Pricing European Call Option

A) Monte Carlo with 30 simulations

In [1]:
```
import pandas as pd
import numpy as np
from scipy.stats import norm
import matplotlib.pyplot as plt
%matplotlib inline
```

In [2]:
```
S0 = 70
K = 65
r=0.02
stdev = 0.3
T = 4 #time to maturity
trading_days = 250 #trading days in a year
daily_step = 1/trading_days
iterations_1 = 30 #_1 is 30 simulations
```

In [3]:
```
np.random.seed(503508) #set random seed
```

In [4]:
```
Z_1 = np.random.standard_normal(((T*trading_days)+1, iterations_1))
Z_1
```

Out[4]:
```
array([[-0.82487461, -0.97546241,  0.88384933, ..., -1.54104887,
         0.1070498 , -1.51797381],
       [-0.27858677,  0.87344842, -0.82073884, ...,  0.55624047,
         0.62003532, -0.42283128],
       [-0.79699613, -1.12370122, -1.40704728, ...,  1.81973281,
         1.15088852,  2.01290958],
       ...,
       [-0.25903026, -0.41459449,  0.25729711, ...,  1.03672024,
         2.18371996, -1.06387822],
       [-1.36538685, -0.4694137 , -0.43581642, ..., -0.46131539,
         0.19199881,  1.27630375],
       [-1.10629852,  1.54976265, -0.11050233, ..., -1.07661901,
        -0.86433654, -1.09168743]])
```

In [5]:
```
S_1 = np.zeros_like(Z_1)
S_1
```

Out[5]:
```
array([[0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       ...,
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.]])
```

In [6]:
```
Z_1.shape
```

Out[6]:
```
(1001, 30)
```

In [7]:
```
S_1.shape
```

Out[7]:
```
(1001, 30)
```

In [8]:
```
S_1[0] = S0
S_1
```

Out[8]:
```
array([[70., 70., 70., ..., 70., 70., 70.],
       [ 0.,  0.,  0., ...,  0.,  0.,  0.],
       [ 0.,  0.,  0., ...,  0.,  0.,  0.],
       ...,
       [ 0.,  0.,  0., ...,  0.,  0.,  0.],
       [ 0.,  0.,  0., ...,  0.,  0.,  0.],
       [ 0.,  0.,  0., ...,  0.,  0.,  0.]])
```

In [9]:
```
for t in range(1,(T*trading_days)+1): #simulating future prices
    S_1[t] = S_1[t-1] * np.exp(((r-(0.5*(stdev**2)))*daily_step) + (stdev*(daily_st
ep**0.5) *Z_1[t]))
```

In [10]:
```
S_1
```

Out[10]:
```
array([[70.        , 70.        , 70.        , ..., 70.        ,
        70.        , 70.        ],
       [69.62400656, 71.16262569, 68.91148241, ..., 70.73561278,
        70.82128457, 69.43371682],
       [68.57221965, 69.65448064, 67.08939423, ..., 73.21323169,
        72.37754935, 72.12962566],
       ...,
       [57.03182854, 78.58758546, 40.79701549, ..., 37.62162715,
        48.32143071, 32.4535967 ],
       [55.56775647, 77.88296432, 40.45700858, ..., 37.29003866,
        48.49293336, 33.24576652],
       [54.4080747 , 80.1990702 , 40.36823686, ..., 36.53237382,
        47.69938242, 32.56096322]])
```

