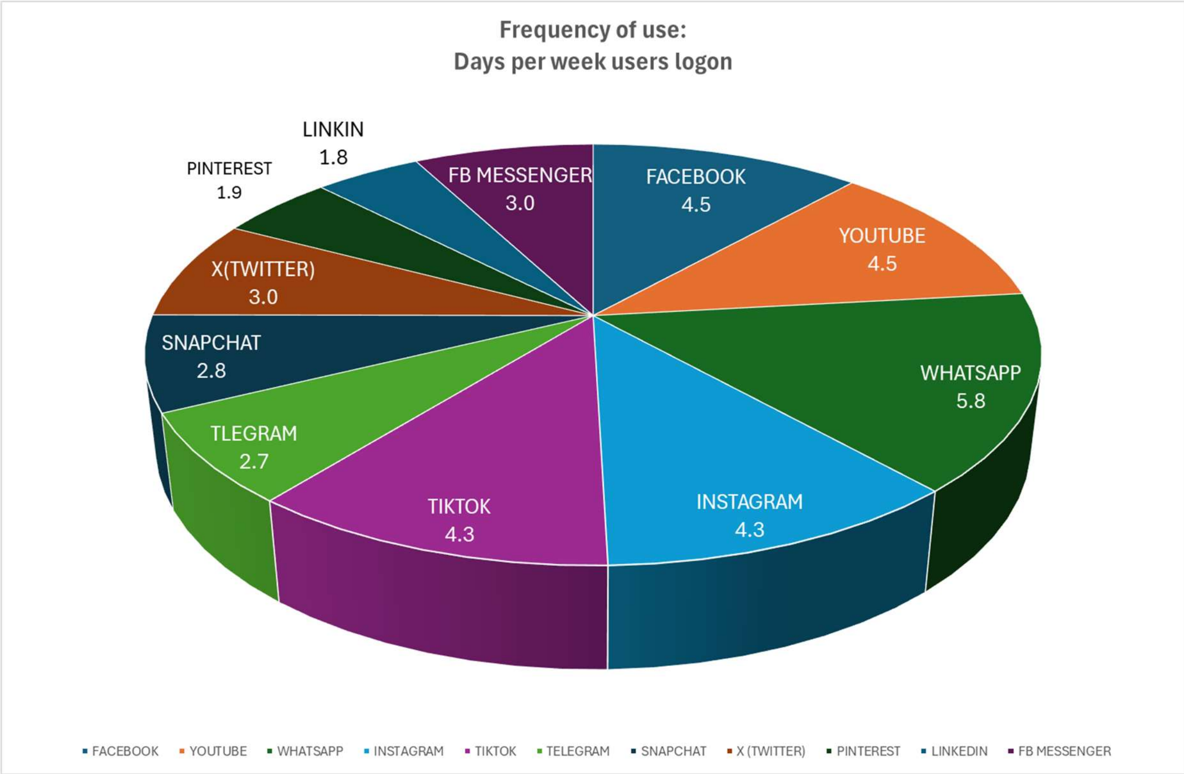

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Figure 6

Considering both the frequency and time spent on each platform, we can compare each platform's depth of engagement in Figure 7. To account for diminishing returns in attention spans, we consider the natural log of seconds per day on the OSM. Analytically, this approach implies that the greatest relative value of time is within the first minute of arriving on any given social media platform.

Our methodology necessarily weighs platforms like X (Twitter), Snapchat, Pinterest, and Telegram, which have less meaningful engagement but higher frequency, more heavily. We differentiate between traffic volume—the determinant of clicks-per-thousand-impressions (CPM) advertising revenue—and depth of engagement—the determinant of cost-per-click (CPC) advertising revenue.