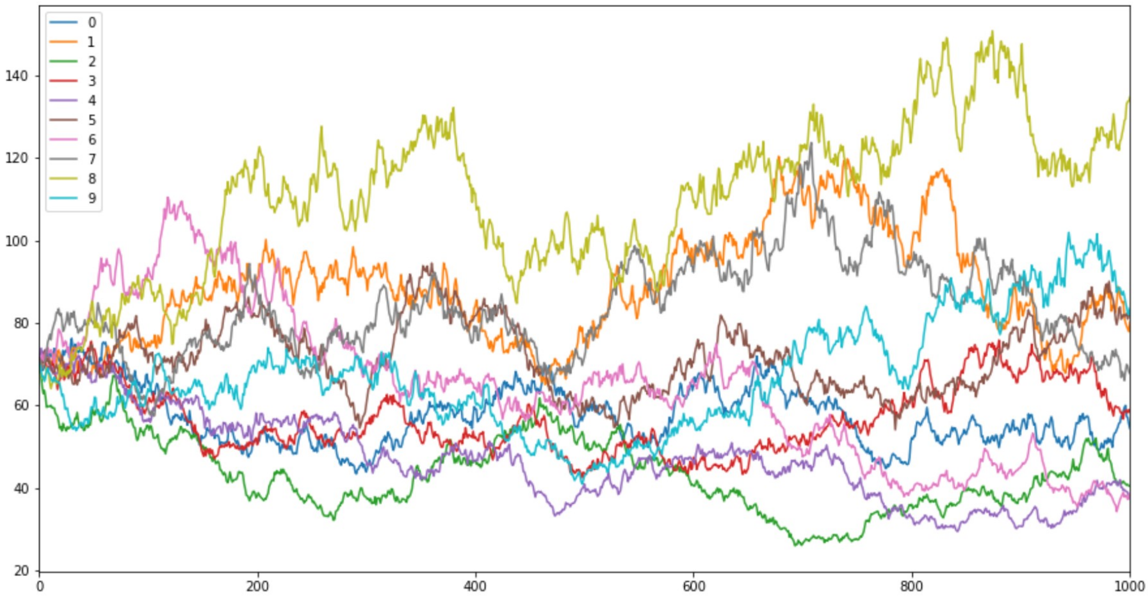
In [11]:
```
future_prices_1 = pd.DataFrame(S_1)
future_prices_1
```

Out[11]:

	0	1	2	3	4	5	6	7	8	
0	70.000000	70.000000	70.000000	70.000000	70.000000	70.000000	70.000000	70.000000	70.000000	70.0
1	69.624007	71.162626	68.911482	70.010619	72.228492	71.421453	70.629574	71.221696	68.027450	69.6
2	68.572220	69.654481	67.089394	70.380418	73.833332	70.160871	71.254261	70.149308	67.337503	68.0
3	68.449998	69.783536	64.372861	70.549411	72.109901	71.653696	72.403920	68.931644	66.610086	66.8
4	68.613365	71.927111	62.830191	70.671667	72.730591	70.427957	70.813807	69.424333	66.689579	66.9
...	...	...	...	...	...	...	...	...	...	
996	59.948406	80.004238	40.928580	58.573599	39.221619	81.945916	38.174345	68.190864	129.450569	85.0
997	57.318547	79.216144	40.602395	58.824701	39.021821	82.206815	38.012989	69.884721	133.022979	83.8
998	57.031829	78.587585	40.797015	58.231462	38.849546	80.923015	37.165321	69.518247	133.645358	82.3
999	55.567756	77.882964	40.457009	58.926796	37.953202	81.873944	37.477743	68.251430	133.713991	81.9
1000	54.408075	80.199070	40.368237	58.345003	37.410088	83.016364	38.649587	67.705492	134.736108	83.5

1001 rows × 30 columns

In [12]:
```
future_prices_1.iloc[:,0:10].plot(figsize=(15,8)) #plot first 10 price simulations
from 30
plt.show()
```



In [13]:
```
call_value_1 = np.maximum(S_1[-1]-K,0)
call_value_1 #value of call for each iteration from 30 simulations
```

Out[13]:
```
array([ 0.        , 15.1990702 ,  0.        ,  0.        ,  0.        ,
       18.01636411,  0.        ,  2.70549238, 69.73610822, 18.51992376,
        1.09670337,  0.        ,  0.        ,  0.        ,  0.        ,
        0.        ,  0.        ,  0.        , 37.35442318,  0.        ,
        0.        ,  6.5992744 ,  0.        ,  0.        , 93.66002073,
       31.4550396 , 53.6422879 ,  0.        ,  0.        ,  0.        ])
```

In [14]:
```
Call_price_1 = (np.exp(-r*T)*np.sum(call_value_1))/iterations_1
Call_price_1 #Price of European Call from 30 simulations
```