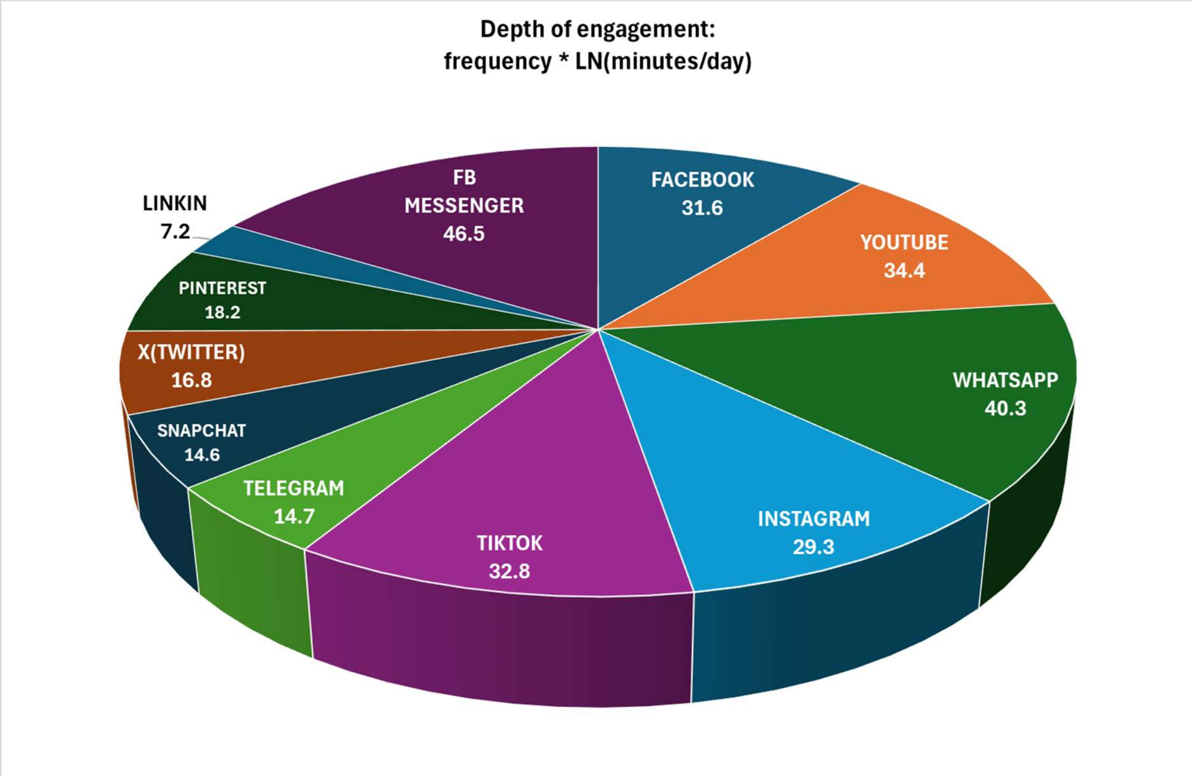

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Figure 7

The gross implication of cross-pollination among online social media platforms by a dedicated pollinator app is increased traffic, higher engagement, and additional advertising revenue from this increased activity. Table 1 provides advertising revenue indices to compare the revenue effects of cross-pollination of content across OSMs.

Online Social Media Implied Advertising Revenue: 1 July 2023 - 30 September 2023									
	TIME	LN(TIME)	%MT	FREQ	DEPTH	CWRI	MWRI	∆CWRI	∆MWRI
	Minutes spent per OSM per day	Natural Log of time in seconds spent per OSM per day	Percent of total Social Media time spent per OSM per day	Frequency of visits per week per OSM	Depth of engagement = Freq. x Ln(time)	CPC Weekly Index Revenue = $2 x %MT x DEPTH	CPM Weekly Index Revenue = $7 x FREQ x TIME / 100	CPC index revenue per pollination per OSM = %MT x CWRI	CPM index revenue per pollination per OSM = %MT x MWRI
FACEBOOK & FB Messenger	22.6	7.21	16.20%	4.5	32.37	$10.49	$7.11	$1.699	$1.152
YOUTUBE	37.3	7.71	26.67%	4.5	34.39	$18.34	$11.63	$4.893	$3.102
WHATSAPP	16.7	6.91	11.98%	5.8	40.25	$9.64	$6.82	$1.155	$0.817
INSTAGRAM	15.5	6.83	11.09%	4.3	29.47	$6.54	$4.68	$0.725	$0.518
TIKTOK	33.3	7.60	23.81%	4.3	32.82	$15.63	$10.06	$3.722	$2.395
TELEGRAM	3.7	5.39	2.63%	2.7	14.42	$0.76	$0.69	$0.020	$0.018
SNAPCHAT	3.5	5.34	2.49%	2.8	15.06	$0.75	$0.69	$0.019	$0.017
X (TWITTER)	4.6	5.61	3.27%	3.0	16.58	$1.08	$0.94	$0.035	$0.031
PINTEREST	1.8	4.67	1.27%	1.9	8.89	$0.23	$0.24	$0.003	$0.003
LINKEDIN	0.8	3.91	0.60%	1.8	6.90	$0.08	$0.10	$0.000	$0.001

Table 1

At any given time, the probability of engagement by the representative user with any respective OSM is determined by the percent of total social media time spent per OSM per day, denoted as %MT. Assume the OSM charges advertisers a $2 cost per click (CPC), with an expected click-through rate determined by the probability of landing, %MT, multiplied by the depth of engagement, DEPTH. The CPC weekly revenue index measures the traffic and engagement-weighted revenue per OSM from the representative user. Between July 1, 2023, and September 30, 2023, the representative user contributed to CPC index revenue as follows: $10.39 to Facebook, $18.34 to YouTube, $9.64 to WhatsApp, etc.

Further assume that each OSM charges advertisers a $7 cost per one thousand impressions (CPM). We calculate the CPM revenue index for the period as the frequency of visits per week multiplied by the time spent by the representative agent on the OSM. Note that OSMs with greater frequency but lower engagement are reflected in the indices. Between July 1, 2023, and September 30, 2023, the representative user contributed to CPM index revenue as follows: $7.11 to Facebook, $11.63 to YouTube, $6.82 to WhatsApp, etc.

Before the introduction of the pollinator app, assume the OSMs' index revenue stream is determined by CWRI and MWRI. Inclusion of the pollinator improves revenue by adding an extra visit from the original landing on the personality's page to another of the personality's pages on a different OSM. If we assume the probability of the second landing is equal to the percentage of social media time spent per OSM per day, %MT, then the additional revenue per level of cross-pollination is %MT multiplied by either index revenue.

Revenue from pollinator traffic to any OSM is strictly greater than or equal to the original revenue from the landing. Users landing on a personality's page will either search for another personality within the same OSM, allocating time based on the first element of Equation [1], or exit the OSM to the pollinator. Since initial user traffic is distributed across N OSMs while secondary pollinator traffic is distributed across N - 1 OSMs, the time added to the trip for every visit to the pollinator app, as defined by the second element of Equation [1], is strictly positive and reflects a continuous search theme.

There are two fundamental points that merit discussion regarding the nature of the increased traffic from the pollinator. The first issue is the quality of the traffic. Is the quality of traffic reaching the OSMs directly from the personality pools different from other types of traffic? The second issue pertains to the users, whom we have assumed to be homogeneous until now. What if we instead account for user heterogeneity?

The pollinator results in increased traffic across the social media landscape. It is important to note that traffic can enter the OSM from the pollinator via two distinct user preference structures.

If the user moves from the landing page of a personality on OSM A to another landing page of the same personality on OSM B, they will necessarily investigate the new landing page and possibly click on one of that personality's pieces of content. The user will have some level of engagement with the personality's content on OSM D.

If the user moves from the landing page of a personality on OSM A to the personality's pool of content in the pollinator, they are faced with a choice set of content rather than a choice set of OSMs. The pools contain the specific pieces of content that personalities want their users to see. Since the user is aware of the curated nature of the content, their engagement is necessarily influenced by the personality's revealed preference for their own content. The pools represent the most pollen-rich environments, offering direct access to the most engaging content from the personality that has captured the user's attention. As a result, the level of engagement with content selected via the personality's pool is likely to be greater than had the user encountered that same piece of content on the personality's landing page.

From the OSM's point of view, the greater engagement from users arriving from a personality's pool on the pollinator translates into more time on the OSM and increased exposure to advertisers.

Consider heterogeneity among users as an example. Suppose that content comes in two forms: long and short. Suppose type A users prefer short-form media, while type B users prefer long-form media. Assume that user types form their preferences through some mechanism of exposure bias. Type A users favor short-form media because they are accustomed to it. As such, there must exist a median media length that simultaneously maximizes engagement for users of both types. This is depicted in Figure 8.