Out[14]:
```
10.70767907013127
```

B) Monte Carlo with 3,000 simulations

In [15]:
```
iterations_2 = 3000 #_2 is 3000 simulations
```

In [16]:
```
np.random.seed(503508) #set random seed
```

In [17]:
```
Z_2 = np.random.standard_normal(((T*trading_days)+1, iterations_2))
Z_2
```

Out[17]:
```
array([[-0.82487461, -0.97546241,  0.88384933, ...,  0.20848602,
         1.82073386, -0.57509071],
       [-1.67211351,  0.76456417, -0.13340726, ...,  1.05727897,
         1.00991974,  0.83407278],
       [-0.96408822,  0.37067098,  0.54517843, ..., -1.05824443,
        -2.52109409, -0.23393317],
       ...,
       [-0.30351753,  0.68843211, -0.9611949 , ...,  0.77714465,
         0.21330369,  0.92727011],
       [-0.671051  , -0.34568453,  0.16676245, ..., -0.29423899,
         0.50229526,  0.35769425],
       [-0.89823555, -0.03939239, -1.81099659, ...,  0.18735359,
         1.22945365,  1.68612629]])
```

In [18]:
```
S_2 = np.zeros_like(Z_2)
S_2[0] = S0
```

In [19]:
```python
for t in range(1,(T*trading_days)+1):
    S_2[t] = S_2[t-1] * np.exp(((r-(0.5*(stdev**2)))*daily_step) + (stdev*(daily_st
ep**0.5) *Z_2[t]))
```

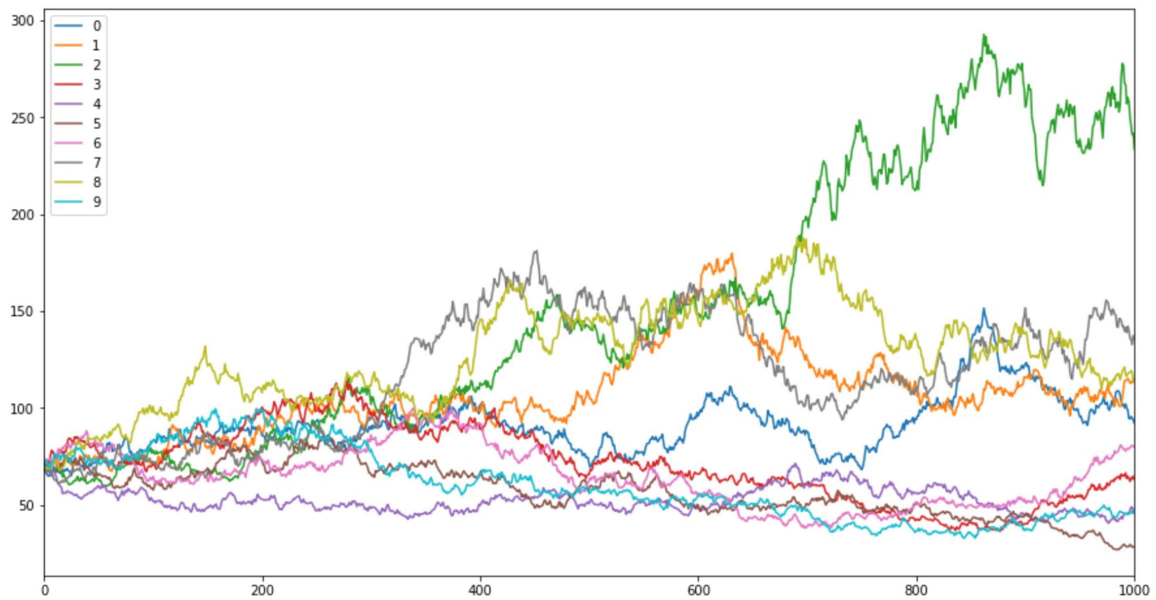
In [20]:
```python
future_prices_2 = pd.DataFrame(S_2)
future_prices_2
```

Out[20]:

	0	1	2	3	4	5	6	7	8
0	70.000000	70.000000	70.000000	70.000000	70.000000	70.000000	70.000000	70.000000	70.000000
1	67.807250	71.015760	69.816056	72.023412	69.491167	68.186206	71.865982	68.835489	69.448863
2	66.571518	71.509822	70.534930	69.707041	67.263501	68.262278	73.716323	67.882283	69.499456
3	65.559906	71.214307	70.042930	71.414651	66.742279	70.369728	73.010950	68.568097	68.798391
4	64.901276	71.718275	69.862922	71.948442	67.132447	70.566755	73.227941	67.553662	68.763255
...	...	...	...	...	...	...	...	...	...
996	94.503636	113.132249	250.253267	62.234180	47.518771	29.572693	79.637812	136.087394	118.518059
997	95.627711	112.797067	245.580945	63.446940	48.895268	29.319620	80.359547	135.384408	119.400699
998	95.069081	114.268669	241.118670	64.634655	48.912585	28.326061	80.809066	132.811062	118.158533
999	93.856920	113.510293	241.858613	63.395408	46.879048	28.422791	80.218970	137.355067	113.646463
1000	92.261661	113.414143	233.665842	64.915213	45.755200	28.334342	79.959589	136.160768	114.892997

1001 rows × 3000 columns

In [21]:
```python
future_prices_2.iloc[:,0:10].plot(figsize=(15,8)) #plotting the first 10 simulation
s
plt.show()
```



In [22]:
```python
call_value_2 = np.maximum(S_2[-1]-K,0) #value of call for each iteration from 3000
simulations
Call_price_2 = (np.exp(-r*T)*np.sum(call_value_2))/iterations_2
Call_price_2 #Price of European Call from 3000 simulations
```

Out[22]: 19.63481331277338

C) Black-Scholes model

In [23]:
```python
from scipy.stats import norm
```

In [24]:
```
#define function for d1
def d1_stock(S,K,r,t,sd):
    return (np.log(S/K)+(r+((sd**2)/2))*t)/(sd*(t**0.5))
```

In [25]:
```
#define function for d2
def d2_stock(S,K,r,t,sd):
    return (np.log(S/K)+(r-((sd**2)/2))*t)/(sd*(t**0.5))
```

In [26]:
```
#define function for BSM for European call option
def BSM_stock(S,K,r,t,sd):
    return ((S*norm.cdf(d1_stock(S,K,r,t,sd))) - (np.exp(-r*t)*K*norm.cdf(d2_stock
(S,K,r,t,sd))))
```

In [27]:
```
d1_stock(S=S0, K=K, r=r ,sd=stdev, t=T)
```

Out[27]:
```
0.5568466202562031
```

In [28]:
```
d2_stock(S=S0, K=K, r=r ,sd=stdev, t=T)
```

Out[28]:
```
-0.04315337974379693
```

In [29]:
```
BSM_stock = BSM_stock(S=S0, K=K, r=r ,sd=stdev, t=T)
BSM_stock
```

Out[29]:
```
20.814256819072327
```

D) BSM vs 30simulations

In [30]:
```
diff_1 = Call_price_1 - BSM_stock
diff_1
```

Out[30]:
```
-10.106577748941056
```

In [31]:
```
pct_diff_1 = diff_1/BSM_stock
print('%error = ',pct_diff_1*100,'%')
```

```
%error =  -48.55603462949632 %
```

E) BSM vs 3000simulations

In [32]:
```
diff_2 = Call_price_2 - BSM_stock
diff_2
```

Out[32]:
```
-1.179443506298945
```

In [33]:
```
pct_diff_2 = diff_2/BSM_stock
print('%error = ',pct_diff_2*100,'%')
```

```
%error =  -5.666517505531153 %
```

Currency European Call Options

A) Using Monte Carlo

In [37]:
```
E0 = 0.007 #spot dollar/yen
K_cur = 0.01 #strike
sd_cur = 0.08
r_domestic = 0.04 #dollar risk-free
r_foreign = 0.02 #yen risk-free
T_cur=2 #time to maturity
```

In [38]:
```
trade_per_year_cur = 250
delta_t_cur = 1/trade_per_year_cur
days_to_maturity_cur = T_cur*trade_per_year_cur
iterations_cur = 3000
```