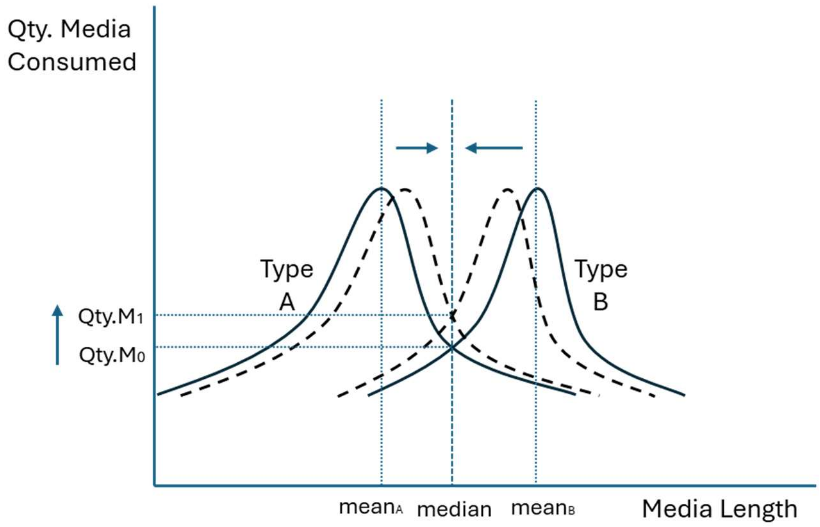

Figure 8

Suppose a type A user is drawn to the curated pool of a personality that produces both types of content. To some degree, type A's bias against long-form media must be tempered by their interest in personality A's content. As more type A users are exposed to long-form media and more type B users are exposed to short-form media, each from their respective preferred personalities, the two user types will naturally become more homogeneous. Greater homogeneity among users implies greater relative capture of the two groups' preference sets by the median media length. If we assume that the median media length reflects media consumption in the most trafficked OSMs, greater capture of user preferences will necessarily benefit the OSMs whose users most closely reflect the median.

Conclusion

The current web-based social media landscape can be described as fragmented, dominated by a few major platforms amidst a vast array of smaller, niche networks. When users land on a personality's page on any given platform, their engagement tends to be confined to that platform—whether they're exploring content by the initial personality or branching out to others within the same network. While users could theoretically jump between platforms in pursuit of more content, the lack of an immediate and cohesive way to maintain a unified search theme across platforms significantly limits overall traffic to each.

We interpret this search constraint as akin to the natural dynamics of insect-mediated pollen transfer. Just as bees move pollen across various species of plants, users seek out digital content across a dispersed media ecosystem. Each platform is a distinct plant species scattered across fields, with the content acting as the pollen that draws in users. Naturally, platforms with the richest and most diverse content capture the highest user traffic.

Cross-pollination across web-based social media platforms indisputably drives up traffic across the entire ecosystem. Like bees moving from flower to flower, users who can flow seamlessly between platforms increase the volume and diversity of content consumed, prolonging their engagement time.

In this context, we consider the impact of a social media aggregator apps such as Link.Tree, Link.Me and &Share that function as pollinators, seamlessly guiding users across pages and platforms in a single browsing session. We also consider "pools" of content: curated collections that showcase a personality's presence across platforms, serving as rich content nodes that encourage deeper, more prolonged engagement compared to standard user interactions.

A cross-platform pollinator app, allowing users to explore content across networks while maintaining their search continuity, would enhance traffic in proportion to each platform's existing user base. Large platforms would capture the largest share of this increase in traffic, engagement duration, and depth. However, due to the diversity of user interests, smaller platforms also benefit from cross-pollination and thus have strong incentives to participate, even as it primarily benefits their larger competitors.

This digital synergy, facilitated by a pollinator app capable of aggregating, pooling, and seamlessly distributing interconnected content across the social media ecosystem, represents an unequivocal positive-sum gain for online media. Platforms across the spectrum—from dominant networks to niche communities—stand to benefit from enhanced traffic, deeper engagement, and broader exposure. However, the impact of cross-pollination likely extends far beyond platform-specific metrics, raising compelling questions about broader societal implications.

Future research could explore the transformative potential of cross-pollination for content consumption, user engagement patterns, and information dissemination. As content pools and cross-pollination mechanisms become more sophisticated, they may reshape user experience, tailoring digital environments to individual interests and enhancing personalization in ways that could redefine online interactions. On a larger scale, this phenomenon might foster the development of novel incentive models, where value generation is not confined to individual platforms but distributed across the ecosystem, challenging traditional advertising and revenue strategies.

Moreover, cross-pollination raises important questions about information flow and content diversity, warranting further research on the effects of inter-platform engagement on user perspectives and community building. Studies could explore whether the ability to easily navigate across platforms promotes exposure to diverse viewpoints or reinforces existing echo chambers. Investigating these questions will be crucial for understanding the full societal implications of an interconnected social media ecosystem and the ethical responsibilities of platforms and developers in shaping such an environment.

We envision future studies examining the ways cross-pollination could be leveraged to support educational, civic, professional, medical, property, and legal initiatives, broadening the boundaries of social media's role in modern society. Whether fostering global discourse, advancing access to medical knowledge, streamlining property and real estate networks, facilitating legal information sharing, or creating unified digital communities, the potential applications of content pools and cross-platform dynamics are vast. These explorations will be key to realizing and responsibly managing the far-reaching impact of this emerging digital phenomenon.

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