In [39]:
```
u = r_domestic - r_foreign
```

In [40]:
```
#Converting Annualized yield to Daily Yield
u_t = ((1+u)**(1/250))-1
u_t
```

Out[40]:
```
7.921364641982898e-05
```

In [41]:
```
#Converting Annualized sd to Daily sd
sd_t = sd_cur*((1/250)**0.5)
sd_t
```

Out[41]:
```
0.005059644256269407
```

In [42]:
```
np.random.seed(503508) #set random seed
```

In [43]:
```
Z_cur = np.random.standard_normal((days_to_maturity_cur+1, iterations_cur))
Z_cur
```

Out[43]:
```
array([[-0.82487461, -0.97546241,  0.88384933, ...,  0.20848602,
         1.82073386, -0.57509071],
       [-1.67211351,  0.76456417, -0.13340726, ...,  1.05727897,
         1.00991974,  0.83407278],
       [-0.96408822,  0.37067098,  0.54517843, ..., -1.05824443,
        -2.52109409, -0.23393317],
       ...,
       [ 0.0676142 ,  1.7188212 , -0.08449221, ..., -0.35333664,
        -0.71783318, -0.57345294],
       [-0.08959904, -0.37358199, -0.14758834, ...,  1.95444955,
        -1.14665003, -0.41256143],
       [-2.40197136, -1.0496224 , -0.23604755, ..., -0.01359282,
         0.02734236, -0.57394795]])
```

In [44]:
```
S_cur = np.zeros_like(Z_cur)
S_cur
```

Out[44]:
```
array([[0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       ...,
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.]])
```

In [45]:
```
Z_cur.shape
```

Out[45]:
```
(501, 3000)
```

In [46]:
```
S_cur.shape
```

Out[46]:
```
(501, 3000)
```

In [47]:
```
S_cur[0] = E0
S_cur
```

Out[47]:
```
array([[0.007, 0.007, 0.007, ..., 0.007, 0.007, 0.007],
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ],
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ],
       ...,
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ],
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ],
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ]])
```

In [48]:
```
for t in range(1,days_to_maturity_cur+1):
    S_cur[t] = S_cur[t-1]*(np.exp(u_t -(0.5*(sd_t**2)) + (sd_t)*Z_cur[t]))
```

In [49]:
```
S_cur
```

Out[49]:
```
array([[0.007     , 0.007     , 0.007     , ..., 0.007     , 0.007     ,
        0.007     ],
       [0.00694149, 0.0070276 , 0.00699574, ..., 0.00703801, 0.00703633,
        0.00703007],
       [0.00690817, 0.00704126, 0.00701553, ..., 0.0070009 , 0.0069476 ,
        0.00702222],
       ...,
       [0.00745738, 0.0082523 , 0.00886775, ..., 0.00741474, 0.00709777,
        0.00730336],
       [0.0074545 , 0.00823726, 0.00886172, ..., 0.00748892, 0.00705718,
        0.00728862],
       [0.00736494, 0.00819418, 0.00885173, ..., 0.00748891, 0.00705863,
        0.00726796]])
```

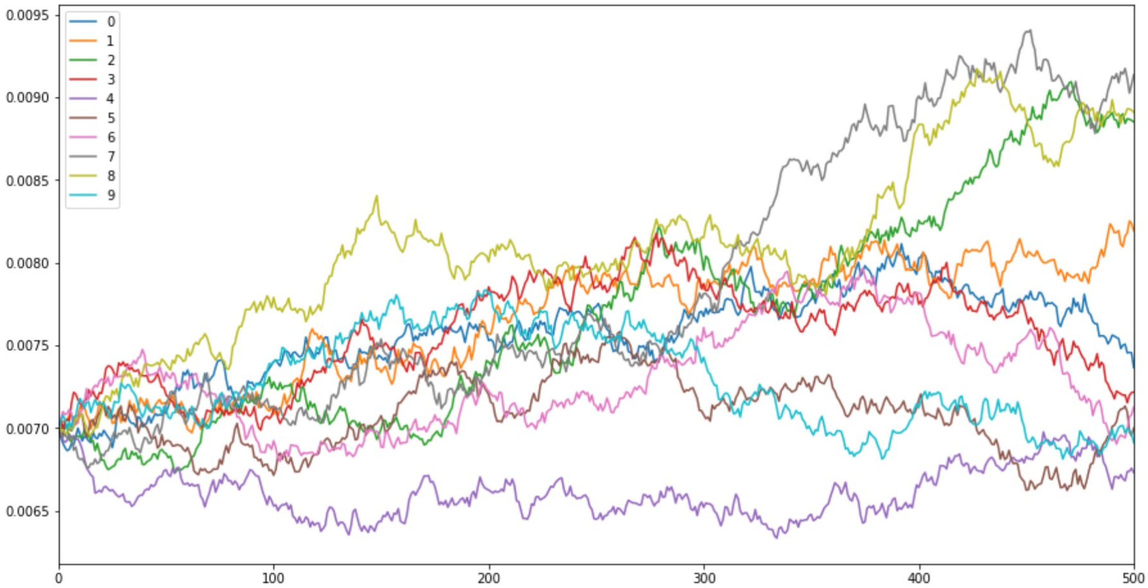
In [50]:
```
future_currency = pd.DataFrame(S_cur)
future_currency
```

Out[50]:

	0	1	2	3	4	5	6	7	8	9	...	
0	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	...	0.
1	0.006941	0.007028	0.006996	0.007054	0.006987	0.006952	0.007050	0.006969	0.006986	0.007033	...	0.
2	0.006908	0.007041	0.007016	0.006993	0.006927	0.006955	0.007099	0.006944	0.006988	0.007076	...	0.
3	0.006881	0.007034	0.007003	0.007039	0.006914	0.007012	0.007081	0.006963	0.006970	0.007052	...	0.
4	0.006863	0.007048	0.006999	0.007054	0.006925	0.007018	0.007087	0.006936	0.006969	0.006990	...	0.
...	...	...	...	...	...	...	...	...	...	...	...	...
496	0.007507	0.008162	0.008843	0.007199	0.006681	0.007132	0.006941	0.009176	0.008895	0.006970	...	0.
497	0.007454	0.008180	0.008871	0.007152	0.006736	0.007096	0.006995	0.009113	0.008931	0.006995	...	0.
498	0.007457	0.008252	0.008868	0.007197	0.006738	0.006976	0.007066	0.009027	0.008930	0.006988	...	0.
499	0.007454	0.008237	0.008862	0.007214	0.006756	0.006952	0.007081	0.009078	0.008924	0.006965	...	0.
500	0.007365	0.008194	0.008852	0.007217	0.006730	0.006999	0.007126	0.009138	0.008910	0.006911	...	0.

501 rows × 3000 columns

In [51]:
```
future_currency.iloc[:,:10].plot(figsize=(15,8))
plt.show()
```



In [52]:
```
call_value_cur = np.maximum(S_cur[-1]-K_cur , 0)
call_value_cur
```

Out[52]: array([0., 0., 0., ..., 0., 0., 0.])

In [53]:
```
Call_price_cur = (np.exp(-u*T_cur)*np.sum(call_value_cur))/ iterations_cur
Call_price_cur
```

Out[53]: 1.1099567810145154e-06

B) Using BSM

In [54]:
```
def d1_currency(E, K, sd, r_domestic, r_foreign, T):
    return ((np.log(E/(K*np.exp(r_foreign*T)))) + ((r_domestic +(0.5*(sd**2)))*T))
/ (sd*(T**0.5))
```

In [55]:
```
def d2_currency(E, K, sd, r_domestic, r_foreign, T):
    return ((np.log(E/(K*np.exp(r_foreign*T)))) + ((r_domestic -(0.5*(sd**2)))*T))
/ (sd*(T**0.5))
```

In [56]:
```
def BSM_currency(E, K, sd, r_domestic, r_foreign, T):
    return np.exp(-r_foreign*T)*((E*norm.cdf(d1_currency(E, K, sd, r_domestic, r_fo
reign, T))) - (np.exp(-r_domestic*T)*np.exp(r_foreign*T)*K*norm.cdf(d2_currency(E,
K, sd, r_domestic, r_foreign, T))))
```

In [57]:
```
BSM_currency = BSM_currency(E=E0, K=K_cur, sd=sd_cur, r_domestic=r_domestic, r_fore
ign=r_foreign, T=T_cur)
BSM_currency
```

Out[57]: 6.797366021106352e-07

C) BSM vs 3000simulations

In [58]:
```
diff_cur = Call_price_cur - BSM_currency
diff_cur
```

Out[58]: 4.3022017890388014e-07

In [59]:
```
pct_diff_cur = diff_cur/BSM_currency
print('%error = ',pct_diff_cur*100,'%')
```

```
%error =  63.292189587556834 %
```

D) Try 100,000 simulations

In [60]:
```
np.random.seed(503508)
```

In [61]:
```
iterations_cur_2 = 100000
```

In [62]:
```
Z_cur_2 = np.random.standard_normal((days_to_maturity_cur+1, iterations_cur_2))
Z_cur_2
```

Out[62]:
```
array([[-0.82487461, -0.97546241,  0.88384933, ..., -0.75805458,
         0.31141964, -1.52225157],
       [-0.38136394,  0.04500309,  0.20725137, ...,  0.5828356 ,
        -0.39111136, -0.03235513],
       [-0.19501404,  1.85818245, -0.73838639, ...,  0.06541506,
         0.69707757,  1.14083037],
       ...,
       [-0.03494417, -0.81749243,  0.48880815, ..., -1.80272723,
         0.22772882, -0.11847408],
       [ 1.14325341,  1.10530197, -1.28366694, ..., -0.94230322,
        -0.63339362, -0.61015812],
       [ 0.58054708, -0.51697922,  0.61233567, ...,  0.13953308,
        -0.87277618, -0.30027168]])
```

In [63]:
```
S_cur_2 = np.zeros_like(Z_cur_2)
S_cur_2
```

Out[63]:
```
array([[0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       ...,
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.]])
```

In [64]:
```
Z_cur_2.shape
```

Out[64]:
```
(501, 100000)
```

In [65]:
```
S_cur_2.shape
```

Out[65]:
```
(501, 100000)
```

In [66]:
```
S_cur_2[0] = E0
S_cur_2
```

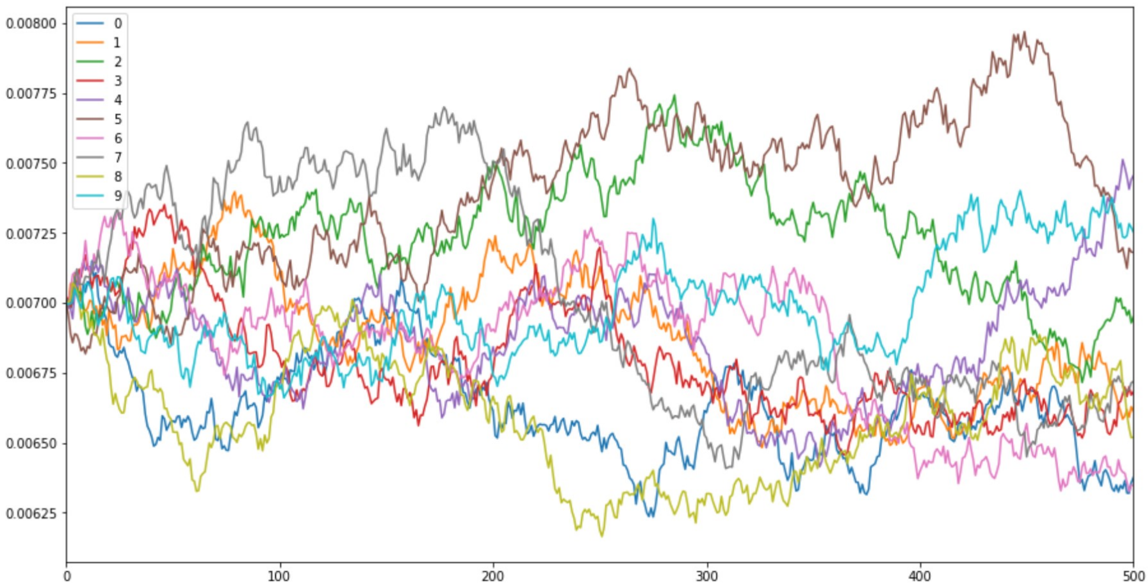
Out[66]:
```
array([[0.007, 0.007, 0.007, ..., 0.007, 0.007, 0.007],
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ],
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ],
       ...,
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ],
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ],
       [0.   , 0.   , 0.   , ..., 0.   , 0.   , 0.   ]])
```

In [67]:
```
for t in range(1,days_to_maturity_cur+1):
    S_cur_2[t] = S_cur_2[t-1]*(np.exp(u_t -(0.5*(sd_t**2)) + (sd_t)*Z_cur_2[t]))
```

In [68]:
```
S_cur_2
```
Out[68]:
```
array([[0.007     , 0.007     , 0.007     , ..., 0.007     , 0.007     ,
        0.007     ],
       [0.00698697, 0.00700206, 0.00700781, ..., 0.00702114, 0.00698663,
        0.00699932],
       [0.00698054, 0.00706867, 0.00698214, ..., 0.00702393, 0.00701178,
        0.0070403 ],
       ...,
       [0.00631969, 0.00659122, 0.00697309, ..., 0.00675077, 0.00783232,
        0.00648816],
       [0.00635677, 0.00662863, 0.00692841, ..., 0.00671911, 0.00780778,
        0.00646859],
       [0.0063759 , 0.00661175, 0.00695037, ..., 0.0067243 , 0.00777389,
        0.0064592 ]])
```
In [69]:
```
future_currency_2 = pd.DataFrame(S_cur_2)
future_currency_2
```
Out[69]:

	0	1	2	3	4	5	6	7	8	9	...	
0	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	0.007000	...	0.
1	0.006987	0.007002	0.007008	0.007018	0.006985	0.006957	0.006995	0.007010	0.007001	0.006995	...	0.
2	0.006981	0.007069	0.006982	0.006984	0.006979	0.006890	0.007048	0.007011	0.007015	0.006996	...	0.
3	0.007000	0.007021	0.007018	0.007026	0.006943	0.006858	0.007101	0.007021	0.007070	0.007010	...	0.
4	0.007041	0.007101	0.007093	0.007035	0.007038	0.006889	0.007109	0.007091	0.007061	0.007050	...	0.
...	...	...	...	...	...	...	...	...	...	...	...	
496	0.006365	0.006596	0.006984	0.006699	0.007484	0.007161	0.006391	0.006669	0.006673	0.007233	...	0.
497	0.006320	0.006618	0.006955	0.006665	0.007451	0.007123	0.006358	0.006689	0.006599	0.007240	...	0.
498	0.006320	0.006591	0.006973	0.006700	0.007406	0.007195	0.006326	0.006689	0.006554	0.007283	...	0.
499	0.006357	0.006629	0.006928	0.006671	0.007440	0.007182	0.006348	0.006714	0.006518	0.007270	...	0.
500	0.006376	0.006612	0.006950	0.006683	0.007455	0.007180	0.006348	0.006719	0.006520	0.007253	...	0.

501 rows × 100000 columns

In [70]:
```
future_currency_2.iloc[:,:10].plot(figsize=(15,8))
plt.show()
```


In [71]:
```
call_value_cur_2 = np.maximum(S_cur_2[-1]-K_cur , 0)
Call_price_cur_2 = (np.exp(-u*T_cur)*np.sum(call_value_cur_2))/ iterations_cur_2
Call_price_cur_2
```

Out[71]:
```
7.345813573449324e-07
```

In [72]:
```
call_value_cur_2
```

Out[72]:
```
array([0., 0., 0., ..., 0., 0., 0.])
```

In [73]:
```
np.sum(call_value_cur_2)
```

Out[73]:
```
0.07645601912454744
```

E) BSM vs 100,000simulations

In [74]:
```
diff_cur_2 = Call_price_cur_2 - BSM_currency
diff_cur_2
```

Out[74]:
```
5.484475523429717e-08
```

In [75]:
```
pct_diff_cur_2 = diff_cur_2/BSM_currency
print('%error = ',pct_diff_cur_2*100,'%')
```

```
%error =  8.068530525500602 %
```

In [ ]: